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Mountain Ecosystems and Resources Management

Volume 1

Edited by
HasratArjjumend

GRASSROOTS INSTITUTE

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Dedicated to
Beloved Mountains

Mountain Ecosystems and Resources Management

Volume 1

Edited by
Hasrat Arjjumend

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Acknowledgements

The idea of this edited book "**Mountain Ecosystems and Resources Management, Vol. 1**" emanated from *Summer Field School on Mountain Ecosystems and Resources Management edition 1* [www.grassrootsglobal.net/mer2020] that was organized very successfully in 2021 with the involvement of near 630 people from 69 countries. A large number of the FSc MER 2020 participants and faculty members submitted their full papers as the contributions to this book; however, many of those full papers could not qualify as quality works. Those having qualitative contents and written texts were included in this Volume 1. Few of those articles will be included in Volume 2 intended to be published in 2024.

We are primarily grateful to the authors who provided their full papers for this Volume 1. Without their agreement to provide their full papers and permit to publish as chapters, this book would not have taken a shape. Next stage of the preparatory work was to obtain peer review of independent experts on each of the full papers. Large number of experts from different countries contributed their time and efforts to read the raw texts and gave their expert comments. We are really indebted to the independent reviewers as listed in the end of this book. Prof. Sanjay-Swami and Prof. G. Poyyamolly had assisted and contributed their massive amount of time not only help in editorial process but also in some initial processes.

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In the design of this book, 3Media Design has played critical role in preparing the cover pages in a precise eloquent graphics. We are especially thankful to Mr. Irshad Mohd. for his farsighted and graphic design works as excellent state of the art. The web version of this book is again the creative works of 3Media Design with the core works of Mr. Sajjad. We thank many other friends who supported still significantly the completion of this book.

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Last but not least, we will be very thankful to the readers of this book and, especially, to those who would give their feedback. Feedbacks are requested to be sent to the respective authors with a copy to the Editor and the Publisher. We will try to place the feedback comments along with identity of the reader on the web pages of the book. We wish that the individual readers and related organizations will benefit from this work.

■ **Dr. Hasrat Arjjumend (*Editor)***

Abbreviations

Chapter 1

ABS	Access and Benefit Sharing
CBD	UN Convention on Biological Diversity
CEO	Chief Executive Officer
CSA	Community Supported Agriculture
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
HG	Healthy Grassland
RG	Restored Grassland
MD	Moderately Degraded Grassland
SD	Severely Degraded Grassland
IRBM	Integrated River Basin Management
NGO	Non-Governmental Organization
OAU	Operational Agricultural Units
RISG	Regional International Support Group
TEK	Traditional Ecological Knowledge
TGI	The Grassroots Institute
UK	United Kingdom
UN	United Nations
USA	United States of America

Chapter 2

CICES	Common International Classification of Ecosystem Services
ES	Ecosystem Services
LS	Landscape Services
MA	Millennium Ecosystem Assessment
TEEB	The Economics of Ecosystems and Biodiversity

Chapter 3

CAP	Common Agricultural Policy
CBD	UN Convention on Biological Diversity
DNA	Deoxyribo Nucleauc Acid
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
SPAs	Special Protection Areas

Chapter 4

E	Edible fish
EN	Endangered[1]
IUCN	World Conservation Union
LC	Least concern
NT	Near threatened

[1] https://www.iucnredlist.org/

O	Ornamental fish
Ot	Other usages (Larvivorous fish)

Chapter 5

IFRM	Integrated Forest Resource Management
NTFPs	Non-Timber Forest Products
PFM	Participatory Forest Management
SDG	Sustainable Development Goal

Chapter 6

Alt	Altitude (m)
Er	Error
HG	Healthy Grassland
RG	Restored Grassland
MD	Moderately Degraded Grassland
SD	Severely Degraded Grassland
LU	Land Use
QTP	Qinghai Tibet Plateau
Std	Standard

Chapter 7

FAO	Food and Agriculture Organization of the United Nations
MCDA	Multi-Criteria Decision Analysis
NTFPs	Non-Timber Forest Products

Chapter 8

NER	North Eastern Region
RDF	Recommended Doses of NPK Fertilizers
VC	Vermicompost

Chapter 9

BMCs	Basin Management Centres
DoSWC	Department of Soil and Water Conservation
FAO	Food and Agriculture Organization of the United Nations
GoN	Government of Nepal
ICIMOD	International Centre for Integrated Mountain Development
ICM	Integrated Catchment Management
IRBM	Integrated River Basin Management
IWRM	Integrated Water Resource Management
JICA	Japan International Cooperation Agency
MoEWRI	Ministry of Energy, Water Resources, and Irrigation
MoFE	Ministry of Forests and Environment
NDAC	National Development Action Committee
RBOs	River Basin Organizations
WECS	Water and Energy Commission Secretariat
WWF	World Wide Fund for Nature
IUCN	World Conservation Union

Chapter 10

ABDI	Agrobiodiversity Index
AGRs	Agricultural Genetic Resources
EB	Economic and Beneficial
HH	Household
OAU	Operational Agricultural Units

Chapter 11

DST	Department of Science and Technology
GHGs	Greenhouse Gases
TA	Traditional Agricultural
TEK	Traditional Ecological Knowledge

Chapter 12

EU	European Unin

Chapter 13

CBS	Class-Bulking Selection
RH	Relative Humidity

Chapter 14

CAAS	Chinese Academy of Agricultural Sciences
CSA	Community Supported Agriculture
CSB	Community Seed Bank
GAAS	Guangxi Academy of Agricultural Sciences
NGOs	Non-Governmental Organizations
PPB	Participatory Plant Breeding
SW	South West

Chapter 15

DAD	Domestic Animal Diversity
AnGR	Animal Genetic Resources
FAO	Food and Agriculture Organization of the United Nations
PRA	Participatory Rural Appraisal

Chapter 16

STAS	Spread through air spaces
USSR	Union of Soviet Socialist Republics

Chapter 17

ITCZ	Inter-Tropical Convergence Zone
MOARF	Multiobjective Optimization Workflow

Chapter 18

AFLP	Amplified fragment length polymorphism
BAF	Brazilian Atlantic Rainforest
CAPES	Coordination for the Improvement of Higher Education Personnel
CNPq	National Council for Scientific and Technological Development

CU	Conservation Units
DNA	Deoxyribo Nucleauc Acid
FAPESP	The São Paulo Research Foundation
GDP	Gross Domestic Product
ISI	International Scientific Indexing
MCTI	Ministry of Science, Technology and Innovation
RAPD	Random Amplified Polymorphism DNA
RFLP	Restriction Fragment Length Polymorphism
SSR	Simple Sequence Repeats
SNPs	Single Nucleotide Polymorphism

Chapter 19

ECTP	European Council of Spatial Planners - Conseil Européen des Urbanistes
ICOMOS	International Council on Monuments and Sites
MIRC	Metsovion Interdisciplinary Research Center in the Hellenic Mountain
NTUA	National Technical University of Athens
UNESCO	United Nations Educational, Scientific and Cultural Organization

Chapter 20

OKR	Osvitnij (Educational) Kvalifikacijnyj (Qualifying) Riven (Level)

Chapter 21

OKR	Osvitnij (Educational) Kvalifikacijnyj (Qualifying) Riven (Level)
TPB	Theory of Planned Behaviour
TRA	Theory of Reasoned Action
VBN	Theory of Value-Belief Norm

Chapter 22

CBD	United Nations Convention on Biological Diversity
FAO	Food and Agriculture Organization of the United Nations
IYM	International Year of Mountains
UN	United Nations

Chapter 23

COVID	Corona Virus Disease
NGO	Non-Government Organization

Foreword

By Prof. Dr. Hussein Baghirov

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Foreword

Prof. Dr. Hussein Baghirov
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Throughout all periods, the significance of ecosystems' biodiversity and the strategies employed in their management has consistently remained important for those engaged in the study of nature. Within the pages of this book, readers will encounter an in-depth exploration of these facets, delivered from a professional perspective.

The brilliant curator of this anthology, Dr. Hasrat Arjjumend, takes readers on a trip that skilfully combines the wonders of nature with human cunning.

This book would not be possible without the combined efforts of many people, to whom we are sincerely grateful. Scholars, writers, and experts have kindly contributed their knowledge, improving our understanding of alpine ecosystems. We especially thank the peer reviewers whose thorough assessments guaranteed the academic integrity of every chapter. We would like to express our gratitude to the editorial and production teams for their hard work in creating and perfecting this manuscript.

Heading innovative programs like the Summer Field School on Mountain Ecosystems & Resources Management, Dr. Hasrat Arjjumend is the Founder, President, and CEO of The Grassroots Institute, demonstrating a dedication to international cooperation and information sharing. Dr. Sining Zhang, an assistant professor at Southwest Jiaotong University in China, addresses the intricate issues at the nexus of urban and natural ecosystems by doing research on landscape planning, design, ecosystem services, and climate adaptation.

This book is a rich tapestry that integrates practical resource management applications with theoretical underpinnings. With its distinct perspectives, approaches, and case studies, every chapter makes a substantial contribution to our understanding of mountain ecosystems as a whole. The first portions introduce the topic and set the stage for talks about mountain ecosystems and the complex interactions between human activity and environmental protection. The parts that follow provide in-depth analyses, delving into concepts, classifications, and relationships between ecosystem services and landscape services in order to lay the groundwork for future discussions.

In order to facilitate a fuller understanding of the fragile balance between human activity and the natural world in mountainous regions, readers are invited to immerse themselves in the richness of knowledge offered by contributing authors. The goal of this book is to further current debates, facilitate decision-making, and stimulate fresh lines of inquiry into the sustainable management of mountain ecosystems.

In this chapter "Mountain Biodiversity in Romania," Daniela Antonescu, a specialist at the Romanian Academy's Centre of Mountain Economy at the National Institute of Economic Research, explains the vital connection between biodiversity and mountainous regions. Every chapter presents a different angle that deepens our understanding of these crucial settings. The editor, Dr. Hasrat Arjjumend, has put together a collection that will be an invaluable resource for academics, policymakers, and anybody with a keen interest in the delicate balance that exists between human activity and the preservation of biodiversity in the mountains.

Alone like majestic sentinels, mountain ecosystems shape landscapes and have an impact on the basic building blocks of life. "Navigating the Peaks" explores the complex interrelationship between biodiversity and mountains, explaining the difficulties these magnificent regions encounter and offering solutions for their preservation. Mountains, which make up around 25% of the planet's surface, are thriving hubs of life that sustain a wide range of plant and animal species as well as human communities. We must face the devastating fact that these unique ecosystems are being threatened by a variety of man-made stressors as we investigate the intricacies of mountain biodiversity.

The purpose of this book is to provide light on the difficulties that mountain biodiversity faces. We piece together the complex web of interactions between human activities and delicate alpine ecosystems via painstaking research. Every chapter functions as a lens, concentrating on certain problems like the effects of mining, forestry, agriculture, tourism, and climate change. But our story is not depressing; rather, it is an appeal to action. We outline conservation strategies based on moral development, environmentally sound practices, and global collaboration within these pages. Given the interconnectedness of mountain regions, a comprehensive plan that crosses national lines and involves local populations in the protection of their natural heritage is imperative.

We extend our gratitude for your insightful feedback, a catalyst in refining "Navigating the Peaks" to offer a more inclusive and nuanced portrayal of our distinctive global landscapes. Embarking on the expedition delineated in "Navigating the Peaks", we intricately explore the folds of untamed landscapes and seek shelter under the protective canopies of ancient forests. This undertaking constitutes a comprehensive inquiry, elucidating the intricate interplay between wildlife and human engagement within mountainous terrains.

The ensuing chapters unfurl a myriad of narratives that collectively form a vibrant tapestry, revealing the diverse ecosystems characterizing our continent. Notably, the scenic landscapes of Asian nations, including China, India, and Nepal, are progressively garnering heightened attention. The narrative evolves through a meticulous examination of these regions, where dedicated chapters delve into their distinctive attributes.

Acknowledging the importance of a global perspective, we ensure the prominence of Asia in the narrative while also appreciating the broader context. Two chapters are dedicated to the captivating highland vistas of Africa, adding a layer of intricacy to the overall narrative. Europe, with a particular focus on the Carpathians, sustains a comprehensive and profound representation. The Carpathians, the protectors of Romania's and Ukraine's landscapes, need special attention where a wide variety of species live in a patchwork of ecosystems that echo the ages-old murmurs of the natural world. We examine the steps and initiatives made to protect these priceless ecosystems, realizing the intricate relationship between sustainable development and conservation.

We are constantly reminded as we go through the book of how vital it is to safeguard and maintain these natural treasures. These breathtaking landscapes bear the scars of climate change as well as the marks left by human activity. However, these difficulties also present chances for cooperation and peaceful coexistence that will guarantee the survival of these essential ecosystems for future generations.

This book is an investigation and a tribute to the mountains that influence the globe. It is an invitation to explore the unspoiled wilderness, to be in awe of life's tenacity, and to acknowledge our common duty to preserve the complex network of biodiversity that adorns the mountains of Europe and Asia.

I hope that reading these pages will inspire a love of the environment, a dedication to sustainable living, and a profound respect for the wonders of our alpine regions. May this book be a resource for comprehending, valuing, and protecting the distinctive ecosystems that adorn the lofty summits of our planet.

I invite readers to delve into the following chapters, where experts from around the world contribute their knowledge to unravel the complexities of mountain ecosystems and resources management. Together, we navigate a terrain where ecological sensitivity meets the demands of human development, seeking sustainable pathways for the future.

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Citation

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Chapter 1

Introduction

By Hasrat Arjjumend

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Introduction

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Abstract
The resource management in mountain regions is not only about sustaining the natural environment but also about harmonizing the needs of local communities and global demands. This edited book sheds light on the diverse range of resources found in mountains, from water and minerals to biodiversity and cultural heritage. It explores critical thinking of varied authors from around the world, inculcating a balance of human development with the preservation of vital ecosystems, ensuring that the prosperity of today does not compromise the well-being of tomorrow. The insights presented in the book aim to foster a deeper understanding of the challenges and solutions that lie ahead. In 23 chapters, we traverse the mountain ecosystems, peeling back the layers to reveal their ecological importance, their unique biodiversity, and their resilience in the face of adversity.

Keywords
Mountains; Ecosystems; Natural resources; Methodologies; Chapters

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Edited by Dr. Hasrat Arjjumend

1. Introduction

Welcome to the book of "Mountain Ecosystems & Resources Management", volume 1. In the following chapters, we embark on a journey to explore the intricate tapestry of mountain ecosystems and the pivotal role of resource management in preserving their delicate balance. This book serves as a comprehensive guide, offering insights into the unique challenges and opportunities presented by these high-altitude landscapes.

Mountains have captivated humanity for centuries, with their majestic peaks and awe-inspiring vistas. Yet, beyond their visual splendor lies a complex web of ecosystems that are both resilient and fragile. The pages ahead delve into the depths of these ecosystems, unraveling their ecological significance, biodiversity, and vulnerability to various stressors. Resource management in mountain regions is not only about sustaining the natural environment but also about harmonizing the needs of local communities and global demands. This book sheds light on the diverse range of resources found in mountains, from water and minerals to biodiversity and cultural heritage. It explores strategies that balance human development with the preservation of these vital ecosystems, ensuring that the prosperity of today does not compromise the well-being of tomorrow.

As you immerse yourself in 23 chapters that follow, consider the intricate connections that bind mountain ecosystems, resources, and humanity. The insights presented here aim to foster a deeper understanding of the challenges and solutions that lie ahead. May this exploration inspire responsible stewardship and informed decision-making, ensuring that the treasures of mountain ecosystems remain resilient and vibrant for generations to come? In the heart of rugged terrain and soaring altitudes, a world of unparalleled beauty and intricate dynamics awaits our exploration. Welcome to "Mountain Ecosystems & Resources Management," a comprehensive journey into the realms where nature's grandeur meets the strategic ingenuity of humanity. Within these pages, we embark on a profound odyssey to uncover the nuances of mountain ecosystems and the pivotal task of managing their resources sustainably. The allure of mountains has forever been etched into our collective consciousness. Their majesty has inspired poets, challenged explorers, and provided solace to seekers of tranquility. Yet, beyond their breathtaking vistas, mountains harbor ecosystems that are as remarkable as they are fragile. In the forthcoming chapters, we traverse these ecosystems, peeling back the layers to reveal their ecological importance, their unique biodiversity, and their resilience in the face of adversity.

Resource management in these lofty landscapes is a venture that demands a delicate equilibrium between human aspirations and environmental preservation. As we delve deeper, this book unearths the rich tapestry of resources that mountains cradle – from life-sustaining water sources to valuable minerals, from diverse flora and fauna to the intangible heritage of local cultures. Our exploration encompasses strategies that intertwine modernity and tradition, offering a path where economic growth and ecological vitality can coexist harmoniously. This literary expedition is an invitation to contemplate the interconnectedness that binds mountain ecosystems, their resources, and humanity. The chapters that follow unravel the intricacies of these relationships, underscoring the urgency to address the challenges at hand and the potential for transformative solutions. As you engage with the narratives woven throughout this book, envision the future that lies ahead – one where responsible management of mountain resources stands as a testament to our commitment to both the magnificence of nature and the prosperity of societies.

So, embark with us upon this voyage of discovery. May the insights gathered within these chapters kindle a fire of awareness and inspire actions that reverberate across peaks and valleys. As stewards of this planet, our choices today will reverberate through the ages, echoing our reverence for the grandeur of mountain ecosystems and our dedication to securing their splendor for generations yet to come.

Chapter 2 by Sining Zhang, "Applying the Landscape Services Concept in Landscape Research: A Review", exposes to the concept of landscape services and unanswered issues regarding landscape services are described. This chapter offers an overview of various assessment and quantification methods used for mapping and studying landscape services, synonymous to the ecosystem services in mountain contexts. Similarly, in chapter 3 on "Mountain Biodiversity in Romania", Daniela Antonescu emphasizes that mountains operate as true refuge for endemic species being affected by uncontrolled human actions. According to the author, negative impact of economic activities in mountain regions is becoming more visible, therefore, necessitating a sustainable approach to preserve the biodiversity and habitat in order to salvage the fragile ecological balance. Through a review of relevant literature, this chapter presents the current knowledge of mountain biodiversity in Europe and Romania and its relationship with sustainable development process.

The chapter 4 on "Fish Diversity of Hill Streams of South Kamrup, Assam, India" is uniquely authored by 4 Ellora Choudhury and Saibal Sengupta. A big pool of diversity of ichthyofauna in hilly streams of Southern Kamrup rivulet was documented in 2017 revealing 60 fish species belonging to 42 genera, 24 families and 9 orders. This study recommends that streams and riparian zones need systematic investigation, as the lotic ecology has significant effect on the aquatic biota. Hyunshik Moon and Tamirat Solomon have written chapter 5 entitling 'Mountain Forests: Challenges and Management' in which they highlighted the importance of forests in the mountains. According to them, many mountain forests are playing the role of carbon sinks to mitigate climate change. They reiterated that, for the sustainability of the ecosystem, proper actions should be taken to save and maintain the productive, protective, socio-cultural roles of mountain forests. In chapter 6 about the grassland ecosystems, Fayiah *et al.* made an interesting case of the "Dynamics of Grassland Vegetation Composition across different Land-use Types on the Qinghai Tibet Plateau". The degree of grassland degradation divided the Tibetan grasslands into four land-use types, i.e., healthy grassland (HG), restored grassland (RG), moderately degraded (MD) grassland, and severely degraded (SD) grassland. About 32 plant species were recorded in Tiebujia county, 28 in Maqin county, and 18 in Maduo county of Tibet. The richness of species in grasslands ranged from 8 to 12 species per land-use, suggesting low richness and diversity in restored and degraded grassland. A positive non-significantly mean change ($p<0.05$) was detected for richness and evenness indices while a negative mean change ($p<0.05$) was detected for Simpson and Shannon indices in the alpine meadow and steppe in both Maqin and Maduo county. The results of this study imply that degradation affects grassland vegetation, health, and distribution.

Very interesting study by Pragya Sherchan is presented in chapter 7 on "Understanding the Nexus of Climate Change and Migration: A Case of Dhye Peoples from Upper Mustang, Nepal". This chapter discusses that people of Dhye in Nepal have migrated mainly to look for livelihood options, water availability and land for cultivation in the sever climatic events. Prof. Sanjay-Swami in his chapter 8 on "Integrated Management of Land, Water and Bioresources for Sustainable Agriculture in North Eastern Region of India" documented the environment, local conditions, socio-economic and socio-cultural life of different tribal communities and the rituals associated with agricultural practices that have developed many Indigenous farming systems, which have in-built eco-friendly systems for conservation, preservation and utilization of natural resources in the mountains. However, with the passage of time, some of these practices have been further refined and modified to cater the location-specific present day needs for conservation of natural resources, particularly soil and water resources. Emphasizing "Integrated River Basin Management", Thapa et al. have authored chapter 9 encompassing water and watershed resources. The chapter aims to review the progress made in the political, legislative, and institutional arenas for the implementation of IRBM in Nepal. It highlights that Nepal is in the preparatory phase of establishing a legal-institutional framework for IRBM and lacks proper institutional mechanisms for translating the principles of IRBM to actions on the ground. The chapter identifies the strengths and gaps in existing institutional arrangements and sheds light on the practical aspects of IRBM implementation, which would be useful learning for the countries aiming to implement IRBM in similar landscapes globally.

In mountain contexts, agro-ecosystems and agrobiodiversity have distinct relevance. Chapter 10 by Bal Krishna Joshi, "Agrobiodiversity Indicators and Measurement using R for Description, Monitoring, Comparison, Relatedness, Conservation and Utilization", highlights that 6 components and 25 groups of agrobiodiversity should be used for agrobiodiversity analysis. Six types and levels of agrobiodiversity can be quantified. Both quantitative and qualitative data are used for estimating scores and indices. The measurement objects for describing agrobiodiversity are community, household, site, crop group, species, landrace, etc. These objects are called operational agricultural units (OAU). Agromorphological, molecular, and perception data are used in agrobiodiversity studies. Among the many software, RStudio is very good. It is an integrated part of R and includes a console, syntax-highlighting editor, tools for plotting, history, debugging, and workspace management. Vegan and BiodiversityR packages are commonly used for estimating diversity indices and multivariate analysis. Richness, Shannon index and Simpson index are very common means of quantifying agrobiodiversity.

Authoring the "Agrobiodiversity and Natural Resource Management in Traditional Agricultural Systems of Northeast India" (chapter 11), Wishfully Mylliemngap documented traditional agriculture in North-East India where farmers practice a mixed cropping pattern through multi-cropping, crop rotation, and use of multipurpose nitrogen (N)-fixing trees, along with protection of semi-domesticated and wild biodiversity, including medicinal plants, wild edible fruits and vegetables, fodder plants and other useful species. A gradual shift from subsistence cultivation to commercial agriculture driven by market forces and modernization leads to a transition, resulting into reduced cultivation of local crop varieties and the disappearance of the associated traditional ecological knowledge (TEK). Within the continuum of agro-ecosystems, Pecheniuk *et al.* in chapter 12 on "Ecosystem Services to Support the Diversification of Agricultural Production" explain how the ecosystem services help diversify the agricultural production systems. The authors argue that effective environmental management must take into account new income opportunities flowing in from various ecosystem services if conserved properly. They have used correlation models to understand the relationship between ecosystem services and the agricultural productivity.

Bal Krishna Joshi described "Indigenous Seeds, Seed Selection and Seed Bank for Sustainable Agriculture" in chapter 13. According to Dr. Joshi, Indigenous seeds are higher level of intra-population variations and the capacity of buffering the adverse factors. Understanding indigenous seeds along with their diversity are useful to diversify their uses, to assess conservation status, to know the factors making farming areas red zone, and to improve their performance. Selection is the simplest and most common method for the improvement of crop varieties. Many different selection approaches can target either developing monomorphic or polymorphic varieties. Based on the genotypic classes, there are three types of selection namely stabilizing selection, directional selection, and disruptive selection. The most simple and common selection methods are pure lines, mass selection, and class-bulking selection. Orthodox seeds in short, medium, and long-term storage facilities are conserved as a seed bank. Major types are household seed banks, community seed banks, national seeds, natural seed banks, and global seed banks. The common works in seed banks are diversity collection, regeneration, characterization, multiplication, and distribution along with online database management. A practical field case on "Enhancing Farmers' Seed Systems through Empowerment of Women: A Case Study from mountain areas of SW China" was elaborated in chapter 14 by Zhang *et al.* The authors articulate that maintaining farmer's seed systems is important to secure the adaptive capacity both ecologically and socially for global food systems, and to secure genetic diversity. In this case study based on more than 20 years research, women-led agricultural cooperatives promoted the economic development of the community and improved the sustainability of farmers' seed system through eco-circular agriculture and the community supported agriculture (CSA) model. In this participatory process, the empowerment of women improved women's comprehensive ability and provided the guarantee of human resources for enhancing farmers' seed system.

The discussions on farm diversity are incomplete without integrating animal diversity. In chapter 15 on "Issues of Declining Livestock Breeds: Revisiting Domestic Animal Diversity in Pastoral Systems", Saverio Krätli described domestic animal diversity through the lenses of cattle breeding among the Wodaabe pastoralists in Niger. The research is based on a combination of qualitative methodologies standard in social anthropology and quantitative analysis of memorized herd genealogies over a 20-year period. Results of his studies show that a competent herder can control cattle mating in over 90 percent of cases. Complex learned behaviour in cattle, particularly related to feeding competence, is a major selection criterion. The Wodaabe specialize in using the short-lived and unpredictable grazing opportunities, which is characteristic of Sahelian rangelands. To favourably interface the unpredictable variability in potential inputs, they breed herds with exceptional levels of within-breed diversity, crucially including epigenetic traits. Udrea *et al.* have discovered that the pastoralists in Romania founded a domestic processing of milk, wool and leather products with positive socio-economic implications on material and spiritual life of local people. In chapter 16 entitling "Study on the Diversity of Products Obtained from Sheep in the Current Bioeconomy Context", the authors emphasized that local sheep breeds of 'Tucana', 'Stogose' and 'Tisigai' have a profound fitness and resistance to harsh weather conditions. These breeds were also fit for traveling long routes in search of food. These sheep breeds were appreciated because they produce a diversity of products having superior nutritional or economic values. It is known especially for its white wool, which is used in domestic industry for making clothes and other products including artifacts, textiles, Persian carpets, etc. Ayman Mustafa and Asim Faraz in chapter 17, "Camel Systems and Pastoralists' Lifestyle in Semi-Deserts and Mountains: Constraints and Challenges", discussed Arabian camels in the pastoral production systems of Butana, Kordofan and Darfur regions of Sudan. They found that social prestige and continuity of traditional heritage are the major reasons for keeping animals rather than economic revenue. However, it was found that the security issues are limiting camel breeding practices and pastoralists' movement in the semi-desert and mountain regions. Internal conflicts between farmers and pastoralists that often develop into tribal wars also affected pastoral production systems. Such constraints in addition to the lack of government support and favorable policies present major challenges to camel pastoral system in the region.

Deviating from core issues of ecosystems and livelihoods, Brazilian authors Siqueira *et al.* analysed published research in chapter 18 entitling "Trends and Patterns of Scientific Publishing during 1990-2020 on Conservation Genetics in Brazilian Atlantic Rainforest". The authors commented on the destruction of Brazilian ecosystems as the most alarming national and international conservation issue. To protect the genetic resources in the long term, it is necessary to consider the characterization (or the study) of genetic diversity of rainforest populations. This approach has been applied to different species, population sizes, distinct biomes and wide range of ecological and molecular questions. The objective of this chapter is to identify trends and patterns of scientific publications in conservation genetics in Brazilian Atlantic Rainforest. Addressing the "Mountain Identity and Development Aspirations", Elena Konstantinidou and Konstantinos Moraitis emphasized on the built environment, highlighting "identity" as a key element for development perspectives and aspirations. The concept of mountain identity is explored through its reference to the elements that constitute mountain settlements, as well as the conditions of its recognition, protection, and promotion. References are made to key concepts related to the issues, such as tradition, tangible and intangible, and the cultural and economic importance of its preservation, considering culture as a key pillar for integrated development.

Understanding the mountain ecosystems from conservation psychology perspectives forms a critical part of this book. Olena Khrushch and Yuliya Karpiuk in chapter 20, "Psychological Discourse in Building the Environmental Consciousness in Special Context of Carpathian Mountains", provide a theoretical analysis of environmental consciousness in terms environmental sensitivity, sustainable consumption, environmental concern and commitment to act pro-environmentally. Ecological crisis is examined through the lens of spirituality, value orientations, attitudes, worldviews and environmental consciousness. Among the other issues addressed are effective environmental literacy programs through school-family partnership and the driving forces of pro-environmental behavior in special context of Carpathian Mountains. In continuation, Khrushch *et al.* in chapter 21 on "Collective Ecological Consciousness from the Prism of Psychological Indicators" present the results of a theoretical analysis of the concept of collective ecological consciousness from the standpoint of mountain environment. They establish a firm correlation with environmental culture, which arises in the process of socialization, and the power of environmental intents aimed at protecting the environment. In particular, in a mountain society with a high level of development of collective ecological consciousness, young people from an early age employ effective strategies for the conservation and restoration of natural resources. Thus, the authors draw attention to the crisis of morality and spirituality, which is the main reason for developing a selfish type of collective ecological consciousness. The authors give examples of environmental education concepts and training to lay the theoretical foundation for developing effective programs to improve environmental culture in the younger generation in Carpathian Mountains.

Giving example of the FAO's Mountain Partnership, Rosalaura Romeo expressed in chapter 22 the "United Nations Mountain Agenda, the Mountain Partnership and Related Regional Mechanisms". She described the Agenda 21's Chapter 13, "Managing Fragile Ecosystems: Sustainable Mountain Development", where global action to promote sustainable mountain development has been supported by the United Nations (UN) and national and international stakeholders. The Mountain Partnership is the UN alliance dedicated to sustainable mountain development. Author articulates that it promotes advocacy and knowledge sharing in support of national policies and international cooperation to sustainably manage mountain landscapes and empower mountain people. Regional level initiatives for transboundary cooperation exist for some of the major mountain ranges, such as the Alps, the Andes, the Carpathians and the Himalayas. Alla Pecheniuk and Alla Kiziun in chapter 23 focused on "Postmodern Transformations of Tourism Development" in cotext of mountains. The contradictions between the present postmodern society and the information-technological development of the rural areas in Ukraine are highlighted. The main indicators of postmodern influences, such as informational and technological, political, social, socio-cultural, and personal (psychological), are earmarked featured. The factors influencing the postmodern tourism consumerism include the awareness of the social crisis, escape from reality, mundane avoidance, search for the self and self-realization, overcoming psychological trauma, the illusion of involvement in certain processes, positioning oneself with the upper class, new experience, and information society.

Overall, this book will give you an opportunity to travel from basics of mountain ecosystems to the applied aspects of science, social science, policy and spiritual contours.

About the Author(s)

The editor of this book, **Dr. Hasrat Arjjumend** is the *Founder President & CEO* of The Grassroots Institute (Canada). Additionally, as *Executive (Chief) Editor*, he manages and executes the Grassroots Journals (5 journals) published by The Grassroots Institute in partnership with different universities. He is involved with the International Year of Rangelands and Pastoralists (IYRP 2026) as *Co-Chair*, RISG – Central Asia & Mongolia, and as *Member*, RISG Europe. Educationally, he attained *Mitacs Elevate Postdoctorate* at Université de Montréal Faculté de Droit, Québec (Canada) in Agrarian/Environmental Law (laws of agri-biologicals in Canada, India, Ukraine and EU), PhD in International Studies (Biodiversity Law & Governance), PG Diploma in Environmental Law, MPhil in Natural Resource Management (MRM), MSc in Environmental Science, MA in Public Administration, MBA Human Resources and BSc Hons in Botany. Additionally, he received advanced practical training from the Canada, UK, Sweden, Thailand, Russia, India, Netherlands and the USA.

His first significant study was his MPhil dissertation work in 1998-99. He wrote a comprehensive critique of nature conservation policies worldwide. It led to denotification of a wildlife sanctuary in India for the interests of farmers/people. It was the first incidence in the conservation history of the Indian subcontinent when a protected area was scrapped for undoing the displacement of local inhabitants. Furthermore, during the past two and half decades, he completed multiple landmark studies and significant fieldwork focused on Indigenous people and their issues in Asia, as well as comparative studies on a global basis, culminating in his PhD work, which encompassed the evaluation of the extent of space, recognition, participation and involvement for/of Indigenous people not only in international law making (Nagoya Protocol), but also in domestic ABS (access and benefit sharing) law making & implementation processes. As the biocultural rights of Indigenous people are key to conservation and sustainable use of biodiversity, the domestic ABS laws require reorientation to be sufficiently effective in translating the spirit of international ABS laws. As a result, benefit-sharing processes (as per 3rd objective of CBD) and biopiracy of traditional knowledge and bioresources of Indigenous people cannot be checked effectively. He discerned and amplified that adequate participation and involvement, which had been lacking across the processes, of Indigenous peoples and local communities during the crafting of both the Nagoya Protocol and its corresponding domestic ABS legislation. His work brought this serious issue to the fore and debates have started within and outside CBD forums. Such a success added to progressive discourses towards advocating and asserting for Indigenous rights, dignity and self-determination. Among his current research orientations is the work on "rangeland governance and pastoralism" involving legal, policy, and social-ecological dimensions. Additionally, he has been trying to discover the utility of modern technologies by mobile pastoralists in managing their livestock across the changing environments and fragmented rangelands.

Along with the direct action with communities, he has carried out a significant quantum of training/teaching and writing/publishing. He has taught a variety of courses; to name but a few: Agriculture and Ecology, Organic Farming Systems, Governance of Land & Water Commons, Biodiversity Law, Pastureland Policies & Law, Development of Land Resources, Watershed Development in Arid Zones, Water Resources Management, Participatory Forest Management, Grasslands & Rangeland Management, Environmental Governance, Research Methods & Techniques, Natural Resource Management, and Urban Green Spaces. These courses constituted the milestones in the core 'natural resource management' syllabus. As an engaged scholar using interdisciplinary approaches, he seeks to provide experiential learning opportunities that not only encourage personal development of participants, but also the intercultural thinking that best informs global perspectives. To this end, being a trainer/teacher is the ultimate opportunity to inspire, empower, and provide transformative experiences for students. His teaching & training philosophy is grounded in his life experiences; he is a self-made person with diverse life experiences in the developing world that he integrates into classroom content. As a trainer/teacher, he emphasizes the mutual benefits of engaged scholarship and the development of an individual's social, emotional, intellectual, and creative well-being. This includes taking risk, thinking outside-the-box, and providing a passionate and fulfilling learning experience. Additionally, as an educator and researcher, his career has been centered on being a change-agent, advocating for solutions. Through training/teaching, he considers that he is transferring to youths and students not only the knowledge, but also an energy that they may retain to transform their lives. Be it a science subject, policy topic or societal reality there is a lot to share by him with the students/participants. Using participatory learning methods, he considers training/teaching as a source of empowerment, transformation and leadership.

As a change agent, he set in a few exceptional model accomplishments. During 2008-11, in the capacity of Project Director of EU-funded IEUPC Education Project, not only he conceptualized and designed the project, but he also created unique procedures, processes, systems, institutions and leaderships that resulted in empowerment of urban poor families in 3 cities for educating girl children and female youths. The exemplary work received UNESCO recognition in 2011. Embedded in that EU project, the Young Citizens Leadership initiative was his exceptional endeavour. Later during 2013-16, he organized agro-pastoralist communities by using Pastureland Policies and Legal Provisions provided in Agrarian & Local Governance Laws in Rajasthan (West India). In the capacity of Dean/Sr. Manager at Foundation for Ecological Security, he nurtured 1017 community collectives (institutions) to liberate about 30,000 hectares of pasturelands (commons) from clutches of local powerful elites, and institutional ownership of pastoral communities had been restored. Liberating lands by him from land grabbers was life threatening work. It brought meaningful change in governance patterns of natural resources impacting livelihoods of poor mass in India's arid zone. In addition to these two most commendable works, he used to be People-Centred Advocacy Campaigner from 1996 till 2012, apart from a popular writer journalist in editorial columns for 10 years. His preferred array of interventions, especially from 2005 to 2016, revolved around building the Stewardship among youths. He enabled thousands of youths who honed their leading capabilities with distinct vision and high-energy convictions.

Professionally, he possesses >30 years' experience of research, training, teaching, field action and organizational management, dealing with multidisciplinary areas of Environment, Natural Resources, Governance, Development, and Indigenous Rights. In the past he served, *inter alia*, as *Senior Agroecology Specialist* with Earth Alive Clean Technologies Inc. Canada, *Assistant Professor* (Natural Resources & Environmental Management) at Ethiopian Civil Service University Addis Ababa, *Dean/Sr. Manager* at FES Prakriti Karyashala Rural College (Rajasthan Campus, India), *Executive Director* of Grassroots India Trust, *Project Director* of EU-funded IEUPC Project, *Senior Program Officer* at Society for Participatory Research in Asia, *Research Officer* at National Centre for Human Settlement & Environment, *Biologist-I* at Wildlife Institute of India (Govt. of India). For over 18 years, he contributed as *Visiting/Guest Faculty* to several institutions in India and Europe, apart from being a *Consultant* to leading NGOs. Having inherent capacities of evolving, building and developing the institutions, he acted as a *leader* of several people-centred initiatives & forums (e.g., Madhya Pradesh Chapter of FIAN International – Germany), and later devolved the systems after completion of institutionalization process. Moreover, he was *Mitacs Elevate Fellow 2017-20* in Canada, *Senior Legal Fellow* at Centre for International Sustainable Development Law (CISDL) affiliated to McGill University in Montreal/Canada, *Visiting Fellow* at Yaroslav Mudriy National Law University of Ukraine, *Commonwealth Professional Fellow 2007* in England and *Social-Impact Fellow 2008-10* in Mumbai, apart from being the recipient of the *Award of Excellence for International Partnership 2021* from Valahia University of Targoviste Romania, CISDL Canada's *Legal Research Award 2019*, UNESCO-*Wenhui Award for Educational Innovation 2010* (Asia-Pacific), *Chairman's Gold Medal 1997-98* in MRM Natural Resource Management, USA's *Charles Evans Hughes Memorial Scholarship 2007*, and *S.J. Jindal Trust Scholarship 1990-91*. He has working exposure across half of India's geography (13 states), and working/study exposure to East Africa, South Asia, South-East Asia, Scandinavia, West Europe, East Europe and Canada. To his credit are about 192 publications of varied types (see Publications List), some of them published in WoS/Scopus indexed international journals. He is sitting in Editorial Boards of the European journals: EU Agrarian Law, Journal of Legal Studies, and Environmental Economics & Sustainable Development.

As the *Founder President & CEO* of The Grassroots Institute Canada, his record of leadership is outstanding. Since the inception in 2018, he has developed a global capacity building program 'Summer Field School on Mountain Ecosystems & Resources Management' of which the 2020-21 version was highly successful. About 66 universities and organizations from 21 countries partnered/ collaborated (and nearly 630 people from 69 countries took part). Likewise, the Summer Field School 2023 www.grassrootsglobal.net/mer2023 was led by 9 Lead Partner universities/organizations from Italy, Romania, Ukraine, India, Kyrgyzstan and Hungary, with 30 General Partners and 7 Collaborators belonging to 18 countries. Nearly 500 people representing 60 countries took part in this program in 2023. To bridge the gaps between field practice/ action and the knowledge generated in academic or research institutions, he is developing 'ggN - Grassroots Global Network' [www.grassrootsglobal.net], which would be a massive networking platform on natural resources management, policy and practice. While imagining a global lectures bank, the Global Lectures | Local Impacts https://www.grassrootsinstitute.ca/gli is his new and unique initiative that allows "lecture pooling", whereby multiple institutions can share the same virtual lecture simultaneously. This amplifies the reach of these valuable lectures to a wider audience across the world. To create space for leadership and skill development by the senior, mid-career and young scientists and professionals, he has successfully started the Grassroots Global Leadership Program https://www.grassrootsinstitute.ca/glp. Acting as publishing wing of TGI, the 'Grassroots Journals' www.grassrootsjournals.org was initiated by him in 2018 and currently, in the capacity of *Executive (Chief) Editor*, he is successfully operating 5 journals, namely 'Grassroots Journal of Natural Resources' [WoS indexed], 'Agrobiodiversity & Agroecology', 'Journal of Environmental Law & Policy' [HEIN indexed], 'Journal of Policy & Governance' [HEIN indexed] and 'Pastures & Pastoralism'. In a new partnership model, he is initiating an Online Education portfolio of TGI on the website https://www.grassrootsinstitute.ca. It is envisaged to take the shape of an educational institution. A complete present and future map of TGI can be understood from the main website www.grassrootsinstitute.net. Finally, Dr. Arjjumend's leadership is distinctly reflected in his networking and partnership building commitments and enthusiasms. Globally, he has developed a large network with academic, research, action and policy institutions, to include signed partnerships with nearly 90 universities, institutes, national parks, city councils, NGOs and networks. He is instrumental in creating a pool of over 450 experts, professors, scientists and professionals associated with and voluntarily contributing to TGI's different initiatives.

His current areas of academic & action interests include *Rangeland Ecosystems and Pastoral Livelihoods; Laws & Governance of Grazing Commons; Governance of Natural Resources; Resource Rights of Indigenous People; Agrarian Laws & Policies; Water Policies and Management*; *Agroecology.*

Chapter 2

Applying the Landscape Services Concept in Landscape Research: A Review

By Sining Zhang

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Applying the Landscape Services Concept in Landscape Research: A Review

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Abstract

Considerable attention has been given to the concept of landscape services since the development of research on ecosystem services. However, from the landscape perspective, there are numerous challenges and unanswered issues regarding landscape services. The objective of this chapter is to provide a comprehensive review about the state-of-the-art concept of landscape services and its corresponding approaches while trying to set up a foundation for further discussions. First, the definitions and classifications of ecosystem services and landscape services are presented. Second, the relationship between ecosystem services and landscape services, and the studies that integrate ecosystem services into landscape research, are discussed. Finally, an overview is provided concerning research conducted at multiple scales, and the various assessment and quantification methods used for mapping and studying landscape services, even though there are many challenges in establishing a comprehensive approach for such quantification and mapping.

Keywords

Landscape services; Ecosystem services; Classification; Quantifying and mapping

Citation

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1. Introduction

The ecosystem services (ES) approach is an effective way to strengthen the link between ecosystems and human well-being. Since the late 1960s (Odum and Odum, 1972), ES have been receiving significant attention in the scientific community. The terminology 'ecosystem services' was first used by Ehrlich and Ehrlich (1981). It represents a critical research agenda in the trans-disciplinary field of ecological economics, aiming to bridge the gap between ecosystem ecology and environmental and resource economics (Costanza *et al.*, 2017) to gain public interest in biodiversity conservation, the societal and economic value of natural assets is emphasised. The mainstreaming of ES was marked by two key publications: Daily (1997) and Costanza *et al.* (1997). In the two decades since its development, an extensive list of publications has been generated regarding key issues such as definitions, classification, valuation and assessments, modelling, and mapping approaches. Furthermore, various associated topics have become key issues in multidisciplinary fields of research. The concept of landscape services (LS) is one of them.

The terminology 'landscape services' (LS) is becoming increasingly popular because it is always regarded as a synonym for ES, especially when referring to landscape research. However, these terms are not always the same. ES act as a bridge between ecosystems and human well-being. However, the landscape is a socio-natural system - a holistic, appreciable and dynamic entity (Antrop, 2000) - that changes based on interactions with human activities. This means that landscapes involve natural ecosystems and total human ecosystems. Landscape science helps better understand the effects of the spatial distribution of human activities on landscape processes and structures through which services are derived (Müller *et al.*, 2008). LS, focusing on the relationship between human interactions and landscape processes and structures, are topical issues in the context of landscape ecology and sustainability (Termorshuizen and Opdam, 2009).

There are many arguments supporting the importance and application of LS in landscape research. For example, the effective use of LS for land use management and planning (De Groot and Hein, 2007), such as the analysis of landscape patterns, processes, and functionality as a premise for land use planning, which is an established process in Central and Eastern Europe. Another application is during policy-making processes and landscape planning, i.e., the assessment and planning of urban green infrastructure (Gulickx *et al.*, 2013). It also supports the development of landscape sustainability (Wu, 2013).

However, there are still many obstacles concerning LS, such as the typology, the relationship with ES, evaluation and visualisation approaches, and practical application in landscape planning and research (De Groot *et al.*, 2010). Several reviews have been published to clarify the development of ES, but not LS. The need to differentiate LS from ES in landscape research using a coherent and unified approach is essential, especially because this confusion can lead to the formation of a non-standard discipline with a blurred boundary. Additionally, LS alone should be treated as the common ground for interdisciplinary research.

This study aims to provide a thorough knowledge base that distinguishes LS from ES and seeks solutions for incorporating the concept of LS into landscape planning and decision-making processes while contributing to the ongoing discussions. Section 2 presents the state-of-the-art concept of LS (definition and classification). Section 3 provides a coherent knowledge base regarding the relationship between ES and LS (similarities and differences), and the integration of ES into landscape research. A research overview of LS is provided (Section 4), incorporating multi-scale studies, and different assessment and mapping methods. In conclusion, future development prospects are discussed (Section 5).

2. Typology of Landscape Services

2.1 Ecosystem Services

Many researchers have discussed the definition of ES (Costanza *et al*., 1997, 2017; De Groot *et al*., 2002; MA, 2005), but a unified definition is still unavailable. Various definitions have been proposed in a multidisciplinary context. De Groot (1992) explained ES as 'the capacity of natural conditions and processes to sustain human needs', emphasising ecological processes and structures. Cairns (1997) believes that ES are functions that promote human survival and development. However, Boyd and Banzhaf (2007) presented ES as biological components, rather than invisible ecological processes and functions, directly utilised for human well-being. Similarly, Fisher, Turner and Morling (2009) proposed that ES are 'the aspects of ecosystems utilised (actively or passively) to produce human well-being' (p. 645).

Currently, the definition of ES proposed by the Millennium Ecosystem Assessment (MA) may be the most widely used and recognised; ES are defined as 'the benefits from ecosystem functions and processes, which are favourable for human well-being, directly or indirectly' (MA, 2005, p. V). The term 'services' is used to denote goods, functions, and services. Regardless of the existing controversy, an extensive discussion has been triggered globally about ecosystem functions, goods, and services. Besides, the TEEB (The Economics of Ecosystems and Biodiversity) study defined ES as "the direct and indirect contributions of ecosystems to human well-being" (TEEB, 2010).

2.2 Definition of Landscape Services

The concept of LS has introduced a new approach for studies on multi-functional landscapes and spatial heterogeneity at the landscape scale. For instance, such alternative methods can be used to tackle the issue of quantifying invisible services (e.g., cultural services / aesthetic values). This concept was first used in a paper about the urban agricultural sector (Leones, 1994). Termorshuizen and Opdam (2009) proposed the terminology 'landscape services' to link landscape ecology and sustainable development, defining LS as 'a spatial human-ecosystems that offers additional ecological, social, and economic values based on human activities and landscape changes'. This concept considers the relationships among the locals, stakeholders, and the environment, promoting further collaboration across scientific disciplines and highlighting landscape patterns.

Currently, even though there are numerous corresponding publications, ambiguous boundaries still exist due to the lack of a unified theory about LS. Some of the key relevant arguments on the definition of LS can be seen in table 1, which aims to clarify the advance in the understanding of LS. This table shows that most researchers consider ES and LS as synonyms; the only difference being the matter of scale, rather than anything fundamental. However, from the perspective of specific disciplines (landscape planning / landscape ecology) and different stakeholders, 'landscape service' is a distinct term. Therefore, a clear dichotomy between the ES and LS concept is essential.

2.3 Classification Systems of Landscape Services

Significant efforts have been made by researchers to develop a clear catalogue for ES assessment, valuation, modelling, and policy-making (i.e., Daily, 1997; Syrbe and Walz, 2012), after Costanza *et al.* (1997) provided a list of seventeen services. Classification systems for ES mainly depend on ecosystem processes and functions. The typology put forth by MA is classified into four broad types of ES: provisioning, regulating, supporting, and cultural services (MA, 2005). However, the typology of ES does not consider the spatial pattern, and landscape elements and characteristics. A systematic typology and comprehensive framework for LS are currently lacking.

Table 1: Definitions of Landscape Services

Source	*Definition*	*Key points*
Termorshuizen and Opdam (2009)	'A unifying multi-disciplinary common ground integrated into multifunctional, actor-led landscape development, and a bridge between landscape ecology and landscape sustainability'. LS are a specification, not an alternative to ES. LS are a core application of landscape ecology based on interdisciplinary science development.	It is a generally recognised definition base on landscape structure, functions, and values, which argues that LS help bring landscape planning processes from theory to practice.
De Groot *et al.* (2010)	LS are defined as 'the capacity of ecosystems to provide goods and services that satisfy human needs'.	They consider ES and LS the same, without fundamental differences, mainly a matter of scale.
Willemen *et al.* (2012); Willemen (2010)	LS are 'the flow of goods and services provided by the landscape to society'.	A modelling approach is elaborated to visualise the regional spatial and temporal dynamics in the LS provided.
Syrbe and Walz, (2012)	The term 'ES' is enlarged to 'LS'. LS are a broader perception manner and highlight the spatial characteristics and relationships.	The LS assessment through landscape metrics integrates three different service provision areas.
Wu (2013)	'ES provided by multiple landscape elements in combination as emergent properties'.	LS are the core of landscape sustainability science in a changing landscape. But this narrow definition of LS refers to ecological services generated by landscape patterns or configurations (Bastian *et al.*, 2014).
Bastian *et al.* (2014)	ES and LS are synonyms. LS are 'the contributions of landscapes and landscape elements to human well-being'.	They proposed that spatial aspects, landscape elements and characteristics, and landscape planning impact the LS provision.
Hermann *et al.*	'All goods and services that landscapes	They argue that LS are

Source	*Definition*	*Key points*
(2014)	provide for well-being'.	more related to human habitats and cultural patterns, rather than natural processes and conservation.
Vallés-Planells, Galiana and Van Eetvelde (2014)	LS involve 'the social dimension of landscapes and the spatial pattern resulting from both natural and human processes in the provision of benefits for human well-being'.	They developed a classification for LS based on the Common International Classification of Ecosystem Services (CICES) and a review of the literature.
Westerink *et al.* (2017)	LS are delivered effectively by the biophysical landscape conditions, with a new role of enhancing social capital in landscape governance.	LS are more suitable for studying social capital and ecological networks.

In order to integrate ES at the landscape scale easily and to apply these services in landscape planning and decision making, researchers proposed classification systems for LS adapted from the classification systems for ES. De Groot *et al.* (2010) provided a categorisation similar to the ES classification since they consider ES and LS to be synonymous. Vallés-Planells, Galiana and Van Eetvelde (2014) developed a categorisation that is built on the CICES and combines the social dimension of landscapes, including three categories: provisioning, regulation and maintenance, and cultural and social life fulfilment services. Human well-being, as well as social and cultural dimensions have been considered at the landscape scale. More specifically, it emphasises the all-inclusive nature of landscapes and the benefits for human welfare, while considering human satisfaction. For example, health, enjoyment, self-fulfilment, and social fulfilment are included in the cultural and social services (See Table 2). Bastian *et al.* (2014) recommended a typology for LS (or ES), including provisioning, regulating, and social-cultural services, which clearly considers spatial aspects, and landscape characteristics and elements related to landscape planning and landscape ecology. ES and LS are considered to be the same only when the landscape dimension has been carefully considered.

Table 2 shows a comparison (differences and similarities) between the selected four ES and two LS classification systems. In this table, Costanza *et al.* (1997) classified ES into seventeen specific services. From the first column to the fourth column (Costanza *et al.*, 1997; MA, 2005; TEEB, 2010; Haines-Young and Potschin, 2010a), different classification systems of ES are shown. Vallés-Planells, Galiana and Van Eetvelde (2014) and Bastian *et al.* (2014) developed LS classification systems based on ES systems that refer to landscape related aspects. Besides, in some cases, a particular category serves two purposes and hence, the additional service theme is mentioned in parentheses.

It should be noted that these systems are broadly similar, especially the ones related to ES. Since the classification systems for LS are generally derived from the ES typology, it is essential to seek a unique, practical, scientific, and rational classification system for LS. On one hand, landscape features, distinct service delivery processes, their relationship to human values, and the application in decision making should be taken into account for an effective classification system. This means that landscape patterns and spatial characteristics are essential. On the other hand, apart from being pleasant and joyful amenities (Haines-Young and Potschin, 2010b), cultural services are also essential when considering services that fulfil personal and social human satisfaction. Furthermore, it is hard to evaluate cultural services without information on spatial patterns and landscape functions.

Table 2: Comparison (differences and similarities) between seven selected main classification systems for ecosystem services and landscape services applied in many research areas (Costanza *et al.*, 1997; MA, 2005; TEEB, 2010; Haines-Young and Potschin, 2010a; Vallés-Planells, Galiana and Van Eetvelde, 2014; Bastian *et al.*, 2014)

Source / *Theme*	*Costanza et al. (1997)*	*Millennium Ecosystem Assessment (MA, 2005)*	*TEEB (2010)*	*CICES 2010 (Haines-Young and Potschin, 2010a)*		*Vallés-Planells, Galiana and Van Eetvelde (2014)*		*Bastian* et al. *(2014)*	
	Categories	*Categories*	*Categories*	*Categories*	*Classes*	*Categories*	*Classes*	*Categories*	*Classes*
Provision-ing Services	Food production	Food	Food	Nutrition	Terrestrial plant and animal	Nutrition	Terrestrial plant and animal	Food	Food and fodder plants
									Livestock
					Marine plant and animal		Marine plant and animal		Wild fruit and game
					Freshwater plant and animal		Freshwater plant and animal		Wild fish
									Aquaculture
	Water supply	Freshwater	Water		Potable water		Potable water	Renewable raw materials &other natural resources	Freshwater
	Raw materials	Fibre	Raw materials	Materials	Biotic materials (Non-food plant fibres; Non-food animal fibres; Ornamental resources; Genetic resources; Medicinal resources)	Materials	Biotic materials (Non-food plant fibres; Non-food animal fibres; Ornamental resources; Genetic resources; Medicinal resources)		Fibre
									Timbers
		Ornamental resources	Ornamental resources						Other natural materials
		Bio-chemical & natural medicine	Medicinal resources						Bio-chemicals & natural medicine
	Genetic resources	Genetic resources	Genetic resources						Genetic resources
					Abiotic materials		Abiotic materials		
				Energy	Renewable biofuels	Energy	Renewable biofuels		Bioenergy
					Renewable abiotic energy		Renewable abiotic energy		
						Daily activities	A place to live/work/move		
Regulating services	Waste treatment	Waste treatment	Waste treatment	Regulation of waste	Bioremediation	Regulation of waste	Bioremediation		
					Dilution and sequestration		Dilution and sequestration		
				Regulation of physical environment	Water quality regulation	Regulation of physical environment	Water quality regulation	Hydrological services	Water purification
	Soil formation	Soil formation (supporting service)	Maintaining soil fertility		Pedogenesis and soil quality regulation		Pedogenesis and soil quality regulation	Pedological services	Maintenance of soil fertility
	Climate regulation	Climate regulation	Climate regulation		Atmospheric regulation		Atmospheric regulation	Meteorological	Climate regulation

Source / Theme	*Costanza et al. (1997)*	*Millennium Ecosystem Assessment (MA, 2005)*	*TEEB (2010)*	*CICES 2010 (Haines-Young and Potschin, 2010a)*		*Vallés-Planells, Galiana and Van Eetvelde (2014)*		*Bastian* et al. *(2014)*	
	Categories	*Categories*	*Categories*	*Categories*	*Classes*	*Categories*	*Classes*	*Categories*	*Classes*
								services	Noise protection
	Gas regulation	Air quality regulation	Air purification	Flow regulation	Air flow regulation	Flow regulation	Air flow regulation		Carbon sequestration
									Air quality regulation
	Water regulation	Water regulation	Regulation of water flow		Water flow regulation		Water flow regulation	Hydrological services	Water regulation
	Erosion control	Erosion regulation	Erosion regulation		Mass flow regulation		Mass flow regulation	Pedological services	Erosion prevention
	Disturbance regulation	Natural hazard regulation	Disturbance prevention						
	Biological control	Disease regulation	Biological control	Regulation of biotic environment	Pest and disease control	Regulation of biotic environment	Pest and disease control	Biological services	Regulation of pests and diseases
		Pest regulation							
	Pollination	Pollination	Pollination		Lifecycle maintenance & habitat protection		Lifecycle maintenance & habitat protection		Pollination
	Refugia (supporting service)		Lifecycle maintenance						
			Gene pool protection (habitat service)		Gene pool protection		Gene pool protection		Conserving biodiversity
						Regulation of the spatial structure	Connection of spaces		
							Buffer disturbing use		
							Provision of spatial complexity		
Supporting services	Nutrient cycling	Photosynthesis; Primary production; Nutrient cycling; Water cycling							
Cultural services								Information services	Environmental indication
									Archive function
	Cultural (incl. aesthetic, artistic, spiritual, education, science)	Knowledge system	Information for cognitive development	Intellectual and experiential	Information& knowledge (scientific & educational)	Self-fulfilment	Didactic resources		Education and training
							Way-finding		
							Scientific resources		
		Inspiration	Inspiration for culture, art, and				Source of inspiration		Intellectual and artistic inspiration

Source / *Theme*	*Costanza et al. (1997)*	*Millennium Ecosystem Assessment (MA, 2005)*	*TEEB (2010)*	*CICES 2010 (Haines-Young and Potschin, 2010a)*		*Vallés-Planells, Galiana and Van Eetvelde (2014)*		*Bastian* et al. *(2014)*	
	Categories	*Categories*	*Categories*	*Categories*	*Classes*	*Categories*	*Classes*	*Categories*	*Classes*
			design						
		Spiritual and religious values	Spiritual experience	Symbolic	Spiritual		Spiritual experience	Psychological goods and services	Ethical, spiritual, religious values
		Aesthetic values	Aesthetic information		Aesthetic & heritage (landscape characteristics, cultural landscapes)				Aesthetic values
		Sense of place				Social fulfilment	Place identity		Identification
		Cultural heritage values					Sense of continuity		
		Cultural diversity							
		Social relations					Social interactions		
	Recreation	Recreation and ecotourism	Recreation & tourism	Intellectual and experiential	Recreation and mmunity tivities	Enjoyment	Passive enjoyment	Psychological services	Recreation
							Active enjoyment		
						Health	Mental health		
							Physical health		

3. Relationship between Ecosystem Services and Landscape Services

3.1 Similarities and Differences

The ES concept is an essential part of research on ecological economics. Assigning monetary value to the services provided by nature is not an innovative idea. McCauley (2006) argued that the term 'service' is a utilitarian approach towards nature, because only the goods and products that are considered valuable for human beings, and not for the landscape or ecosystems, are considered. However, owing to the fact that humans and other species all belong to the biosphere, Costanza *et al.* (2017) emphasised that ES should not only focus on human beings alone, but also consider other species in the world. Furthermore, ES recognise that human well-being and survival are closely related to nature; therefore, humans should show the appropriate understanding and gratitude towards nature.

The LS evolve from ES, but they do not have an owner-member relationship (Figure 1). A landscape includes different kinds of ecosystems (usually a mix of ecosystems), indicating that LS are a mixture and/or a superimposition of ES, with different functions at different scales (e.g., aesthetic attractiveness). Furthermore, when compared to an ecosystem scale study, a regional ecological landscape is the most practical scale to conduct research on sustainable processes and mechanisms (Wu, 2013). It is also the bridge that links landscape ecology and sustainability science. However, landscape sustainability science is still in its formative stages, and few researchers have systematically studied the theories and methods related to regional ecological landscapes.

Both LS and ES highlight the link between ecosystems and human values and focus on the human dimensions of ecosystems. However, LS can describe the benefits provided by both natural and artificial landscapes, whereas ES focus on natural systems.

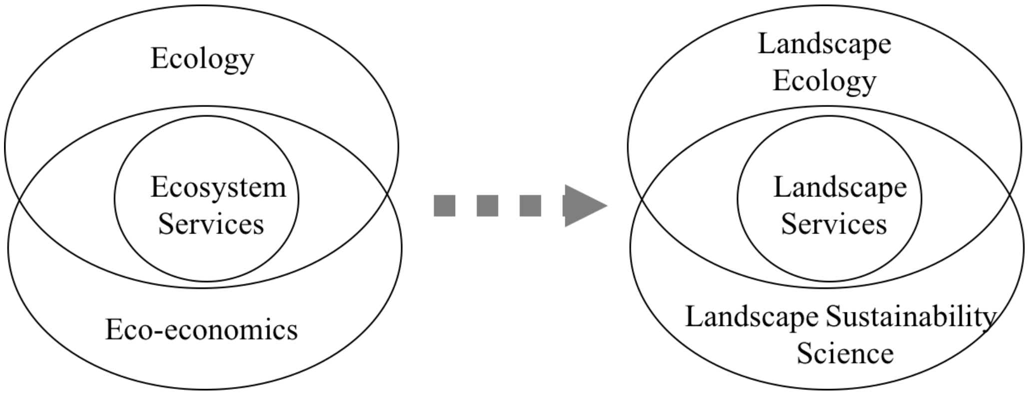

Figure 1: Chart of relationship between ecosystem services and landscape services. It portrays the effects of human activities.

The research on ES emphasizes the functional relationships between ecological processes and composition, but the spatial relationships between landscape structure and patterns are neglected. LS highlight the importance of spatial patterns and the spatial relationship between service providers and beneficiaries (Sun *et al.*, 2018). It also underlines the society property, since landscapes provide social benefits to human beings.

There is a visible indication to see the rapid development of ES research, which is the soaring quantity of literature. A search using SCOPUS on November 11, 2018, produced 19,461 papers using the term 'ecosystem service' in the title, abstract, or keywords between 1994 and 2018. There are over 2,000 papers from 2015 to 2018, and over 2,800 from 2017 to 2018 alone. The papers typically focus on valuation, quantification assessments, and mapping. Contrarily, there are only 99 papers employing the term 'landscape services' in the title, abstract, or keywords between 1994 and 2018 (SCOPUS, Figure 2), of which 86 papers were published in the last decade.

The number of publications on LS is only 0.5% of those on ES. An increase in the number of publications since 2005 can be observed in figure 2. Most of the papers with the term 'landscape services' in the title, abstract, and keywords, were published in Ecological Indicators and Landscape Ecology. Each of these journals published nine articles since 2009, followed by the Shengtai Xuebao Acta Ecologica Sinica (5 papers) and the Sustainability Switzerland journal (5 papers). Four papers were published in Horttechnology (2013 - 2016). The most important topics addressed were landscape planning, and the effects of landscape structure and patterns on the scale. Based on the data presented, collaborative efforts in LS research are absolutely imperative.

3.2 Integrating Ecosystem Services into Landscape Research

In the last decade, researchers have tried to integrate the concept of ES into landscape research. Using the search terms 'ecosystem services' and 'landscape' in the title in SCOPUS (November 11, 2018), 333 relevant papers were found, published between 2008 and 2018, with over 50 papers per year from 2016 to 2018 (Figure 3). 225 papers tackled case studies across the globe.

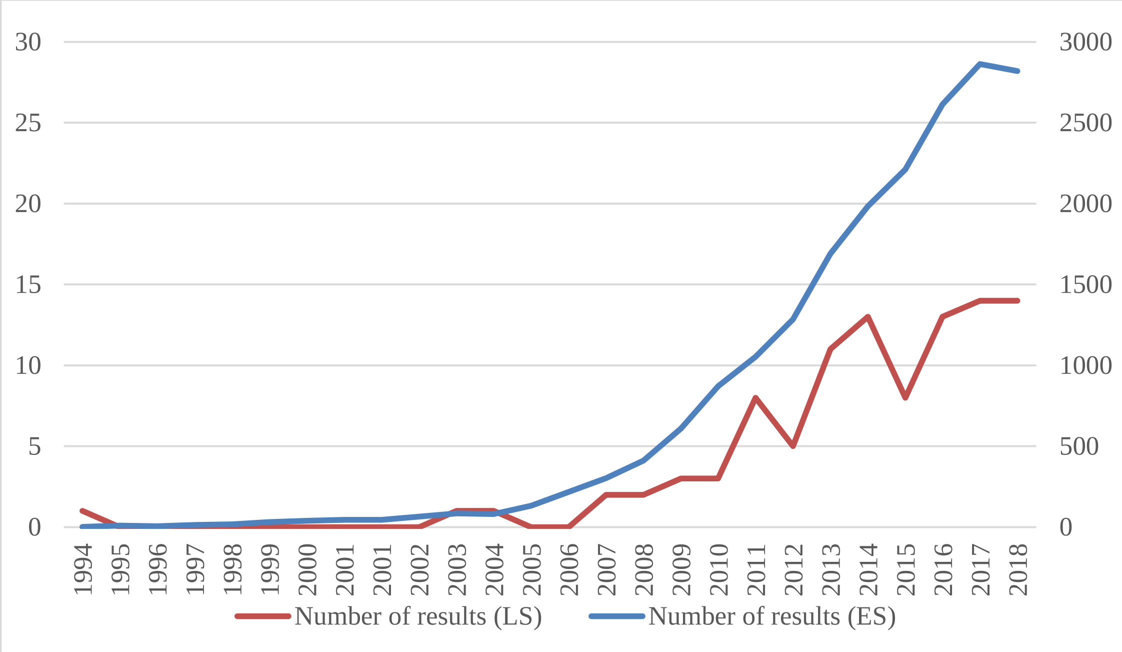

Figure 2: Comparison of published papers on ecosystem services and landscape services. Graphical representation based on SCOPUS search (November 11, 2018).

In general, ES and LS are considered synonyms only in the field of landscape planning (De Groot *et al.*, 2010). An abundance of research has been carried out on integrating ES and landscape planning, such as the impact of climatic and land-use change on ES (Lautenbach *et al.*, 2011), the impact of changes in landscape patterns on ES (Duarte *et al.*, 2018), the development and planning of green infrastructure (Liquete *et al.*, 2015; Zhang and Muñoz Ramírez, 2019), and, the advances in landscape planning (Ahern, Cilliers and Niemelä, 2014). LS are inevitably mentioned in these topics, because the LS concept is the key to analysing the relationship between spatial patterns and scales related to human activities.

4. Overview of Research Areas

4.1 Research Conducted at Multiple Scales

ES demonstrate a dominant role only at specific spatial-temporal scales (Hein *et al.*, 2006), as observed in studies on the supply, demand, and flow of ES are in a dynamic state at the different spatial (local, regional, national, and global) and temporal (short, medium, and long term) scales. It is important for stakeholders to analyse these scales in terms of varied interests and gain an insight into the applicable institutional scales for ecosystem management decisions. There is an increasing awareness of the significance of spatial-temporal scales when analysing and evaluating ES. For instance, Syrbe and Walz (2012) investigated the spatial characteristics of ES and their relationship with quantified measures of landscape structure. Hein *et al.* (2006) analysed the spatial scales of ES and elaborated the framework that enhances the applicability of ES valuation for decision making in the De Wieden wetland in the Netherlands. Wang and Dai (2020) identified the main factors affecting ES in the Heng-duan Mountain region.

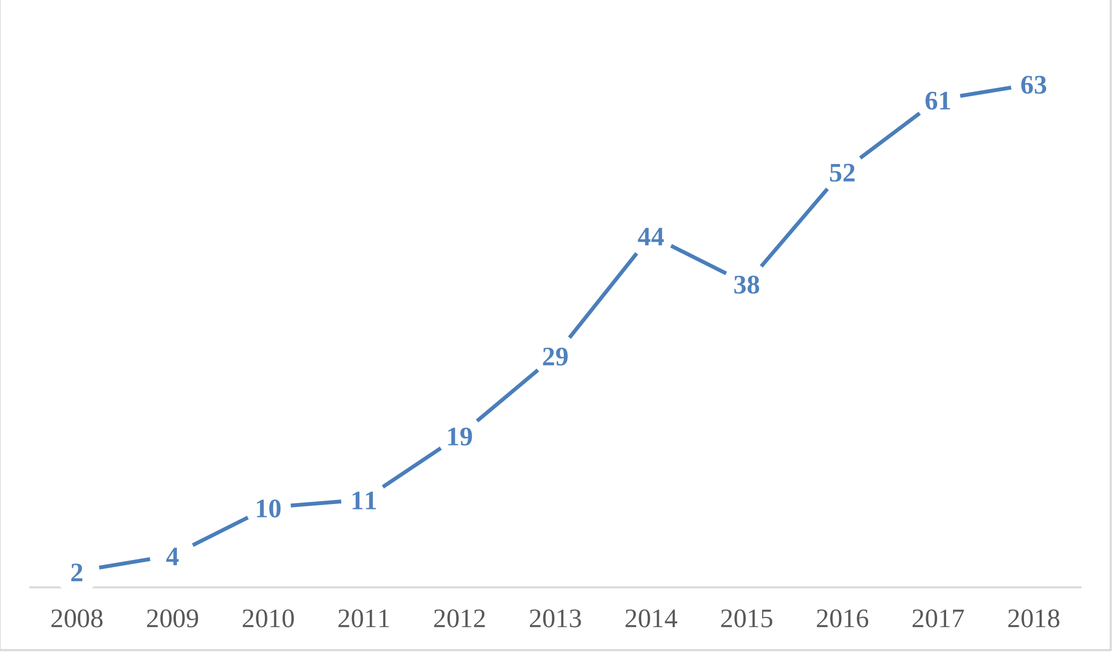

Figure 3: Number of published papers integrating the ecosystem services concept into landscape research. Source: SCOPUS search, November 11, 2018

However, when ES are applied at the landscape scale, many functions are often lost or degraded, due to an excessive emphasis on landscape functions (Costanza, 2008). For example, an overemphasis of recreational functions may result in the destruction of historical heritage and biodiversity loss. Therefore, it is important to balance various landscape functions while exploring the relationship between the delivered services. In order to explain and analyse the complicated relationships of LS at various scales, it is essential to know the association relationship of different LS at different spatial scales (Aertsen *et al.*, 2012). Also, it is necessary to consider the dominant services at the same spatial-temporal scale, and the coordination of services and functions at multiple scales that contributes to meeting various community demands.

Landscapes are constantly changing, resulting in a change in LS provision. Each of the LS has spatial heterogeneity. For example, climate regulation services, at the local scale, are presented as services that relieve urban heat island effects and maintain favourable weather (Niemelä *et al.*, 2010; Young, 2010). At the regional scale, it has a positive influence on maintaining a habitable environment for residents and good weather conditions for food production (Serna-Chavez *et al.*, 2014). On the global scale, it plays a crucial role in controlling carbon emissions and reducing global warming.

Therefore, before applying LS to landscape research and further decision-making processes, it is essential to consider LS in different scales at the same time. The transmission mechanisms of multi-scale ES and LS analysed with a spatial-temporal perspective requires further investigation.

4.2 Assessment Framework and Quantification Mapping

The assessment and mapping of ES aims to understand the process of transforming data to visualise the results regarding the spatial distribution of ES with advanced GIS technology that has proved to be a great instrument in decision-making (Sherrouse, Clement and Semmens, 2011), and landscape planning (Zhang and Muñoz Ramírez, 2019). In the published literature, there are four main methodologies:

(1) Literature survey method: It is based on the data applicability (Haines-Young and Potschin, 2009), but has high requisitions about the diversity and reliability of data.
(2) Modelling method (Nelson *et al.*, 2009): Most cases using it that neglect the landscape patterns and spatial heterogeneity.
(3) Assessment index method: It uses criteria and indicators to evaluate and map ES, including monetary evaluation methods, e.g., the market-valuing method (De Groot *et al.*, 2010), and, the value of monetization; and non-economic evaluation methods, e.g., the participatory, deliberative choice experiment approach (Kenter *et al.*, 2011).
(4) Land-cover based approach (Burkhard *et al.*, 2015; Burkhard *et al.*, 2009): This method considers the land use patches alone, but ignores the mosaics of boundaries, which are also important in landscape assessment (Martín de Agar, Ortega and de Pablo, 2016). Also, it does not support detailed evaluation and applies only to large scale data.

There are only 26 articles with a title that includes the term 'landscape services' (in SCOPUS search, on November 14, 2018). 17 of them focus on assessment and (or) quantification mapping of LS, which is a critical topic. In order to merge with landscape research, the existing literature usually combines the four methods used for ES to assess LS. Compared to the ES assessment results, the results of LS assessments can provide more accurate and valuable information, therefore, providing a knowledge base for broader decision processes. There are several reasons illustrating the importance of LS assessment results.

First, LS assessment results are helpful for community/regional stakeholders and land managers. For example, Kienast *et al.* (2009) utilised expert-and literature-driven binary links in Europe, which generates a broad-scale multi-functionality assessment framework of LS for land managers. Additionally, the public participatory approach utilises the knowledge of community stakeholders (Fagerholm *et al.*, 2012) to reach a collaborative, bottoms-up landscape management approach, and capture the non-utilitarian value of landscapes and sensitivity to cultural services. It is also used in land management by the American Indian tribes (Carver *et al.*, 2009) and conservation efforts in the Amazon (Bernard, Barbosa and Carvalho, 2011). However, it is limited by the experience and knowledge of stakeholders. Wu *et al.* (2013) combined the results of a field survey with spatial index data that identify hotspots and the relationships between LS in Beijing and its surrounding areas, illustrating the importance of LS for stakeholders.

Second, LS can be used in broader decision-making processes, especially in landscape planning. Willemen *et al.* (2012) proposed a modelling approach, which tackles the multi-functional characteristics of a landscape, classifies different spatial levels, and proposes a spatially explicit method to show the potential relevance of LS for decision-making in Gelderse Vallei, Netherlands. Hermann *et al.* (2014) assessed and visualised an array of LS, considering different spatial scales and levels of services, to adopt three different approaches - the Broader Habitat Approach, the Socio-cultural Approach, and the Landform Approach. They provide an efficient tool to support cross-border landscape planning processes.

Furthermore, in order to promote landscape sustainability research, a LS approach is necessary. Fang *et al.* (2015) provided the LS capability-flow-demand framework that can utilize LS for practical applications. Nowak and Grunewald (2018) assessed the LS supply in seven different study areas in the Malopolska Province, and characterised landscape sustainability by combining a qualitative and a quantitative analysis.

In conclusion, the assessment and mapping approaches of LS are mainly derived from ES but have distinctive features. The former synthesizes various methods during the evaluation and visualization of LS in the landscape dimension to help meet human needs, enhances the participation of the public and stakeholders, promotes practical applications of the concept, and addresses landscape sustainability in the context of trans-disciplinary research.

However, some factors of LS (landscape patterns, heterogeneity, elements and features) are not fully understood. Additionally, there is insufficient research based on practical case studies. Furthermore, landscapes are always in a dynamic state, hence, ES and LS are also dynamic changes in the development process. The dynamics regarding LS are significantly relevant to environmental management and decision making. Therefore, identifying these dynamic changes and determining its possible critical thresholds will be among the challenges for future researchers.

5. Conclusions and Recommendations

Although the concept of LS is derived from ES, and they are treated as synonyms in many studies, LS generate higher added value and provide a common ground unifying various disciplines (Termorshuizen and Opdam, 2009). Furthermore, LS can meet the demands of different stakeholders, promote broad-scale decision-making processes, and enhance landscape sustainability research. Hence, in future studies, LS should be regarded as a separate concept, instead of being a substitute for ES, and pursued in detail.

First, it is essential to develop and clarify the definition and typology of LS associated with landscape characteristics related to spatial patterns and the dimension of human activities. However, according to the typology of ES in the literature, one universal classification system does not exist since different disciplines and scientific purposes have led to different classification standards. Although Vallés-Planells, Galiana and Van Eetvelde (2014) and Bastian *et al.* (2014) have attempted to classify LS, it is still challenging to identify a fundamental category.

Second, the assessment and quantification methods for ES and LS are almost the same. Although in most studies on LS, several assessment methods are applied at the same time. Therefore, the next step would be to develop specific methods or tools to support the assessment and quantification of LS, and to establish a comprehensive framework involving socio-cultural, ecological, and economic values to support decision-making processes.

The existing literature has depended on the data on land use to ignore other choices. There is a large amount of data waiting to be explored. For example, mapping LS are not related to land use alone, but also to landscape features. The current maps of landscape functions and services include models and geo-statistical simulations (Ungaro, Zasada and Piorr, 2014), on-ground observations and spatial indicators (Gulickx *et al.*, 2013), and the knowledge of community stakeholders about aerial images (Fagerholm *et al.*, 2012). Although the map of landscape functions should also show heterogeneity in the quantity and quality of services provision (Meyer and Grabaum, 2008), spatially explicit data on landscape heterogeneity is still unavailable.

Additionally, spatial and temporal scales are key issues in the assessment and mapping of LS, since the landscape perceptions of stakeholders, regarding both supply and demand, are varied at different scales.

The last but not least, at present, the world is seriously threatened by climate change, and scholars have begun to explore solutions based on ES. When it comes to concepts such as carbon sinks, it is necessary to mention mountain ES. Many current studies have assessed the trade-offs (Briner *et al.*, 2013; Mina *et al.*, 2017), and influencing factors (Arjjumend, Shibata and Fakana, 2018; Boix-Fayos *et al.*, 2020), and temporal and spatial variations of mountain ES in the context of climate change. Even if the climate change factors are not considered in the assessment, the studies show that the trade-offs of MES in future scenarios are significantly affected by climate change (Briner *et al.*, 2013). Therefore, continued scientific research and case studies are needed in order to achieve a comprehensive methodology to assess and map LS, with respect to landscape features, patterns, processes, and scales, as well as pay more attention to how to combine mountain ES with LS theory and methods.

In conclusion, the LS research community is still in the early stages. Further effort is required to improve this scientific knowledge bases and overcome obstacles. Taking the development of ES as a reference, more studies and projects on LS should be conducted, similar to the TEEB and the CICES project for ES.

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7. References

Aertsen, W., Kint, V., Muys, B. and Van Orshoven, J. (2012). Effects of scale and scaling in predictive modelling of forest site productivity. *Environmental Modelling and Software*, 31: 19–27. DOI: https://doi.org/10.1016/j.envsoft.2011.11.012.

Ahern, J., Cilliers, S. and Niemelä, J. (2014). The concept of ecosystem services in adaptive urban planning and design : A framework for supporting innovation. *Landscape and Urban Planning*, 125: 254–259. DOI: https://doi.org/10.1016/j.landurbplan.2014.01.020

Antrop, M. (2000). Background concepts for integrated landscape analysis. *Agriculture, Ecosystems and Environment*, 77(1–2): 17–28. DOI: https://doi.org/10.1016/S0167-8809(99)00089-4.

Arjjumend, H., Shibata, S. and Fakana, S. (2018). Ecosystem Services of Forest Ecosystem in Nechisar National Park, Ethiopia: Identifying the Challenges and Conservation Measures. *Journal of Global Resources*, 4(2): 18–29. Available online at: https://www.researchgate.net/publication/326097643_ECOSYSTEM_SERVICES_OF_FOREST_ECOSYSTEM_IN_NECHISAR_NATIONAL_PARK_ETHIOPIA_IDENTIFYING_THE_CHALLENGES_AND_CONSERVATION_MEASURES [accessed 22 October 2022].

Bastian, O., Grunewald, K., Syrbe, R.U., Walz, U. and Wende, W. (2014). Landscape services: the concept and its practical relevance. *Landscape Ecology*, 29(9): 1463–1479. DOI: https://doi.org/10.1007/s10980-014-0064-5.

Bernard, E., Barbosa, L. and Carvalho, R. (2011). Participatory GIS in a sustainable use reserve in Brazilian Amazonia: Implications for management and conservation. *Applied Geography*, 31(2): 564–572.

Boix-Fayos, C., Boerboom, L.G.J., Janssen, R., Martínez-Mena, M., Almagro, M., Pérez-Cutillas, P., Eekhout, J.P.C., Castillo, V. and de Vente, J. (2020). Mountain ecosystem services affected by land use changes and hydrological control works in Mediterranean catchments. *Ecosystem Services*, 44(October 2019): 101136.

Boyd, J. and Banzhaf, S. (2007). What are ecosystem services? The need for standardized environmental accounting units. *Ecological Economics*, 63(2–3): 616–626. DOI: https://doi.org/10.1016/j.ecolecon.2007.01.002.

Briner, S., Huber, R., Bebi, P., Elkin, C., Schmatz, D.R. and Grêt-Regamey, A. (2013). Trade-offs between ecosystem services in a mountain region. *Ecology and Society*, 18(3): 35. DOI: https://doi.org/10.5751/ES-05576-180335.

Burkhard, B., Kroll, F., Müller, F. and Windhorst, W. (2009). Landscapes' capacities to provide ecosystem services - A concept for land-cover based assessments. *Landscape Online*, 15(1): 1–22.

Burkhard, B., Kroll, F., Nedkov, S. and Müller, F. (2012). Mapping ecosystem service supply, demand and budgets. *Ecological Indicators*, 21: 17–29. DOI: https://doi.org/10.1016/j.ecolind.2011.06.019.

Burkhard, B., Müller, A., Müller, F., Grescho, V., Anh, Q., Arida, G., Bustamante, J., Victor J., Van C. H., Heong, K. L., Escalada, M., Marquez, L., Thanh T., Dao T., Sylvia B. and Settele, J. (2015). Land cover-based ecosystem service assessment of irrigated rice cropping systems in southeast Asia-An explorative study. *Ecosystem Services*, 14: 76–87. DOI: https://doi.org/10.1016/j.ecoser.2015.05.005.

Cairns, J. (1997). Protecting the delivery of ecosystem services. *Ecosystem Health*, 3(3): 185-194.

Carver, S., Watson, A., Waters, T., Matt, R., Gunderson, K. and Davis, B. (2009). Developing computer-based participatory approaches to mapping landscape values for landscape and resource management (pp. 431–448). Springer, Dordrecht.

Costanza, R. (2008). Ecosystem services: Multiple classification systems are needed. *Biological Conservation*, 141(2): 350–352. DOI: https://doi.org/10.1016/j.biocon.2007.12.020.

Costanza, R., D´Arge, R., De Groot, R.S., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, Sh., O´Neill, R., Pauelo, J., Raskin, R., Sutton, P., van den B. and Man den Belt, M. (1997). The value of the word´s ecosystem services and natural capital. *Nature*, 387: 253–260.

Costanza, R., De Groot, R. S., Braat, L., Kubiszewski, I., Fioramonti, L., Sutton, P., Farber, S. and Grasso, M. (2017). Twenty years of ecosystem services: How far have we come and how far do we still need to go? *Ecosystem Services*, 28: 1–16. DOI: https://doi.org/10.1016/j.ecoser.2017.09.008.

Daily, G.C. (1997). *Nature's Services: Societal Dependence on Natural Ecosystems*. Washington, DC: Island Press.

De Groot, R.S. (1992). *Functions of nature : evaluation of nature in environmental planning, management and decision making*. Groningen: Wolters-Noordhoff BV.

De Groot, R. S., Alkemade, R., Braat, L., Hein, L. and Willemen, L. (2010). Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. *Ecological Complexity*, 7(3): 260–272. DOI: https://doi.org/10.1016/j.ecocom.2009.10.006.

De Groot, R.S. and Hein, L. (2007). Concept and valuation of landscape functions at different scales BT - Multifunctional Land Use: Meeting Future Demands for Landscape Goods and Services. In: Ü. Mander, H. Wiggering, and K. Helming (Eds.) (pp. 15–36). Berlin, Heidelberg: Springer. DOI: https://doi.org/10.1007/978-3-540-36763-5_2.

De Groot, R.S., Wilson, M.A. and Boumans, R.M.J. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics*, 41(May): 1–20. DOI: https://doi.org/10.1016/S0921-8009(02)00089-7.

Duarte, G.T., Santos, P.M., Cornelissen, T.G., Ribeiro, M.C. and Paglia, A.P. (2018). The effects of landscape patterns on ecosystem services: meta-analyses of landscape services. *Landscape Ecology*, 33(8): 1247–1257. DOI: https://doi.org/10.1007/s10980-018-0673-5.

Ehrlich, P. and Ehrlich, A. (1981). Extinction: the causes and consequences of the disappearance of species. New York: Random House.

Fagerholm, N., Käyhkö, N., Ndumbaro, F. and Khamis, M. (2012). Community stakeholders' knowledge in landscape assessments - Mapping indicators for landscape services. *Ecological Indicators*, 18: 421–433. DOI: https://doi.org/10.1016/j.ecolind.2011.12.004.

Fang, X., Wenwu, Z. and Bojie Fu, J.D. (2015). Landscape service capability , landscape service flow and landscape service demand : A new framework for landscape services and its use for landscape sustainability assessment. *Progress in Physical Geography*, 39(6): 817-836. DOI: https://doi.org/10.1177/0309133315613019.

Fisher, B., Turner, R.K. and Morling, P. (2009). Defining and classifying ecosystem services for decision making. *Ecological Economics*, 68(3): 643–653. DOI: https://doi.org/10.1016/j.ecolecon.2008.09.014.

Gulickx, M.M.C., Verburg, P.H., Stoorvogel, J.J., Kok, K. and Veldkamp, A. (2013). Mapping landscape services: A case study in a multifunctional rural landscape in the Netherlands. *Ecological Indicators*, 24: 273–283. DOI: https://doi.org/10.1016/j.ecolind.2012.07.005.

Haines-Young, R. and Potschin, M. (2009). *Methodologies for defining and assessing ecosystem services. Final Report, JNCC.*

Haines-Young, R. and Potschin, M. (2010a). Proposal for a common international classification of ecosystem goods and services (CICES) for integrated environmental and economic accounting. Report to the European Environment Agency. Department of Economic and Social Affairs Statistics Division, United Nations, Nottingham, UK.

Haines-Young, R. and Potschin, M. (2010b). The links between biodiversity, ecosystem services and human well-being. *Ecosystem Ecology*, 1: 110-139. DOI: https://doi.org/10.1017/CBO9780511750458.007.

Hein, L., van Koppen, K., De Groot, R.S. and van Ierland, E.C. (2006). Spatial scales, stakeholders and the valuation of ecosystem services. *Ecological Economics*, 57(2): 209–228. DOI: https://doi.org/10.1016/j.ecolecon.2005.04.005.

Hermann, A., Kuttner, M., Hainz-Renetzeder, C., Konkoly-Gyuró, É., Tirászi, Á., Brandenburg, C., Allex B., Ziener K. and Wrbka, T. (2014). Assessment framework for landscape services in European cultural landscapes: An Austrian Hungarian case study. *Ecological Indicators*, 37(PART A): 229–240. DOI: https://doi.org/10.1016/j.ecolind.2013.01.019.

Kenter, J.O., Hyde, T., Christie, M. and Fazey, I. (2011). The importance of deliberation in valuing ecosystem services in developing countries-Evidence from the Solomon

Islands. *Global Environmental Change*, 21(2): 505–521. DOI: https://doi.org/10.1016/j.gloenvcha.2011.01.001.

Kienast, F., Bolliger, J., Potschin, M., De Groot, R. S., Verburg, P. H., Heller, I., Wascher, D. and Haines-Young, R. (2009). Assessing landscape functions with broad-scale environmental data: Insights gained from a prototype development for Europe. *Environmental Management*, 44(6): 1099–1120. DOI: https://doi.org/10.1007/s00267-009-9384-7.

Lautenbach, S., Kugel, C., Lausch, A. and Seppelt, R. (2011). Analysis of historic changes in regional ecosystem service provisioning using land use data. *Ecological Indicators*, 11(2): 676–687. DOI: https://doi.org/10.1016/j.ecolind.2010.09.007.

Leones, J. (1994). Landscape Services: An Urban Agricultural Sector. *Agribusiness*, 10(1): 13–26.

Liquete, C., Kleeschulte, S., Dige, G., Maes, J., Grizzetti, B., Olah, B. and Zulian, G. (2015). Mapping green infrastructure based on ecosystem services and ecological networks : A Pan-European case study. *Environmental Science and Policy*, 54: 268–280. DOI: https://doi.org/10.1016/j.envsci.2015.07.009.

MA (Millennium Ecosystem Assessment) (2005). *Ecosystems and Human Well-being: Synthesis*. Washington, DC.: Island Press.

Mander, Ü., Helming, K. and Wiggering, H. (2007). Multifunctional land use: meeting future demands for landscape goods and services. In: *Multifunctional land use* (pp. 1–13). Berlin, Heidelberg: Springer.

Martín de Agar, P., Ortega, M. and de Pablo, C.L. (2016). A procedure of landscape services assessment based on mosaics of patches and boundaries. *Journal of Environmental Management*, 180: 214–227. DOI: https://doi.org/10.1016/j.jenvman.2016.05.020.

McCauley, D.J. (2006). Selling out on nature. *Nature*, 443: 27. DOI: https://doi.org/10.1038/443027a.

Meyer, B.C. and Grabaum, R. (2008). MULBO: Model framework for Multicriteria Landscape Assessment and Optimisation. A support system for spatial land use decisions. *Landscape Research*, 33(2): 155–179. DOI: https://doi.org/10.1080/01426390801907428.

Mina, M., Bugmann, H., Cordonnier, T., Irauschek, F., Klopcic, M., Pardos, M. and Cailleret, M. (2017). Future ecosystem services from European mountain forests under climate change. *Journal of Applied Ecology*, 54(2): 389–401. DOI: https://doi.org/10.1111/1365-2664.12772.

Müller, F., Jones, K.B., Krauze, K., Li, B.L., Victorov, S., Petrosillo, I. and Zurlini, G. (2008). Landscape approaches to assess environmental security: summary, conclusions, and recommendations. In: *Use of landscape sciences for the assessment of environmental security* (pp. 475–486). Springer. Dordrecht.

Nelson, E., Mendoza, G., Regetz, J., Polasky, S., Tallis, H., Cameron, D.R., Chan, Kai M.A., Daily, G.C., Goldstein, J., Kareiva, P. M., Lonsdorf, E., Naidoo, R., Ricketts, T. H. and Shaw, M.R. (2009). Modeling multiple ecosystem services, biodiversity conservation, commodity production, and tradeoffs at landscape scales. *Frontiers in Ecology and the Environment*, 7(1): 4–11. DOI: https://doi.org/10.1890/080023.

Niemelä J., Saarela S-R., Söderman T., Kopperoinen L., Yli-Pelkonen V., Väre S., K.D.J. (2010). Using the ecosystem services approach for better planning and conservation of urban green spaces : a Finland case study. *Biodiversity and Conservation*, 19 (11): 3225–3243. DOI: https://doi.org/10.1007/s10531-010-9888-8.

Nowak, A. and Grunewald, K. (2018). Landscape sustainability in terms of landscape services in rural areas: Exemplified with a case study area in Poland. *Ecological Indicators*, 94(February): 12–22. DOI: https://doi.org/10.1016/j.ecolind.2018.01.059.

Odum, E.P. and Odum, H.T. (1972). Natural areas as necessary components of man's total environment. *Trans North Am Wildl Nat Res Conf*, 3: 178–189.

Serna-Chavez, H.M., Schulp, C.J.E., Van Bodegom, P.M., Bouten, W., Verburg, P.H. and Davidson, M.D. (2014). A quantitative framework for assessing spatial flows of ecosystem services. *Ecological Indicators*, 39(April): 24–33. DOI: https://doi.org/10.1016/j.ecolind.2013.11.024.

Sherrouse, B.C., Clement, J.M. and Semmens, D.J. (2011). A GIS application for assessing, mapping, and quantifying the social values of ecosystem services. *Applied Geography*, 31(2): 748–760. DOI: https://doi.org/10.1016/j.apgeog.2010.08.002.

Sun, J., Liu, L., Müller, K., Zander, P., Ren, G., Yin, G. and Hu, Y. (2018). Surplus or deficit? Spatiotemporal variations of the supply, demand, and budget of landscape services and landscape multifunctionality in suburban Shanghai, China. *Sustainability (Switzerland)*, 10(10): 1–21. DOI: https://doi.org/10.3390/su10103752.

Syrbe, R.U. and Walz, U. (2012). Spatial indicators for the assessment of ecosystem services: Providing, benefiting and connecting areas and landscape metrics. *Ecological Indicators*, 21: 80–88. DOI: https://doi.org/10.1016/j.ecolind.2012.02.013.

TEEB (2010). *The economics of ecosystems and biodiversity: ecological and economic foundations*. (P. Kumar, Ed.). London: Routledge.

Termorshuizen, J.W. and Opdam, P. (2009). Landscape services as a bridge between landscape ecology and sustainable development. *Landscape Ecology*, 24(8): 1037–1052. DOI: https://doi.org/10.1007/s10980-008-9314-8.

Ungaro, F., Zasada, I. and Piorr, A. (2014). Mapping landscape services, spatial synergies and trade-offs. A case study using variogram models and geostatistical simulations in an agrarian landscape in North-East Germany. *Ecological Indicators*, 46: 367–378. DOI: https://doi.org/10.1016/j.ecolind.2014.06.039.

Vallés-Planells, M., Galiana, F. and Van Eetvelde, V. (2014). A Classification of Landscape Services to Support Local Landscape. *Ecology & Society*, 19(1): 1–11. DOI: https://doi.org/10.5751/ES-06251-190144.

Wang, Y. and Dai, E. (2020). Spatial-temporal changes in ecosystem services and the trade-off relationship in mountain regions: A case study of Hengduan Mountain region in Southwest China. *Journal of Cleaner Production*, 264: 121573. DOI: https://doi.org/10.1016/j.jclepro.2020.121573.

Westerink, J., Opdam, P., van Rooij, S. and Steingröver, E. (2017). Landscape services as boundary concept in landscape governance: Building social capital in collaboration and adapting the landscape. *Land Use Policy*, 60: 408–418. DOI: https://doi.org/10.1016/j.landusepol.2016.11.006.

Willemen, L., Veldkamp, A., Verburg, P. H., Hein, L. and Leemans, R. (2012). A multi-scale modelling approach for analysing landscape service dynamics. *Journal of Environmental Management*, 100: 86–95. DOI: https://doi.org/10.1016/j.jenvman.2012.01.022.

Willemen, L. (2010). Mapping and modelling multifunctional landscapes. Wageningen University and Research, the Netherlands.

Wu, J. (2013). Landscape sustainability science: Ecosystem services and human well-being in changing landscapes. *Landscape Ecology*, 28(6): 999–1023. DOI: https://doi.org/10.1007/s10980-013-9894-9.

Wu, J., Feng, Z., Gao, Y. and Peng, J. (2013). Hotspot and relationship identification in multiple landscape services: A case study on an area with intensive human activities. *Ecological Indicators*, 29: 529–537. DOI: https://doi.org/10.1016/j.ecolind.2013.01.037.

Young, R.F. (2010). Managing municipal green space for ecosystem services. *Urban Forestry & Urban Greening*, 9(4): 313–321. DOI: https://doi.org/10.1016/j.ufug.2010.06.007.

Zhang, S. & Muñoz Ramírez, F. (2019). Assessing and mapping ecosystem services to support urban green infrastructure: The case of Barcelona, Spain. *Cities*, 92: 59–70. DOI: https://doi.org/10.1016/j.cities.2019.03.016.

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Chapter 3

Mountain Biodiversity in Romania

By Daniela Antonescu

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Mountain Biodiversity in Romania

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Abstract
There exists a strong link between mountain regions and biodiversity. These regions represent the most important source of regional and global ecosystems forming the core elements of environmental and sustainable development policies. Mountains operate as true refuge for endemic species but are affected by uncontrolled human actions, while alpine meadows are exposed to losses of traditional pasture practices. Mountains can be analyzed from the economic, ecological, environmental, social, cultural viewpoints and their multidisciplinary nature is acknowledged both in the academic milieu and by decision makers involved in territorial development policy. The negative impact of economic activities in mountain regions is becoming more visible, therefore, necessitating a sustainable approach to preserve the biodiversity and habitat in order to salvage the fragile ecological balance. The present paper gives an overview of the relationship between biodiversity and sustainability within mountain regions and its implications on the economic and social development process. By interpreting the finding of previous research and studies, the article presents the current knowledge of mountain biodiversity in Europe and Romania and its relationship with sustainable development process.

Keywords
Biodiversity; Mountain region; Sustainable development

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1. Introduction

The mountain areas covering about 22% of the Earth's surface (32 million km^2), sustain directly about 13% of the world's population (915 million inhabitants), of them 70% is the rural population. Mountains provide approximately 60-80% of the water resources of the Earth[1]. Due to the unique natural exquisiteness, mountains host most of the protected areas. Thus, approximately 25% of the total land surface covered by mountains represent the permanent dwelling place of some rare species of fauna and flora, either relict or in peril (Blyth *et al.*, 2002, p. 494) or shaping unique habitats and ecological shelter corridors for forest species (Körner and Ohsawa, 2005).

The mountain regions hold 60% of the biosphere's reserves that contribute by 15-20% to the tourism activities at global level (Romeo *et al.*, 2021). They are covered by 23% by forests. They shape a living supporting life-environment of populations continuously and aggressively subjected to severe economic pressures (unemployment, migration, change of land use models, habitat fragmentations, deforestation, industrialization, mining pressure, pollution and uncontrolled exploitation of natural resources, and environmental degradation, water deficit, etc.) contributing to decreasing intrinsic values. Mountain regions are found in all continents, at all latitudes and within all types of ecosystems (from the arid desert and tropical rainforests to the polar zones).

Mountain regions are relevant and play an important role in the economic, social, environmental development, as well as in the culture and traditions of local communities. They provide ecosystem services, such as water provisioning and cycling to both mountain and lowland communities. They also host a high diversity of habitats and species highly adapted to extreme climatic conditions. Mountain ecosystems are fragile and vulnerable, and are severely threatened by land abandonment or intensified agriculture, infrastructure development and rapid climate change (Korner, 1985). The use and exploitation of natural resources within the mountains affect biodiversity, sometimes, causing inestimable damage to it (Zemp, Hoelzle and Haeberli, 2009), which are as follows:

1. *Impact of the agricultural sector on mountain biodiversity*: There are mutual and complex interactions between agriculture and mountain biodiversity. Agriculture affects biodiversity. The mountain biodiversity is one of the main element of the ecological production in agriculture field. On the one hand, sustains the crops and domestic livestock and the variety within them. On the other hand, components of wild biodiversity in agricultural provide and maintain ecosystem services that are essential to agricultural production. The heterogeneous mountain environment contributes to the evolution of a variety of agricultural cultures adapted to the environmental conditions and human needs. The cultivation of food crops (corn, potatoes, barley, sorghum, tomatoes, apples, etc.) and rearing of domestic animals (sheep, goats, etc.) originated from the mountainous regions. Over time, the genetic diversity of the plants and animals from the mountain region are on the increase due to the cultural diversity and extreme variations of the environmental conditions. Currently, the mountainous biodiversity is threatened by the continuing modernization processes of agricultural production, an aspect that leads to the pauperization of the ecosystem by using few sorts and lacking

[1] https://gridarendal-website-live.s3.amazonaws.com/production/documents/:s_document/412/original/SynthesisReport_screen.pdf?1544437610

genetic variation[2]. The expansion of agricultural production on untilled land triggers the destruction of habitats for some species and the deterioration of ecosystems, especially where the lands are not adequately exploited for agriculture. The mountainous agricultural ecosystems may bear invasions of some alien habitats thereby affecting local species and, implicitly, the local biodiversity as they are separated by valleys and mountain peaks (Romanian Parliament, 2003).

2. *Impact of the forestry sector on mountain biodiversity*: Mountain forests deliver ecosystem goods and service to millions of individual in mountain communities and adjacent lowland areas. Globally, 23% of the world's forests are located in mountain regions, covering 9 million square kilometers. Mountain forests and biodiversity provide many benefits, such as erosion control, improved water quality and quantity, carbon fixation, recreation and aesthetic appeal, timber, fuel wood and non-timber forest products (Mountain Partnership, 2020). The vast majority of the mountainous area is made out of the forest ecosystems of low and medium altitude. Under certain conditions, the mountain forests provide basic goods and services to local communities. The forest ecosystems within the mountain areas are threatened by the unsustainable methods of wood exploitation (uncontrolled, abusive wood-cutting, setting-up forest monocultures, etc.). The situation of forests in Europe appears to be relatively promising with respect to their biodiversity in the future. Approximately 10% of the forest area in Europe is in conservation areas. Nevertheless, an increase in area of conservation appears not to be the only remedy to protect forest biodiversity. While some authors concluded that conserved forests have higher biological diversity than managed plantations, others have found that some taxa or species profit from human-managed forests (Horák *et al.*, 2019).

3. *Impact of the tourism sector on mountain biodiversity*: During the past some years, tourist activities in the mountain region had important dynamics (winter sports, outdoor activities, etc.), a fact which led to extending the tourism infrastructure and tourism services. This affected rapidly the fragile ecosystems and the mountain biodiversity in an uncontrollable manner. For instance, the remodeling of mountain slopes for skiing and other winter sports has a strong impact on the integrity of the mountain ecosystems. The building of tourist infrastructure has resulted in the urbanization of some mountain areas with (total or partial) biodiversity loss.

4. *Impact of mining on mountain biodiversity*: Exploitation of ore, metal and other resources has a negative impact within mountain regions leading to severe water pollution and disturbance of the downstream areas. Moreover, the cutting of trees/plants and digging of the soil in areas where mining is practiced result into the destruction of landscapes, habitats, soil and agricultural lands. At the same time, rains wash away the land of open strip mining and the sediments pollute groundwater, poisoned fish, disfigure the rivers and rivulets, and generate flooding and landslides.

5. *Impact of the hydropower plants on mountain biodiversity*: The mountains and mountain lakes are frequently used in building power plants for generating electricity. Even if they represent an important source of renewable (green) energy, their design has negative impact on rivers and ecosystems in the vicinity. The creation of artificial lakes and the alteration of watersheds also affect negatively the habitats, ecosystems and valleys in the immediate proximity (Romanian Parliament, 2003).

[2] According to a recent FAO estimate, 78% of the world's mountain area is unsuitable or only marginally suitable for growing crops.

6. *Impact of climate change on biodiversity*: Another process that has an important impact on mountain biodiversity is climate change. Mountain environments are very sensitive to climate change (Beniston, 2003). They appear among the most severely and rapidly impacted ecosystems, and can be affected by any change in temperature and precipitation patterns at all scales (Zemp, Hoelzle and Haeberli, 2009). Thus, global warming affects negatively mountain ecosystems by the retraction and sometimes extinction of some life forms from the alpine area. Endemic mountainous species pulled back at high elevations and some destroyed due to habitat loss. Changes in the precipitation periods and increase in temperatures have triggered the melting of glaciers and decline of snow-covered mountain areas, thus, reducing the capacity of rejuvenating waters. By a process of non-compliant water management process in the mountain areas, both low altitude and vicinity areas were subjected to water scarcities.

Moreover, air pollution influences negatively the mountain biodiversity. In the mountain areas, the high rates of precipitation results to the depositing polluters from the atmosphere in soils and/or its accumulation in the snow layers affecting ecosystems and vulnerable species. Acid rain triggers the destruction of trees, although it involves intensive research and careful monitoring activities of polluters and main sources (Rey and Gruia, 2016).

This chapter addresses a number of problems relating to mountain biodiversity in Romania. Following an introduction outlining the overarching issues, a short summary is given on important factors that affected the biodiversity of mountain regions. The biodiversity of mountain is subjected to a phenomena correlated directly to the activities of the local communities (and not only): abandoning the area, tourism and winter sports development, infrastructure development, urbanization, soil compaction, etc.

2. Biodiversity of the Mountain European Area

In Europe, the mountain area covers 40% of the total surface area hosting 20% of the population[3]. On European continent, seven of the longest and highest mountain chains of the globe do exist, namely: the Alps (localized in the Central Europe), the Apennines (Italy), the Pyrenees (on the border between Spain and France), the Scandinavian Mountains (Sweden, Finland and Norway), the Carpathians (covering 7 countries with the shape of an ark from Slovakia to Romania), the Balkan Mountains (Croatia, Bosnia & Herzegovina, Serbia, Albania, Macedonia) and the Rhodope Mountains (Bulgaria). The main mountain regions from Europe and its countries are presented in table 1.

The extremely complex topography (south-oriented sheltered slopes, snow pockets, wind-blasted crags and rugged land covered by debris) explain the particularly rich biodiversity of the alpine areas (two-thirds of the plants are found in the mountain area) (Korner, 1985, p.93) (Table 2).

Table 1: Mountain areas and the countries involved

Countries involved	*% of the EU territory*	*Regions*
Belgium, Germany, Denmark, Spain, France, Ireland, Portugal, the Netherlands, the United Kingdom	18.4	Atlantic

[3] http://www.turismulresponsabil.ro/wp-content/uploads/2017/01/2.-Danut-Ungureanu-Zona-montana.pdf

Estonia, Finland, Latvia, Lithuania, Sweden	18.8	Boreal
Austria, Belgium, Bulgaria, Czech Republic, Germany, Denmark, France, Italy, Luxemburg, Poland, Romania, Sweden, Slovenia	29.3	Continental
Austria, Bulgaria, Germany, Spain, Finland, France, Italy, Poland, Romania, Sweden, Slovenia, Slovakia	8.6	Alpine
Czech Republic, Hungary, Romania, Slovakia	3.0	Pannonian
Romania	0.9	Steppic
Bulgaria, Romania	0.3	Black Sea
Cyprus, Spain, France, Greece, Italy, Malta, Portugal	20.6	Mediterranean
Spain, Portugal	0.2	Macronesian

Source: European Union[4]

Table 2: Mountain chains in the alpine biogeographic region of Europe

Mountains	*Characteristics of the mountain biodiversity*	*Socio-economic characteristics*
The Pyrenees ($430\ km^2$)	There are 60 types of habitats are present in these mountains (Habitat Directive[5]). The mountains are characterized by numerous torrents, cascades and lakes. At elevations over 1,000 m, there are over 1,500 lakes. The diversity of the flora is exceptionally high: 3,000 species of plants, from among which at least 120 are endemic. There is vast diversity of birds and animals (over 40 species of mammals, including rare endemic species). One of the extinct species is the Pyrenees Ibex[6].	The mountains are relatively low populated, the agricultural sector and sheep breeding being the main activities. In the past, the Pyrenees underwent an intensive deforestation process (and with visible traces mainly on the mountainsides). The beech was intensively used as firewood and in feeding the furnaces for ore extraction. Tourism is another economic activity of high intensity next to winter sports.
The Alps (1200 km.)	The forests are in relatively natural state as at high elevations they are true refuge and ecological corridor for many large species (bears, birds of prey). The grasslands and alpine meadows make up 25% of the mountain vegetation (the majority semi-natural, affected over time by moderate agricultural practices) and many of them are threatened by farmstead abandon. 84 types of habitats are listed, from among which 47 species of plants. The Alps have over 40% of the European flora but also 200 species of birds (which lay their eggs here) and	In the Alps live over 11 million inhabitants mainly in the urbanized valleys. To them are added 100 million tourists visiting the Alps with tourist or recreational purposes. These phenomena exert an important pressure on the mountainous environment which has a particular fragility.

[4] http://ec.europa.eu/environment/nature/info/pubs/docs/biogeos/Steppic%20Region/KH7809607ROC_002.pdf
[5] The Habitats Directive ensures the conservation of a wide range of rare, threatened or endemic animal and plant species. Some 200 rare and characteristic habitat types are also targeted for conservation in their own right.
[6] In January 2000, the Pyrenean Ibex was completely extinct. Nevertheless, scientists have attempted to clone this species by using DNA from one of the last females; such a clone died seven minutes after birth. Other sub-species survived: the Spanish western Ibex, or the Ibex Gredos, and the Ibex from the south-eastern part of Spain, while the Portuguese Ibex is extinct. The last Ibex from the Pyrenees disappeared before scientists could analyse the species accordingly, the taxonomy of this sub-species being controversial.

Mountains	*Characteristics of the mountain biodiversity*	*Socio-economic characteristics*
	other 200 migrant birds. The Alps represent one of the most biodiversity richest mountain chains from European, but also one which is heavily exploited.	
The Apennines (1350 km)	In the Apennines on the Italian side, during the last Ice Age the ice sheets advanced and after their meltdown the populations began their separate evolution. One of the species running the risk of extinction is the Abruzzo chamois (*Rupicapra pyrenaica* ornate) the reason being excessive hunting (450 individuals that are vulnerable to diseases and consanguinity).	The inhabitants are in small numbers and on a decreasing trend. Consequently, the traditional agricultural systems of cattle breeding are vanishing; however, efforts are made for repopulating the area due to the fact that these mountains are included in a network of interconnected national parks.
The Scandes (1400 km.)	The diversity of the species in the area of the Scandes is relatively low. Nevertheless, they represent an essential component of the European biodiversity due to their considerable size and the unaltered character. They are counted among the few locations in Europe where we might discover authentic wilderness. 44 types of habitats are represented, 29 species of plants and 18 species of animals (Habitats Directive).	The low presence of humans in the Scandes is not surprising. Some of the activities, such as river damming for generating hydroelectric power, reindeer herding, or the disappearance of summer grazing had negative impact at local level. However, the majority of the mountainous lands remain unperturbed by human presence, and therefore this remains one of the largest intact natural areas in Europe.
The Carpathians (1450 km.)	The habitats have a long tradition regarding the exploitation of lands but also sheep and cattle breeding. The Carpathians host many species, with a high level of biodiversity: over 3500 species of plants from among which 481 endemic species. Here we find large carnivores, a varied selection of small mammals, many endemic species from among which the Tatra pine vole and the Carpathian marmot. Over 300 species of birds (the Ural owl, the white-backed woodpecker, the black stork, etc.).	In the Carpathians live about 18 million individuals, who are exerting pressure on maintaining and preserving the biodiversity
The Balkans[7] (550 km.)	These mountains display a typical alpine character and have a strong Mediterranean influence regarding the make-up of the species. Over 60 types of habitat (Habitats Directive) with a considerable forests' component, with	The population density is extremely low. The mountains are in remote areas and still unexplored.

[7] They are constituted from three distinct mountain formations: the Rila Mountains, the Pirin Mountains and the Rhodope Mountains.

Mountains	Characteristics of the mountain biodiversity	Socio-economic characteristics
	many endemic species of trees (the Balkan pine, King Boris fir, and the black (Bosnian) pine. The area contains a huge variety of plant species and numerous large carnivore populations, and species of birds of prey (in Rhodope is found the largest agglomeration of day birds of prey from Europe).	

Source: European Commission (2010)[8]

Most of the important-for-community habitats are found in the continental area (7,475), followed by the Mediterranean (2,928) and the Atlantic (2,747) ones. Regarding the special protection areas (SPAs), most of them are designated in the Continental region (1,478) followed by the Boreal (1,165). Nevertheless, the widest surfaces covered by important-for-community habitats are found in the Black Sea region (71.8%) and those of special protection in the Pannonian region (31.3%), according to Habitat Directive[9].

In the mountain areas of Europe, the extensive agricultural practices, the transhumance, forestry, etc. have contributed to creating an important diversity of landscapes and cultures (Huddlestone, Ataman and Fed'Ostiani, 2003). Nowadays, this biodiversity is subjected to a phenomena correlated directly to the activities of the local communities (and not only): abandoning the area, tourism and winter sports development, infrastructure development, urbanization, soil compaction, etc. The development of mountain tourism expanded practically over the entire continent, in parallel with the intensification of traffic and the building of the transport infrastructure (which turns into an important barrier for species migration[10]).

Damming the main rivers in the mountains for the hydropower sector or for irrigation has modified considerably the natural mountain environment. These activities influenced the biodiversity of the mountain areas, a fact mentioned in various reports and analyses at EU level. As might be seen, most mountain areas from Europe are in an unfavorable preservation state (60.68%) from among which 32.57% are in a very bad situation, a fact which should impose the implementation of swift and drastic measures required for rebuilding the state of the affected habitats (EEA Report No. 6/201[11]) (Table 3).

Table 3: Numbers of habitat types in each massif classified by conservation status (no.)

Massif	*Favorable*	*Unfavorable (inadequate)*	*Unfavorable (bad)*	*Unknown*	*Total*
Apennines	47	26	3	8	84
Balkans/South-east Europe	32	27	23	1	83

[8] https://op.europa.eu/ro/publication-detail/-/publication/9a738f76-c937-478d-b720-1562a53385e4/
[9] The Habitats Directive ensures the conservation of a wide range of rare, threatened or endemic animal and plant species. Some 200 rare and characteristic habitat types are also targeted for conservation in their own right.
[10] Yearly, about 150 million individuals travel in the Alps, from among which 83% travel on paved roads https://www.eea.europa.eu/themes/regions/the-alpine-region/transport-climate-change-tourism/transport-climate-change-tourism/topics)
[11] http://ec.europa.eu/environment/nature/info/pubs/docs/biogeos/Alpine/KH7809637ROC_002.pdf; http://ec.europa.eu/environment/nature/info/pubs/docs/biogeos/Steppic%20Region/KH7809607ROC_002.pdf

Massif	*Favorable*	*Unfavorable (inadequate)*	*Unfavorable (bad)*	*Unknown*	*Total*
Atlantic islands	11	12	7	1	31
Nordic mountains	22	13	27	2	64
Central European middle mountains (Belgium and Germany)	16	18	12	2	48
Eastern Mediterranean islands	13	18	6	8	45
Carpathians	10	21	18	2	51
Alps	14	37	35	7	93
French/Swiss middle mountains	11	22	37	7	77
Western Mediterranean islands	7	17	14	15	53
Central European middle mountains (Czech Republic, Austria, Germany)	4	15	32		51
Pyrenees	3	19	30	36	88
British Isles	1	7	52	4	64
Iberian mountains		6	3	77	86
Total mountains (no.)	191	258	299	170	918
Total mountains (%)	20,81	28,10	32,57	18,52	100

Source: European Environment Agency (2010)[12]

The negative effects of climate changes led in time to promote some actions that would counteract them and contribute to reinstating the natural balance. The effects of climate change phenomenon in European mountains (Kohler and Maselli, 2009) are illustrated as follows. Climate change is a reality in present. Some of the best evidence, such as melting glaciers, comes from mountain areas. Many scientists believe that the changes occurring in mountain ecosystems may provide an early glimpse of what could come to pass in lowland environments, and that mountains, thus, act as early warning systems. Because the mountains exist in many regions of the world and they occupy very different positions on the globe and differ in shape, extension, altitude, vegetation cover, and climate regime, they will, therefore, be affected differently by climate change. However, they share following some common features relating to climate change: mountain areas have a marked and complex topography and their climates vary considerably over short distances, temperature changes with altitude and melting of glaciers, the permafrost will trigger the release of loose rock and soil and exacerbate the danger of rockfall, debris and mud flows have a major role in influencing regional and global climates (IPCC, 2007).

Internationally, some legislation has changed the course. Since 1970 various international cooperation agreements regarding the mountain regions of Alps and Carpathians came into existence. In 1975, the European Commission under the *Directive on mountain and hill farming and farming in less-favored areas no. 75/268*[13] acknowledged the necessity of supporting agriculture from mountain areas. In 1978, at the Conference of the

[12] https://www.eea.europa.eu/publications/europes-ecological-backbone
[13] https://www.sciencedirect.com/science/article/pii/0264837786900621

EU Council of Ministers responsible with regional planning (CEMAT), launched was the official paper *"Pressures and regional planning problems in mountain regions"*[14], which was the point of reference for all future development and regional planning strategies. After 2000, the mountain areas became important component of the regional development policy of the European Union. This attention consisted of determining some areas where human actions of economic nature cannot take place; such areas were designed as protected areas. Many of the mountain areas were declared as pprotected areas under the influence of international programmes (Huddlestone, Ataman and Fed'Ostiani, 2003). At EU level, these protected areas represent up to 33%[15]. For instance, *Natura 2000*[16] is the European Network of Natural Protected Areas comprising a representative sample of wild species and natural habitats of community interest. It was constituted not only with the purpose of protecting nature, but also for preserving the natural riches on long-term basis and for ensuring the resources required for the socio-economic development[17]. The proportion of protected areas included in Natura 2000 differs from one country to another: Cyprus - 95%, Slovenia - 83%, Greece 82%, Italy - 81%, Slovakia - 79%, Austria - 78%, Spain - 73%, Czech Republic - 71%, Romania - 65%. In total, in the alpine region, there are 1,496 habitats of community importance (Habitats Directive[18]) and 365 areas of special protection (Directive Birds)[19]. These areas with special protection status cover about 40% of the total surface area of the alpine region.

3. Biodiversity of Mountain Areas in Romania

The status of protected area presupposes a mix of actions regarding the strengthening of conservation, restoration and sustainable valorization of biodiversity and landscape based on efficient management underlying harmonization of the natural capital with its habitats and species, by preserving and promoting natural values (Antonescu, 2017: 71).

The Earth Summit 1992 adopted the Convention for Biologic Diversity (CBD) and Romania ratified the Convention in the year 1994. As compliance, the Government of Romania promulgated the Law No. 58/1994 addressing the biologic diversity by which the following major objectives were set: conservation of biologic diversity, sustainable use of biodiversity's resources, and equitable distribution of benefits resulting from the use of genetic resources. The establishment of some protected natural areas under law was initiated with the purpose of obtaining a more efficient control over maintaining and protecting biodiversity (Popa, 2016). In Romania, the main categories of Protected Areas are established by Law No. 5/2000[20] encompassing the National Plan for Territorial Arrangement (PATN) in Section III (Protected Areas). In accordance with the law, Romania has 845 protected areas classified in IUCN Category-V (Table 4).

[14] http://www.bbsr.bund.de/BBSR/EN/Publications/IzR/2003/7DejeantPons.pdf?__blob=publicationFile&v=3
[15] Only 5 % from the areas with high natural value are not included also in the category of less-favoured areas.
[16] Natura 2000, the widest world network of natural protected areas. In order to fight against the loss of natural areas, Europe drafted two important laws: the Directive Birds (1979) and Habitats (1992). These laws are the founding milestones for the environmental protection policy and led to setting up Natura 2000 the largest network of protected natural areas in the world covering - 1 million square kilometres of land, (over 18% from the EU land surface) - 250.000 square kilometres of marine habitats (almost 4% of the EU marine habitats), respectively 27.000 habitats and 1.000 species are under special protection.
[17] https://natura2000.ro/ce-este-reteaua-natura-2000/
[18] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31992L0043
[19] European Topic Centre for Biodiversity (European Environment Agency): http://biodiversity.eionet.europa.euOctober2008.
[20] Law no. 5/2000, Section III, Protected Area [Law no. 5/2000, section III, protected areas] [In Romanian].

Table 4: Romania's Protected Area System

Type	*IUCN Category/ International Designation*	*Number of Protected areas*	*Total area*
Scientific Reserve	I	53	101,288 ha
National Park	II	11	300,819 ha
Natural Monument	III	231	2,177 ha
Natural Reserve	IV	542	117,265 ha
Natural Park	V	6	326,305 ha
Biosphere Reserve Danube Delta	Biosphere Reserve	Retezat (II) Rodnei (II)	576,216 ha. 38,138 ha 47,227 ha
Wetlands of International Importance	Ramsar Site	Danube Delta Small Island of Braila	576,216 ha 20,455 ha
Natural Sites for Universal Natural Heritage	Word Heritage Site	Danube Delta[21]	732,220 ha
Special Areas for Conservation	SAC	None	
Areas for Special Protection of Bird	SPA	None	

Source: Lee and Middleton (2003)

After Romania's accession to EU, the Emergency Ordinance No. 57 of June 20, 2007 was promulgated to regulate the regime of protected natural areas and the conservation of natural habitats (updated in 2016). It determined the areas of major conservation interest, and also included in the National Strategy for Sustainable Development 2013-2030[22]. In order to protect biodiversity of the mountain areas, Romania ratified the Framework Convention on the Protection and Sustainable Development of the Carpathians (Carpathian Convention[23]) in 2006 (Law No. 389/2006). The law stipulates that the Carpathian Mountains represent a unique natural wealth of impressive beauty and ecological value, an important reservoir of biodiversity, the area from which main rivers flow, an essential habitat and refuge for numerous endangered species of plants and animals, and the widest area covered by virgin woods in Europe (Gruia and Gaceu, 2021).

Romanian forests in the mountains area represent 65.25%, followed by forest hills with 26.67% of total (MAP, 2018). In terms of age-class distribution, 71% are maximum 80 years of age and 15% are older than 100 years, most of them are managed using different sylvicultural systems that are typical to high forests with long rotation ages (over 100-120 years) (Nicolescu, 2022). The changes in the ownership structure after 1990 brought important challenges to the management of the forests. Due to forest land restitution, Romanian forestry moved from a heavily centralized sector to a multilayer type of governance, with more actors playing different and even conflicting roles (Dragoi and Toza, 2019). The bioeconomy strategy must be considered as a vector to support new governance models needed to ensure the financial viability of forest management (Nichiforel, 2022).

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[21] https://en.unesco.org/biosphere/eu-na/danube-delta
[22] https://faolex.fao.org/docs/pdf/rom195029.pdf
[23] http://www.carpathianconvention.org/tl_files/carpathiancon/Downloads/01%20The%20Convention/1.1.1.1_CarpathianConvention.pdf

In the National Strategy[24], it is shown that Romania displays a relative variety and proportionality of landscapes: 29.94% mountain massifs (elevations over 1,000 meters), 42% hills and plateaus (elevations between 300 and 1,000 meters) and 30% flatlands/plains (elevation under 300 m) (Antonescu, 2017). The total surface of the mountain area is 71,381.48 square kilometers (29.94% of total surface). The special biodiversity of the mountain area from Romania determined the inclusion of a share of 57% from its surface in the ecologic network Natura 2000. In the mountain area are found 197 Natura 2000 sites (habitats): respectively, 37% from national sites and 67% from the protected area. Romania's lands fall 54% under the Carpathian Mountain chains, mountains of mid-elevation (with an average of 1,136 meters) with only few peaks over 2,500 m[25].

In Romania the mountains represent the least disturbed parts having a low density of the inhabitant population residing in small localities, which are almost depopulated as a result of internal and external migration (Avădănei and Avădănei, 2016). This situation exists in the mountain area of 12 out of the 13 national parks[26] and of 10 out of the 14 natural parks[27]: the forests from the mountain areas display increased biodiversity as there are 150 types of forest ecosystems differentiated depending on the species, the type and quantity of humus in the soil, the water and ionic stress of the soil, etc. Thus, forests shape important wood sources and other non-wood produces (berries, mushrooms, game, etc.). In Romania, surface covered by forests in the mountain area is 4.4 million hectares, from which about 40% ((World Bank, 2014) are private property, the rest being the public ownership of the State or under the territorial administrative units (National Institute of Statistics). In the mountain area of Romania, there are 948 local administrative units (30% of the country's surface), most of them in the counties of Harghita (9.38%), Hunedoara (6.92%), Maramures (6.77%), Alba (6.15%), Suceava (5.85%), Covasna (5.38%), and Brasov (5.1%). In the mountains, there are about 4.892 inhabitants (21.97 % of the total population) (World Bank, 2014).

4. Measures & Actions Supporting the Biodiversity in Mountain Areas of Romania

According to the *Strategy of the Romanian Academy for the next 20 years* (Zaman *et al.*, 2015), the general objective of evolution and development of the protected areas is represented by the protection, valorisation and recovery of the biodiversity, including ecosystem services that it provides (natural capital), by taking into account the intrinsic value it represents and the essential contribution to economic and social development (Zaman *et al.*, 2015). Thus, the general action framework aims at biodiversity conservation

[24] National Strategic Guidelines for the Sustainable Development of the Carpathians 2014 – 2020, http://ier.gov.ro/wp-content/uploads/2018/12/Daniela-Giurca-Cracovia-2015.pdf

[25] https://biodiversity.europa.eu/countries/romania/green-infrastructure

[26] 12 National Parks: four in the Oriental Carpathians (NP Rodnei Mountains, NP Călimani Mountains, NP in the Ceahlău Massif, NP Cheile Bicazului – Lacul Roşu (Red Lake) –Hăşmaş Mountains), six in the Mid-Carpathians (NP Piatra Craiului, NP in the Coziei Mountains, NP Buila – Vânturariţa, NP in the Jiului Gorge, NP Retezat, NP Domogled – Valea Cernei) and two in the Occidental Carpathians (NP Cheile Nerei – Beuşniţa, NP Semenic Mountains – Cheile Caraşului).

[27] 10 Natural Parks: four in the Oriental Carpathians (NP Maramureşului Mountains, NP Mureşului Superior Gorge, NP Vânători Neamţ which breaks through also in the Neamtului Sub-Carpathians, NP Putna-Vrancea), four in the Mid-Carpathians (NP Bucegi, NP Grădiştea Muncelului-Cioclovina, Geoparcul Dinozaurilor (Dinosaurs' Geo-park) – Haţegului Country, Geo-park Mehedinţi Plateau which overlapps partially also with the areal of the Mehedinti Mountains) and two in the Occidental Carpathians (NP Apuseni Mountains, NP Cazanele Dunării-Porţile de Fier (Danube Cauldrons – Iron Gates). In the period 2007-2016 a series of changes were recorded regarding the surface of the protected mountain areas (increases or diminishments of the included surfaces).

practices and at economic and social activities that would provide to local communities with the possibility of achieving their own requirement.

Romania ranks on the first position in Europe from the viewpoint of biodiversity and owns the last 100% natural ecosystems of the continent. Even though the national legislation translating the Natura 2000[28] in Romania does not provide for complete protection, and the implementation issues are identified frequently, a first measure would be the one of continuing with the implementation of these directives and compliance with the statutes of Protected Area in the mountain areas where these are set up.

Due to the important impact of the agricultural sector on the biodiversity from the mountain areas, a first action that might be supported financially is accessing the funds allocated for the mountain biodiversity by the Common Agricultural Policy[29] (CAP). Regarding the mountain area, after 2007, began the implementation of the following measures of CAP: Measure 211 – the less-favoured mountain area; Measure 212 – less favoured areas (others than the mountain area) and Measure 214 – agro-environment. The measures are financed by CAP and support the users of agricultural lands in areas characterised by unfavourable natural conditions, including here the compensation of income losses, and additional expenditures resulting from practicing extensive and ecologic agriculture (by protecting biodiversity, water protection, soil protection, diminishing polluting emissions and adjusting to the effects of climate changes).

In the current programming period, there are supported measures for promoting efficient use of resources and smart/sustainable growth favourable to inclusion in agriculture and in the rural areas, in accordance with the Strategy Europe 2020[30]. The measures package for the current programming period addresses both the objectives of agro-environment and climate (Measure 10), to ecologic agriculture (Measure 11), and to areas faced with natural constraints (Measure 13). Farmers will benefit from funds of about 2.66 billion Euro (Measure 10 – 1.071 billion Euro, Measure 11 – 236.42 million Euro, Measure 13 – 1.355 billion Euro)[31]. These actions might contribute to maintaining the mountain biodiversity, which might be financed from community funds: keeping the youths in these areas, in parallel with encouraging increased birth-rates, professional training and adjusting vocational school curricula in accordance with the demand on the labour market, supporting businesses start-up by youths, promoting education-learning centres in the mountain areas for setting up didactic farms (these would provide learning material for the students and would contribute to the integrated valorisation of resources, from the perspective of the concepts of pluri-activity and sustainable development).

For the mountain areas faced with natural or specific constraints have been determined by the National Rural Development Programme 2014-2020, a series of compensation payments that are granted to users of agricultural lands placed in areas defined as eligible after concluding some yearly/multi-annual voluntary commitments. The compensation is aimed at:

- additional costs and income losses resulting from the enforcement of some extensive management measures on agricultural lands targeted on achieving some environmental objectives (biodiversity conservation, water and soil protection);

[28] https://ec.europa.eu/environment/nature/natura2000/index_en.htm
[29] https://www.sciencedirect.com/topics/earth-and-planetary-sciences/common-agricultural-policy
[30] https://en.wikipedia.org/wiki/Europe_2020
[31] https://ec.europa.eu/eu2020/pdf/COMPLET%20EN%20BARROSO%20%20%20007%20-%20Europe%202020%20-%20EN%20version.pdf

- additional costs and income losses resulting from the enforcement of practices specific to ecologic agriculture; and
- additional costs and income losses born by farmers because of natural and specific constraints which are present in areas with influence on agricultural production.

5. Recommendations for the Biodiversity of Mountain Areas

In the context of sustainable development, the following actions aimed at supporting the mountainous areas in Romania can be considered (Popescu *et al.*, 2022):

1. the local mountain population should to be involved in the specific activities, which preserve local economy, cultural identity and heritage, maintain biodiversity;
2. the improvement of infrastructure (all types of communications, dwellings, water supply, sewerage collection and use, waste management, electricity, gas, internet access, broadband network, work digitalization, education, medical and sanitary points, agriculture, water drainage systems, investments in isolated chalets etc.);
3. sustain the specific economic activities that have to stimulate young people and firms;
4. to provide some facilities for farmers;
5. to stimulate the creation of associative forms (associations and cooperatives) in order to assure the needed inputs, to increase production, and better promote the mountain products;
6. special measures to encourage the young farmers who grow more than 5 LU (livestock units); and
7. to sustain the tourism to improve their offer (to enlarge the accommodation capacity, facilities, service quality etc.).

The issue of biodiversity loss and the one about ensuring the sustainable development of local communities in areas declared as protected areas is very complex, both from the theoretic and practical viewpoints. At theoretical level, significant debates take place about the methods and techniques for evaluating and interpreting the existing issues of the area. From the practical viewpoint, not enough data and statistic information are supplied in order to support certain specific measures and actions of political, economic and social nature. The acknowledged complexity of these issues and aspects regarding protected areas imposes currently a multi- and trans-disciplinary approach. At the same time, practitioners in the field of development resort frequently to holistic-type approaches. Their requirements are supported by the modern social sciences that consider that, over time, the localization of economic activities and the environment are relevant categories for analyses and research (Turner *et al.*, 1993).

The interdisciplinary approach appears as necessary when environmental changes are evaluated, while the living conditions for humans are aimed in particular, along with the ones regarding the economic situation. The combination of knowledge from several fields brings its contribution to identifying the best measures leading to improving the living standard for the inhabitants of the mountain areas, being at the same time a challenge for all those involved. Any model should focus the attention on an objective of the study. The definition of the concept bears, in its turn, a multidimensional approach: well-delineated geographic areas, with specific characteristics (economic, social, infrastructural, etc.) of high biodiversity and particular issues for which specific actions/policies are required with the purpose of attaining a certain living standard. From the viewpoint of mountain research, the analysis of the pressure on the environment might be realised by a general and comparative analysis of the mountain regions based on demand, and by disaggregation at household level of some indicators specific to the mountain area.

The global models of analysis for the households' welfare in the mountain area resort, as a rule, to indicators regarding quality of life assuming the idea that development is based on universal values and not on localised experiences and different value systems. These indicators might reflect the basic elements of the subsistence means and the quality of institutions involved in promoting change. Because human activities (economic, social, cultural, etc.) cannot be omitted in this equation, we consider that the basic principle of any model should be: a conservation framework for development in which the conservation practices for the mountain biodiversity maintain both services of economic and social nature and the ones of protection for ecosystems and biodiversity.

6. Conclusions

In Romania, the mountain areas should play a strategic role in the economic and social development constituting a conducive environment, over time for maintaining the continuity and durability of the Romanian people. It is imperative that the development vision in the field of protected areas. The mountain areas offer a protection, valorization and recovery to the mountains' biodiversity, including ecosystem services they provide (natural capital). Thus, development should meet the protection requirements of the mountain environment because, in a contrary situation, biodiversity might undergo negative, sometimes irreversible, changes caused by the loss of habitats being caused by conversion of agricultural lands to urban areas, by the emergence of some invasive alien species, and by the overexploitation of natural resources. Over exploitation of services/products provided by biodiversity leads to influencing the natural balance with negative impact on human welfare and on the entire process of economic growth.

These mountain areas with high biodiversity should benefit from specific, multidimensional policy that would take into account the principles of sustainable development and would contribute to diminishing ecological and economic imbalances. The mountain policy might be considered as a true link that would ensure the good inter-community and interregional cooperation, as well as partnerships at national and international level.

To combat the negative factors having a direct or indirect influence on the biodiversity of mountain areas, a series of measures and actions are needed. Some important factors increase resilience to the major threats to mountain ecosystems. In addition to designating protected areas, measures to improve connectivity and ecosystem-based management are keys for conserving mountain ecosystems, particularly helping them to adapt to climate change. Another action is needed to minimize the risk of local extinction of several species and to counteract the effects of habitat fragmentation and changes in land use. At the same time, national cooperation across European mountain regions can support improved integrated management practices.

7. References

Alfthan, B., Gjerdi, H.L., Puikkonen, L., Andresen, M., Semernya, L., Schoolmeester, T. and Jurek, M. (2018). Mountain Adaptation Outlook Series – Synthesis Report. United Nations Environment Programme (UNEP), and GRID, Nairobi, Vienna, and Arendal.

Antonescu, D. (2017). Protected Area. In: Vlad, V. (Ed.), *Strategia de dezvoltare a României în următorii 20 de ani* (sinteză). Bucharest: Romanian Academy, ISBN 978-973-27-2756-0, pp.71-73 [In Romanian]. Available online at: https://academiaromana.ro/bdar/strategiaAR/doc14/Strategia-Sinteza.pdf [accessed on 12 February 2023].

Antonescu, D. (2018). Biodiversity of the natural mountains heritage – present challenges and sustainable perspectives. Institutul National de Cercetari Economice 'Costin C. Kiritescu', Bucharest, Romania. Available online at: https://mpra.ub.uni-muenchen.de/84460/1/MPRA_paper_84460.pdf [accessed on 15 February 2023]

Avădănei, V. and Avădănei, L. (2016). Mediocritas aurea – a possible and suitable solution for sustainable, smart and inclusive mountain development. *Journal of Montanology*, V: 69.

Beniston, M. (2003). Climatic Change in Mountain Regions: A Review of Possible Impacts. In: Diaz, H.F. (Ed.), *Climate Variability and Change in High Elevation Regions: Past, Present & Future. Advances in Global Change Research*, vol. 15. Dordrecht: Springer. DOI: https://doi.org/10.1007/978-94-015-1252-7_2.

Beniston, M. (2003). Climatic Change in Mountain Regions: A Review of Possible Impacts. *Climatic Change*, 59: 5–31. DOI: https://doi.org/10.1023/A:1024458411589.

Blyth, R.E., Kaiser, M.J., Hart, P.J.B. and Edwards-Jones, G. (2002). Conservation with voluntary management in an inshore fishery. *Environmental Conservation*, 29: 493-508.

Drăgoi, M. and Toza, V. (2019). Did Forestland Restitution Facilitate Institutional Amnesia? Some Evidence from Romanian Forest Policy. *Land*, 8(6): 99. DOI: https://doi.org/10.3390/land8060099.

European Commission (2010). Europe's ecological backbone: recognizing the true value of our mountains, EEA Report No. 6/2010. DOI: https://doi.org/10.2800/43450.

FAO (2001). *Global Forest Resources Assessment 2000*, p. 512. Food and Agriculture Organization of the United Nations, Rome, Italy.

Gruia, R. and Gaceu, L. (2021). Strategic element of post-pandemic development of the Romanian mountain agritourism. *Journal of Montology*, 12. Available online at: https://montology-journal.eu/strategic-elements-post-pandemic-development-romanian-mountain-agriturism/ [In Romanian] [accessed 10 March 2023].

Horák, J., Materna, J., Halda, J.P., Mladenović, S., Bogusch, P. and Pech, P. (2019). Scientific Reports. Biodiversity in remnants of natural mountain forests under conservation-oriented management. *Sci. Rep.*, 9: 89. DOI: https://doi.org/10.1038/s41598-018-35448-7.

Huddlestone, B., Ataman, E. and Fed'Ostiani, L. (Eds.) (2003). Towards a GIS-based analysis of mountain environments and populations. Environment and Natural Resources Working Paper No. 10, FAO, Rome 2003. Available online at: http://www.fao.org/3/a-y4558e.pdf [accessed 21 January 2023].

IPCC (2007). Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)].

Intergovernmental Panel on Climate Change, Geneva, Switzerland, p.104. Available online at: https://www.ipcc.ch/report/ar4/syr/ [accessed 11 March 2023].
Kohler, T. and Maselli, D. (Eds.) (2009). Mountains and Climate Change - From Understanding to Action. Geographica Bernensia, Bern, Switzerland.
Korner, C. (1985). Alpine plant diversity: a global survey and functional interpretations. In: Arctic and Alpine Biodiversity: Patterns, Causes and Ecosystem Consequences. In: F.S. Chapin III and C. Korner (Eds.), *Ecological Studies*, Berlin: Springer, p.113.
Körner, C., and Ohsawa, M. (2005). Mountain systems. In: R Hassan, R., Scholes, and N Ash (Eds)., *Ecosystems and human well-being: current state and trends*. Washington, DC: Island Press.
Lee, T. and Middleton, J., (2003). Guidelines for Management Planning of Protected Areas. IUCN Gland, Switzerland and Cambridge, UK.
MAP (2018). Raport privind starea pădurilor României în anul 2017 [Report on the state of Romanian forests in 2017]. Ministerul Apelor și Pădurilor, București. Available online at: http://roifn.ro/site/rezultate-ifn-2/ [accessed on 11 January 2023].
Mountain Partnership (2020). Why mountain matters for forests and biodiversity. Mountain Partnership, FAO, Rome, Italy. Available online at: https://sustainabledevelopment.un.org/content/documents/1915SDGs%20and%20mountains_forests%20and%20biodiversity_en.pdf [accessed 21 January 2023].
Nichiforel, L. (2022). Forest Ownership and its Challenging Role in the Forest based Bioeconomy. In: Giurcă A. and Dima, D.P. (Eds.), *The Plan B for Romania's Forests and Society*, Braşov: Editura Universităţii "Transilvania", ISBN 978-606-19-1463-0, p.504.
Nicolescu, V.N. (2022). Romanian Forests and Forestry: An Overview. In: Giurcă A. and Dima, D.P. (Eds.), *The Plan B for Romania's Forests and Society*, Braşov: Editura Universităţii "Transilvania", ISBN 978-606-19-1463-0, p.504.
Popa, I. (2016). Protected areas (forests) between strict protection and rural development engine. *Journal of Montanology*, V: 53 [In Romanian].
Popescu, A., Dinu, T.A., Stoian, E., Şerban, V. and Cioca H.H. (2022). Romania's mountain areas – present and future in their way to a sustainable development, *Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development*, 22(4). Available online at: https://managementjournal.usamv.ro/pdf/vol.22_4/Art61.pdf [accessed on 11 January 2023].
Rey, R. and Gruia, R. (2016). Responsible tourism in mountain area, an opportunity for local communities. *Journal of Montanology*, V: 37 [In Romanian].
Romanian Parliament (2003). Framework Convention of 22 May 2003 regarding the protection and sustainable development of the Carpathians, Issued by the Parliament of Romania, Buchrest. Available online at: https://legislatie.just.ro/Public/DetaliiDocumentAfis/76244 [accessed on 11 January 2023].
Romeo, R., Russo, L., Parisi, F., Notarianni, M., Manuelli, S. and Carvao, S. (2021). Mountain tourism – Towards a more sustainable path. Mountain Partnership, FAO, Rome. DOI: https://doi.org/10.4060/cb7884en.
Turner, B.L., Clark, C.W., Kates, R.B., Richards, J.F., Mathews, J.T. and Meyer, W.B. (Eds.) (1993). *The Earth as Transformed by Human Action: Global and Regional Changes in the Biosphere over the Past 300 Years*. Cambridge: Cambridge University Press.

Vasile, M. and Iordăchescu, G. (2022). Forest crisis narratives: Illegal logging, datafication and the conservation frontier in the Romanian Carpathian Mountains. *Political Geography*, 96: 102600. DOI: https://doi.org/10.1016/j.polgeo.2022.102600.

World Bank (2014). Romania Climate Change and Low Carbon Green Growth Program Component B Sector Report: Forest Sector Rapid Assessment. The World Bank, Europe and Central Asia Region, Washington, DC, USA. Available online at: https://documents1.worldbank.org/curated/zh/832671468143712589/pdf/842620WP0P14660Box0382136B00PUBLIC0.pdf [accessed on 11 March 2023].

Zaman, G., Vlad, I.V., Vasile, V., Pavelescu, F.M.TH., Sandu, S. and Georgescu, G. (2015). Strategia de dezvoltare a Romaniei in urmatorii 20 de ani, 2016-2035, VOLUMUL I (The development strategy of Romania in the next 20 years), Vol. I, Ch. "Proiectul 6 – Economia si Calitatea Vietii", Analiza situatiei existente a Romaniei in domeniul economiei (pp.235-263) (Project no. 6 –The Economy and the Quality of life). Bucharest: Editura Academiei Romane, ISBN: 978-973-27-2556-6. Available online at: https://www.researchgate.net/publication/299595759_Strategia_de_dezvoltare_a_Romaniei_in_urmatorii_20_de_ani_2016-2035_VOLUMUL_I_The_development_strategy_of_Romania_in_the_next_20_years_Vol_I_Ch_Proiectul_6_-_Economia_si_Calitatea_Vietii_Analiza_situa [accessed on 11 March 2023].

Zemp, M., Hoelzle, M. and Haeberli, W. (2009). Six decades of glacier mass-balance observations: A review of the worldwide monitoring network. *Annals of Glaciology*, 50(50): 101-111. DOI: https://doi.org/10.3189/172756409787769591.

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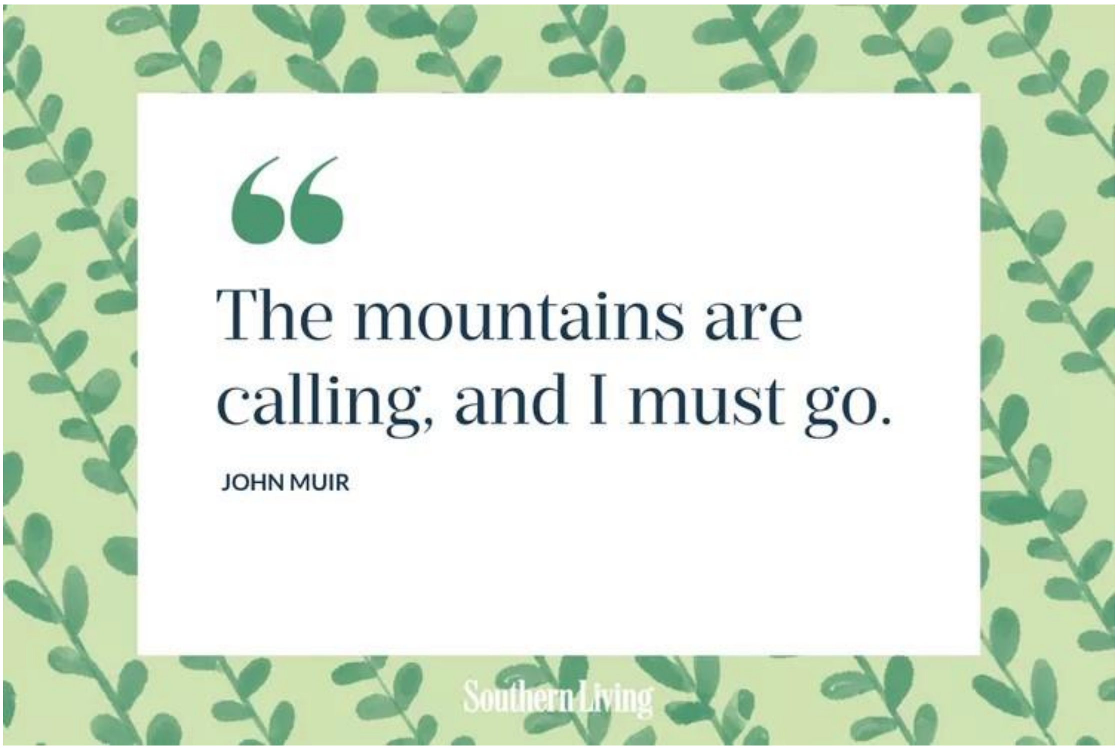
The mountains are calling, and I must go.
JOHN MUIR
Southern Living

Chapter 4

Fish Diversity of Hill Streams of South Kamrup, Assam, India

By Ellora Choudhury and Saibal Sengupta

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Fish Diversity of Hill Streams of South Kamrup, Assam, India

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Abstract

Mountains are unique geographical features on the Earth comprising many hill ranges and offering unique aquatic habitat for fish fauna. The hilly streams of Southern Kamrup provide diverse types of habitat gradients, such as head water, riffles, seepage, puddles etc., supporting the species-rich community. A study, carried out on the ichthyofauna in a few selected hill streams during June 2017 to December 2017 revealed 60 species belonging to 42 genera, 24 families and 9 orders. From this study, it was found that the order Cypriniformes represented the highest species diversity followed by Perciformes. These streams and riparian zones need systematic investigation, as the lotic ecology has significant effect on the biota.

Keywords

Mountains; Streams; Ichthyodivesity; Southern Kamrup; Assam

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1. Introduction

Himalayan mountains comprise hill ranges that have numbers of streams with rich icthyofaunal diversity. Streams offer a wide array of ecological conditions like torrential water, light intensity, high dissolved oxygen, fluctuating temperature and availability of food in the form of algal filaments, microbes, insect larva and invertebrate organisms especially benthos (Biswas and Boruah, 2000). Stream fishes present in the mountains have different structural modifications making their life more adaptive to the habitat. Fishes of the upper reaches of the stream are especially modified having suckers of diverse types, mostly acting as holdfast organ in the rapid current of water.

Many of the hill stream fishes also have ornamental value, apart from the good indicators of stream habitat. Small pelagic dwellers, including fishes, have ecological importance in regulating carbon flux and taking part in the regulation of food web dynamics (Fortier, Le Fevre and Legendre, 1994; Legendre and Michaud, 1998). South Kamrup (Assam) has a unique geological formation representing a zone of integration between Mesozoic and Triassic formations. Thus, it has a mosaic of various ecosystems including its gradients of stream habitats. The hilly terrain of this area contains a number of waterfalls, headwater, streams (rapids, riffles, creeks, ephemeral channels), pools and lakes, which offer diverse types of habitat (Power *et al.*, 1988).

Few studies on ichthyofauna and their habitats were carried out in the Kamrup district, but mostly on the flood plain, rivers and ox-bow lakes, locally called as Beels (Acharjee, 2016; Islam *et al.*, 2013; Kar, Goswami and Saharia, 2014; Malakar and Boruah, 2017; Rahman *et al.*, 2014). However, reports on ichthyofauna of these ecologically important streams of hills and mountains are lacking. The present investigation was designed to study the ichthyodiversity of selected streams of South Kamrup of Assam.

2. Materials and Methods

2.1 Study Area

The present study was carried out on three streams namely Ranikhama (25°50′25″ N, 91°21′31″E), Saloka Dare (25°50′59″N, 91°22′55″ E) and Rani Kopili (26°01′25″N, 91°36′90″E) between June 2017 and December 2017. The study area is situated in Assam-Meghalaya border area and geologically is a part of Shillong Plateau having Precambrian rocks. Ranikhama and Saloka Dare have streams originating from West Khasi Hills and flow down to join the Kulsi River at Baregaon. The Rani Kopili stream originating from West Khasi hills flows through Rani reserve forest, draining into Brahmaputra.

2.2 Ecological Features of the Streams

The studied hill streams viz., Ranikhama, Saloka Dare and Rani Kopili, originate from the mountains of the Khasi Hills. The bed of the upper reaches of the streams is rocky with large boulder based in a matrix of fine sand. The upper parts of the boulders are partially covered with algae. Water is quite shallow in winter but the volume increases during the monsoon season. The banks of the streams (riparian zone) immediate to the shore line consist of large trees and shrubs. The stream water flows at medium speed but, as the monsoon approaches, the speed increases. It carries sand, small rocks and pebbles downstream. The stream flows for a considerable length and small pools are formed, again takes its course to join with the Kulsi river, a tributary of the Brahmaputra river. The streams before meeting with the river Kulsi is of slow speed. The stream bed at the lower reaches is composed of mainly coarse sand and small rocks. The water of the streams in winter season in some portion flows below the surface in between the large rocks.

2.3 Data Collection and Analysis

Sample of fishes were collected from the streams with the help of fishing gears and local fisherman. The fishing gears used were scoop net, dip net and cast net. The natural history notes of fishes were recorded. Collected fishes were photographed in live and then preserved in 8% buffered formalin and brought to the laboratory for identification and morphometric analysis. Identification of fishes were done following the methods suggested by Jayaram (1999), Nath and Dey (2000), Sen (1985), Talwar and Jhingran (1991), and Vishwanath *et al.* (2014).

Standardized measurements and landmarks for morphometrics of fishes used include: total length, standard length, head length, head breath, eye diameter, body depth, pre-pelvic length, pre-dorsal length, caudal peduncle length, peduncle depth, pre-orbital length, post-orbital length, pectoral length, pelvic fin base length, and anal fin base length. Standardised meristic counts include number of spines and rays of all fins, lateral line scales, scales above the lateral line, scales below the lateral line, pre-dorsal scales, post-anal scales, caudal-peduncle scales, circumpeduncular scales and circumferential scales (Armbruster, 2012). The status of the fishes is expressed following IUCN Red List[1].

3. Results and Discussion

The mountainous region is bestowed with vast and varied resources in the form of rivers, rivulets, lakes, ponds, tanks and reservoirs (Meenakumari and Mahanta, 2012). Northeast India has about 300 fish species falling under more than 100 genera and 30 families. While the hill streams harbour diverse colourful small sized ornamental fishes, the larger streams, rivers and wetlands support medium to large sized food fishes (Vishwanath, 2012). The hill streams are unique habitats representing small water bodies flowing in its own course. The present investigation was conducted in three different streams originating from Khasi hills of Meghalaya flowing down to the Kulsi River in Kamrup district of Assam. The studied streams, viz. Ranikhama, Saloka Dare and Rani Kopili, have heterogeneity of habitat including water falls, riffles, pools, sluggish moving stretches and confluence with the small rivers. The stream water is composed of boulders, small gravels, pebbles, cobbles, sand and a variety of dissolved and suspended materials in it. The riparian zones of the stream are having rich forest cover. The streams having these substrates in its bed provide shelter for fishes, make substratum for attachment of algae, which again make food for hill stream fishes and even provide spawning and breeding grounds for fishes. Fishes usually lay eggs in these microhabitats for survival and to maintain lifecycle. The study reveals rich icthyofaunal diversity in the studied streams. 60 species of fishes belonging to 42 genera, 24 families and 9 orders were identified from the sampled streams (Table 1). From the study, it is observed that medium sized carps, mainly major and minor carps (family Cyprinidae), are present in the downstream, but not in upland water with rocky substratum. They are represented by the species of the genus *Labeo* and genus *Cirrhinus*. Small sized ornamental fish species of the genera *Cabdio, Devario, Esomus*, etc.

[1] https://www.iucnredlist.org/

are mostly recorded from the confluences of small rivulets in the downstream and flood plain (Table 1).

Table1: Fishes of different orders and families recorded during the present study

S.N.	*Order*	*Family*	*Name*	*IUCN Status*	*Economic Importance*
1	Cypriniformes	Cyprinidae	*Labeo rohita* (Hamilton, 1822)	LC	E
2			*Labeo gonius* (Hamilton, 1822)	LC	E
3			*Labeo calbasu* (Hamilton, 1822)	LC	E
4			*Labeo bata* (Hamilton, 1822)	LC	E, O
5			*Labeo catla* (Hamilton, 1822)	LC	E
6			*Cirrhinus mrigala* (Hamilton, 1822)	LC	E
7			*Cirrhinus reba* (Hamilton, 1822)	LC	E, O
8			*Amblypharyngodon mola* (Hamilton, 1822)	LC	E, O
9			*Barilius bendelisis* (Hamilton, 1807)	LC	E, O
10			*Barilius barna* (Hamilton, 1822)	LC	E, O
11			*Cabdio morar* (Hamilton, 1822)	LC	E, O
12			*Devario aequipinnatus* (McClelland,1839)	LC	E, O
13			*Devario devario* (Hamilton, 1822)	LC	E, O
14			*Esomus danricus* (Hamilton, 1822)	LC	F, O
15			*Puntius sophore* (Hamilton, 1822)	LC	E, O
16			*Puntius chola* (Hamilton, 1822)	LC	F, O
17			*Pethia conchonius* (Hamilton, 1822)	LC	E, O
18			*Pethia ticto* (Hamilton, 1822)	LC	E, O
19			*Salmostoma bacaila* (Hamilton, 1822)	LC	E, O
20			*Salmophasia phulo* (Hamilton, 1822)	LC	E, O
21			*Osteobrama cotio* (Hamilton, 1822)	LC	E, O
22			*Botia dario* (Hamilton, 1822)	LC	E, O
23		Cobitidae	*Lepidocephalichthys guntea* (Hamilton, 1822)	LC	E, O
24			*Canthophrys gongota* (Hamilton, 1822)	LC	E, O
25		Balitoridae	*Paracanthocobitis botia* (Hamilton, 1822)	LC	E, O
26		Psilorhynchidae	*Psilorhynchus sucatio* (Hamilton, 1822)	LC	E, O
27	Clupeiformes	Clupeidae	*Gudusia chapra* (Hamilton, 1822)	LC	E, O
28	Siluriformes	Bagridae	*Mystus cavasius* (Hamilton, 1822)	LC	E, O
29			*Mystus tengara* (Hamilton, 1822)	LC	E, O
30			*Mystus vittatus* (Bloch,1794)	LC	E, O
31		Schilbeidae	*Ailia coila* (Hamilton, 1822)	NT	E, O
32			*Eutropiichthys vacha* (Hamilton, 1822)	LC	E, O
33			*Pachypterus atherinoides* (Bloch, 1794)	LC	E, O

S.N.	Order	Family	Name	IUCN Status	Economic Importance
34		Siluridae	*Ompok pabda* (Hamilton, 1822)	NT	E, O
35		Sisoridae	*Gagata cenia* (Hamilton, 1822)	LC	E, O
36			*Gagata gagata* (Hamilton, 1822)	LC	E
37		Clariidae	*Clarias magur* (Hamilton, 1822)	EN	E, O
38		Heteropneustidae	*Heteropneustes fossilis* (Bloch, 1794)	LC	E, O
39	Perciformes	Ambassidae	*Chanda nama* (Hamilton, 1822)	LC	E, O
40			*Parambassis ranga* (Hamilton, 1822)	LC	E, O
41			*Parambassis lala* (Hamilton, 1822)	NT	E, O
42		Anabantidae	*Anabas testudineus* (Bloch, 1792)	LC	E, O
43		Badidae	*Badis badis* (Hamilton, 1822)	LC	O
44		Nandidae	*Nandus nandus* (Hamilton, 1822)	LC	E, O
45		Mastacembelidae	*Mastacembelus armatus* (Lacepède, 1800)	LC	E, O
46			*Macrognathus pancalus* (Hamilton, 1822)	LC	E, O
47			*Macrognathus aral* (Bloch and Schneider, 1801)	LC	E, O
48		Synbranchidae	*Monopterus cuchia* (Hamilton, 1822)	LC	E, O
49		Gobiidae	*Glossogobius giuris* (Hamilton, 1822)	LC	E, O
50		Osphronemidae	*Ctenops nobilis* (McClelland, 1845)	NT	E, O
51			*Trichogaster fasciata* (Bloch and Schneider, 1801)	LC	E, O
52			*Trichogaster lalius* (Hamilton, 1822)	LC	E, O
53	Channiformes	Channidae	*Channa gachua* (Hamilton, 1822)	LC	E, O
54			*Channa punctatus* (Bloch, 1793)	LC	E, O
55			*Channa striata* (Bloch, 1793)	LC	E, O
56			*Channa marulius* (Hamilton, 1822)	LC	E, O
57	Beloniformes	Belonidae	*Xenentodon cancila* (Hamilton, 1822)	LC	E, O
58	Tetraodonti-formes	Tetraodontidae	*Leiodon cutcutia* (Hamilton, 1822)	LC	O
59	Cyprinodo-ntiformes	Aplocheilidae	*Aplocheilus panchax* (Hamilton, 1822)	LC	E, O, Ot
60	Osteogloss-iformes	Notopteridae	*Notopterus notopterus* (Pallas, 1769)	LC	E, O

E = Edible fish, O = Ornamental fish, Ot = Other usages (Larvivorous fish)
LC= Least concern, NT= Near threatened, EN= Endangered[2]

The fishing is done mostly for consumption, irrespective of their ornamental value. The economic importance of the collected fishes is mentioned in table 1. Among the fishes, Barbs accounted for the highest number of species in the entire habitat mentioned above (Figure 1). Barbs belong to the family Cyprinidae, which comprises majority of fishes like Carps, Barbs, Barils, etc. Fishes of the group Barils are represented by *Barilius* spp. They are

[2] https://www.iucnredlist.org/

highly specialized species and are found in the downstream stretch of the streams. The genera *Barilius* and *Puntius* are few such genera, which have more species included in it. *Puntius* is represented by four species and *Barilius* genus by two species. These fishes are found usually in the confluent zones where streams meet with small rivers. Loaches of the family Cobitidae and Balitoridae are common in all types of hill stream habitats, usually found in the bottom of the stream beds, by the side of the rocks. Rheophilic fishes like Loaches and Catfishes occupy head water zone of the streams (Sehgal, 1988). It is seen in the present investigation that they can also be present in muddy bottom i.e., they are common in wetland habitat also. It shows that, apart from *Glypthorax* spp., other catfishes choose broad range of habitat for living and can withstand ecological variations. Species of the genera like *Lepidocephalus*, *Acanthocobitis* and *Botia* are found underneath the stones and pebbles. In the present investigation, it is seen that catfishes belonging to the family Bagridae are represented by *Mystus* spp., family Siluridae by *Ompok* spp., Sisoridae family by *Gagata* spp., Schilbeidae family by three species, and Clariidae and Heteropneustidae by single species each. These fishes are often found in the middle zone of the streams and were collected from the habitats having sands, gravels and muddy bottom. Catfishes are also found in lentic habitat apart from streams showing a wide tolerance to changes in ecological variations. Some of the fishes found in the streams are also common in flood plain wetlands and small rivers. The brilliantly colourful fishes of family Ambassidae are represented by *Chanda* sp. and *Parambassis* spp., family Badidae is represented by *Badis* sp., and family Nandidae is represented by *Nandus* sp. They are found both in flood plain wetlands and in confluent zone where streams meet with rivers. Among the recorded fish species, many have good consumption value and ornamental value. The presence of fish species like *Barilius* spp., which are also cold water species, have prospect for sport fishery (yet to be explored) in the region. Sarkar (2021) also recorded *Barilius* species among the 71 recorded cold water fishes from Dooars region of West Bengal.

In the present study, among the families, the highest number of species diversity was observed in the family Cyprinidae. A similar finding was also observed by Baro and Sharma (2015), Das, Boruah and Kar (2015), Dey and Sarma (2018), Dutta *et al.* (2021) Gurumayum (2021), Gurumayum, Kosygin and Tamang (2016), and Valentina *et al.* (2015). Species richness in a region is governed by a number of biotic and abiotic factors that operate at different spatial and temporal scales (Das, Boruah and Kar, 2015). These biotic as well as abiotic factors act together in regulating the local species richness (Kar, 2007).

A typical feature of hill streams of the region is that the upper stretches (above 1,500 meter msl) have poor but distinctive fauna (Biswas and Boruah, 2000). On the other hand, the hill streams fishes are more abundant where streams meet with larger streams because of the nutritive water and warm temperature (Ahmed, Rahman and Mandal, 2013). Fish communities in riverine systems typically follow a pattern of increasing species richness, diversity and abundance from upstream to downstream (Welcomme, 1985). Similar observation was noticed in the present investigation because diversity of fish species is more in the confluence of streams and rivers. This fact was also observed by Ahmed, Rahman and Mandal (2013) in hill stream fish diversity studied in Bangladesh. It is also a common fact that a hill stream with fast flowing water over a rocky or a bed with boulder may not have large sized carps (Kar and Sen, 2007; Kar, 2013). However, these habitats have a greater diversity of stream fishes having adaptive structural modification to thrive in the fast flowing water condition. The distribution pattern and migration of the hill stream fishes throughout the stream depends on seasonal and ecological variation. Fish usually migrate during the breeding season. From the study it was seen that some hill stream fishes are also found in the downstream area that may be due to flood and migratory behaviour of fishes.

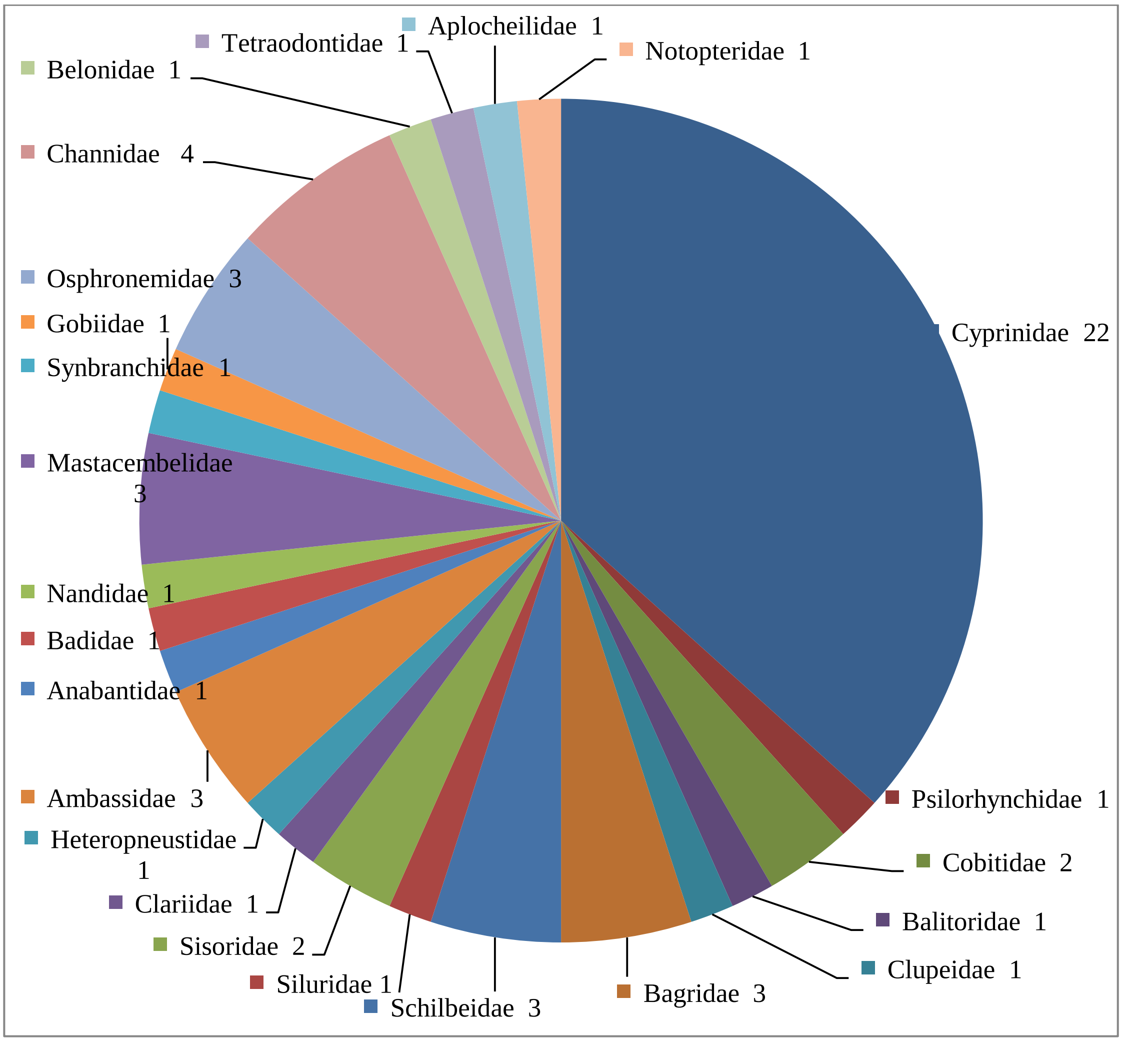

Figure 1: Number of fish species represented family wise

4. Conclusion

Northeast India, criss-crossed with numerous river systems has a rich freshwater fish diversity. This diversity is attributed to the past geological history and the Himalayan orogeny, which played an important role in the speciation and evolution of groups inhabiting mountain streams (Vishwanath, 2012). Fishes represent visible measure of stream ecosystem structure and functions (Arunachalam, Johnson and Sankaranarayanan, 2003). Stream fishes of the study area found in different habitat gradients play important role in the stream ecology, as the assemblage of it helps in monitoring the stream quality. Many of these fishes have ornamental value and serve as good bioindicators.

The stream fishes need immediate attention because many species are yet to be discovered. Anthropogenic landscape disturbances, such as sand and boulder mining, deforestation, row crop agriculture and grazing, shift the structural and functional relationship between the landscape elements and the stability of the physical environment

(Arunachalam, Johnson and Sankaranarayanan, 2003). Thus, there is a need of immediate inventorization of the icthyodiversity of these hill streams so that necessary measures could be taken for their conservation. Otherwise, these fish germplasm will be lost in near future.

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6. References

Acharjee, B. (2016). Exotic fish and their impact on the aquatic environment: A case study of a wetland in lower Assam. *Helix*[+], 1(1): 77-84. Available online at:https://www.ustm.ac.in/helix/ (accessed on 21 March 2023).

Ahmed, A.T.A., Rahman, M. and Mandal, S. (2013). Biodiversity of hill stream fishes in Bangladesh. *Zootaxa,* 3700(2): 283-292. Doi: https://doi.org/10.11646/zootaxa.3700.2.6.

Armbruster, J.W. (2014). Standardized measurements, landmarks, and meristic counts for cypriniform fishes. *Zootaxa*, 3586: 8-16. Doi: https://doi.org/10.11646/zootaxa.3586.1.3

Arunachalam, M., Johnson, J.A. and Sankaranarayanan, A. (2003). Fishes of Rain Forest Streams/Rivers of India a Research Overview.In: A.K. Gupatha and Ajithukumar, V. Ramakantha (eds.), *Wildlife and Protected areas, Conservation of Rainforests in India*. Dehradun: Wildlife Institute of India, pp.152-172. Available online at:https://www.researchgate.net/publication/320183669_Fishes_of_Rain_forest_streams_rivers_of_India_-_A_Research_overview(accessed on 21 March 2023).

Baro, D.C. and Sharma, D. (2015). Distribution, habitat and conservation status of some threatened fishes in Sonkosh River, Bodoland Territorial Council, India. *International Journal of Current Research,* 7(11): 22239-22244. Available online at: https://www.journalcra.com/article/distribution-habitat-and-conservation-status-some-threatened-fishes-sonkosh-river-bodoland (accessed on 21 March2023).

Biswas, S. and Boruah, S. (2000). Fisheries ecology of the Northern Himalayas with special reference to Brahmaputra River. *Ecological Engineering*, 16: 39-50. Doi: https://doi.org/10.1016/S0925-8574(00)00075-6.

Bloch M.E. (1793). Naturgeschichte der ausländischen Fische. Berlin: Naturgeschichte der Ausländischen Fische,v.7: i-xiv + 1-144, pp.325-360.

Bloch M.E. (1794). Naturgeschichte der ausländischen Fische. Berlin: Naturgeschichte der Ausländischen Fische, v.8: i-iv + 1-174, pp.361-396.

Bloch, M.E. (1792). Naturgeschichte der ausländischen Fische. *Berlin*. v. 6. i-xii + 1-126, Pls. 289-323.

Bloch, M.E. and Schneider, J.G. (1801).M.E. Blochii, systema ichthyologiae iconibus cx illustratum. Post obitum auctoris opus inchoatum absolvit, correxit, interpolavit Jo (M.E. Blochii, systema ichthyologiae iconibum cx illustrated. After the obituary, he completed the work begun, corrected, interpolated Jo). Gottlob Schneider, Saxo. Berlin:Berolini, Sumtibus Austoris Impressum et Bibliopolio Sanderiano Commissum, 584 p.

Das, B.K., Boruah, P. and Kar, D. (2015). Icthyofaunal Diversity of Siang in Arunachal Pradesh, India. *Proceedings of the Zoological Society,* 70(1): 52–60. Doi: https://doi.org/10.1007/s12595-015-0155-6.

Das, S., Das, B.K. and Kar, D. (2015). Study of fish diversity and physico-chemical parameters of river Singla, Assam, India. *International Journal of Environmental Sciences*, 5(6): 1140-1146. Doi: https://doi.org/10.6088/ijes.2014050100108.

Dey, A. and Sarma, D. (2018). Diversity, distribution and conservation approach of hillstream ornamental fishes in Manas river, India: A eastern hotspot region. *Journal of Coldwater Fisheries*, 1(1): 103-112. Available online at:https://dcfr.res.in/download/Journal-Sept-2018.pdf (accessed on 21 March 2023).

Dutta, B., Borah, J.N., Borah, U., Baruah, P. and Kar, D. (2021). Pattern of Distribution and Diversity of Icthyospecies in the Towkak River in Assam and Nagaland. *Journal of Veterinary and Marine Research*, 1(1): 1-4. Available online at: https://manuscriptscientific.com/article/14/journal-of-veterinary-and-marine-research/62/1 (accessed on 21 March 2023).

Fortier, L., Le Fevre, J. and Legendre, L. (1994). Export of biogenic carbon to fish and to the deep ocean: the role of large planktonic microphages. *J. Plankton Res.,* 16: 809-839.

Goswami, U.C., Basistha, S.K., Bora, D., Shyamkumar, K., Saikia, B. and Changsan, K. (2012). Fish diversity of North East India, inclusive of the Himalayan and Indo Burma biodiversity hotspots zones: A check list on their taxonomic status, economic importance, geographical distribution, present status and prevailing threats. *International Journal of Biodiversity and Conservation*, 4(15): 592-613. Doi: https://doi.org/10.5897/IJBC11.228.

Gurumayum, S.D. (2021). A preliminary report on fish diversity of Poma river and its tributaries, Arunachal Pradesh, India. *International Journal of Fisheries and Aquatic Studies*, 9(2):158-162. Doi: https://doi.org/10.22271/fish.2021.v9.i2c.2437.

Gurumayum, S.D., Kosygin, L. and Tamang, L. (2016). Ichthyofaunal diversity of Arunachal Pradesh, India: A part of Himalaya biodiversity hotspot. *International Journal of Fisheries and Aquatic Studies,* 4(2): 337-346. Available at: https://www.fisheriesjournal.com/archives/2016/vol4issue2/PartE/4-1-71.pdf (accessed on 21 March 2023).

Hamilton, F. (*1822). An account of the fishes found in the River Ganges and its branches*. Edinburg: Archibald Constable and Company 405 p.

Islam, M.R., Das, B., Baruah, D., Biswas, S.P. and Gupta, A. (2013). Fish Diversity and Fishing Gears used in the Kulsi River of Assam, India. *Annals of Biological Research*, 4(1): 289-293. Available online at: https://www.researchgate.net/publication/260298092_Fish_Diversity_and_Fishing_Gears_used_in_the_Kulsi_River_of_Assam_India (accessed on 21 March 2023).

Jayaram, K.C. (1999). *The Freshwater Fishes of Indian Region*. New Delhi: Narendra Publishing House.

Kar, A., Goswami, N.K., and Saharia, D. (2014). Biological resources of Silsako Wetland in Kamrup Metro District of Assam: uses of macrophytes and icthyofauna. *Pleione*, 8(1): 79-88. Available online at http://pleione.ehsst.org/journals/Pleione81/010%20Bio-resource%20SilkolaWetland%20Assam.pdf (accessed on 21 March 2023).

Kar, D. (2007). *Fundamentals of limnology and aquaculture biotechnology*. New Delhi: Daya Publishing House.

Kar, D. (2013). *Wetlands and Lakes of the World*. London: Springer.

Kar, D. and Sen, N. (2007). Systematic list and distribution of fish biodiversity in Mizoram, Tripura and Barak drainage in North East India. *Zoos Print Journal,* 22(3): 2599-2607. Available at https://www.zoosprint.zooreach.org/index.php/zpj/article/view/6624/6039 (accessed on 21 March 2023).

Lacepède, B.G.E. (1800). Histoire naturelle des poisons (Natural history of fish). *BM (Nat. hist),* I: 281; III: 1041. Doi: https://doi.org/10.5962/bhl.title.11645

Legendre, L. and Michaud, J. (1998). Flux of biogenic carbon in oceans: size-dependent regulation by pelagic food webs. *Mar. Ecol. Prog. Ser.*, 164: 1-11.

Malakar, M. and Boruah, S. (2017). Diversity and Present Status of Fish Species in Three Floodplain Wetlands of Central Assam, India. *IOSR Journal of Environmental Science: Toxicology and Food Technology*, 11(1): 54-59. Available online at: https://www.iosrjournals.org/iosr-jestft/papers/Vol11-%20Issue%201/Version-1/J1101015459.pdf (accessed on 21 March 2023).

McClelland, J. (1839). Indian Cyprinidae. *Asiatic Researches*, 19(2): 217-471.

McClelland, J. (*1845*). Description of four species of fishes from the rivers at the foot of the Boutan Mountains. *Calcutta Journal of Natural History*, V: 274-283

Meenakumari, B. and Mahanta, P.C. (2012). Mountain Fishery Development: Constraints and Remedies. Souvenir, Workshop on Sustainable Utilization of Mountain Fishery Resources of North East Region 24-25 March, 2012. Directorate of Cold Water Fisheries Research (ICAR), Guwahati, Assam. Available online at: https://www.dcfr.res.in/download/souvenir-abstracts/Workshop-on-Sustainable-Utilization-of-Mountain-Fishery-Resources-of-North-East-Region-24-25-March-2012-Guwahati(Assam)-SOUVENIR.pdf (accessed on 21 March 2023).

Nath, P. and Dey, S.C. (2000). *Fish and Fisheries of North Eastern India*. New Delhi: Narendra Publishing House.

Pallas, P.S. (1769).Spicilegia Zoologica quibus novae imprimis et obscurae animalium species iconibus, descriptionibus atque commentariis illustrantur. (Zoological Spices in which new and obscure species of animals are illustrated with icons, descriptions and notes. Berlin, Gottl. August Lange Zoological Spices in which new and obscure species of animals are illustrated with icons, descriptions and notes), *Berolini, Gottl. August. Lange.*, 1(7): 1-42.

Power, M.E., Stout, J.R., Cushing, C.E., Harper, P.P.F., Hauer, R., Matthews, W.J., Moyle, P.B., Statzner, B. and Irene, R.W.D.B. (1988). Biotic and abiotic controls in river and stream communities. *J. N. Am. Benthol. Soc.*, 7(4): 456-479.

Rahman, S., Kakati, S., Choudhury, J.K., Sarma, P.C., Barua, E. and Dutta, A. (2014). Ichthyofaunal Diversity of North Guwahati, Assam, India. *IOSR Journal of Agriculture and Veterinary Science*, 7(4): 10-13. Available online at: https://www.iosrjournals.org/iosr-javs/papers/vol7-issue4/Version-2/C07421013.pdf (accessed on 21 March 2023).

Ramanujam, S.N., Manorama, M., and Dey, S. (2010).Ichthyodiversity of Meghalaya: India. *Electronic Journal of Ichthyology,* 6(2): 15–26. Available online at:https://www.tau.ac.il/~ichthyol/2010/RamanujamManoramaDey.pdf (accessed on 21 March 2023).

Sarkar, T. (2021).Cold water fish diversity and their conservation status in the Teesta, Jaldhak, Torsa, Kaljani and Sankosh River of the Dooars region, West Bengal, India. *Asian Journal of Conservation Biology*, 10(1):146-152. Doi: https://doi.org/10.53562/ajcb.WIMQ5691.

Sehgal, K.L. (1988). Ecology and fisheries of mountains streams of the north-western Himalayas. D.Sc. Thesis, University of Meerut, India.

Sen, T.K. (1985). The Fish Fauna of Assam and the Neighbouring North-Eastern States of India. Records of the ZSI. Occasional Paper No. 64, Zoological Survey of India, Kolkata.

Talwar, P.K. and Jhingran, A.G. (1991). *Inland Fishes of India and Adjacent Countries*. New Delhi: Oxford and IBN Co. Pvt. Ltd.

Valentina, T., Singh, H.T., Tamuli, A.K. and Teron, R. (2015). Assessment of Physico-Chemical Characteristics and Fish Diversity of Hill streams in Karbi Anglong district, Assam, India. *International Research Journal of Environment Sciences*, 4(5): 6-11. Available online at: http://www.isca.in/IJENS/Archive/v4/i5/2.ISCA-IRJEvS-2015-018.pdf (accessed on 21 March 2023).

Vishwanath, W. (2012). Fish Diversity of Northeast India: A Glimpse. Souvenir, Workshop on Sustainable Utilization of Mountain Fishery Resources of North East Region, 24-25 March, 2012. Directorate of Cold Water Fisheries Research (ICAR), Guwahati, Assam.

Vishwanath, W., Nebeshwar, K., Lokeshwar, Y., Shangningam, B.D. and Rameshori, Y. (2014). Freshwater fish taxonomy and a manual for identification of fishes of Northeast India.Manipur University and NBFGR, Imphal, Manipur, India, p.132.

Welcomme, R.L. (1985). River fisheries. FAO Fish Tech. Pap., 262: 1-318.

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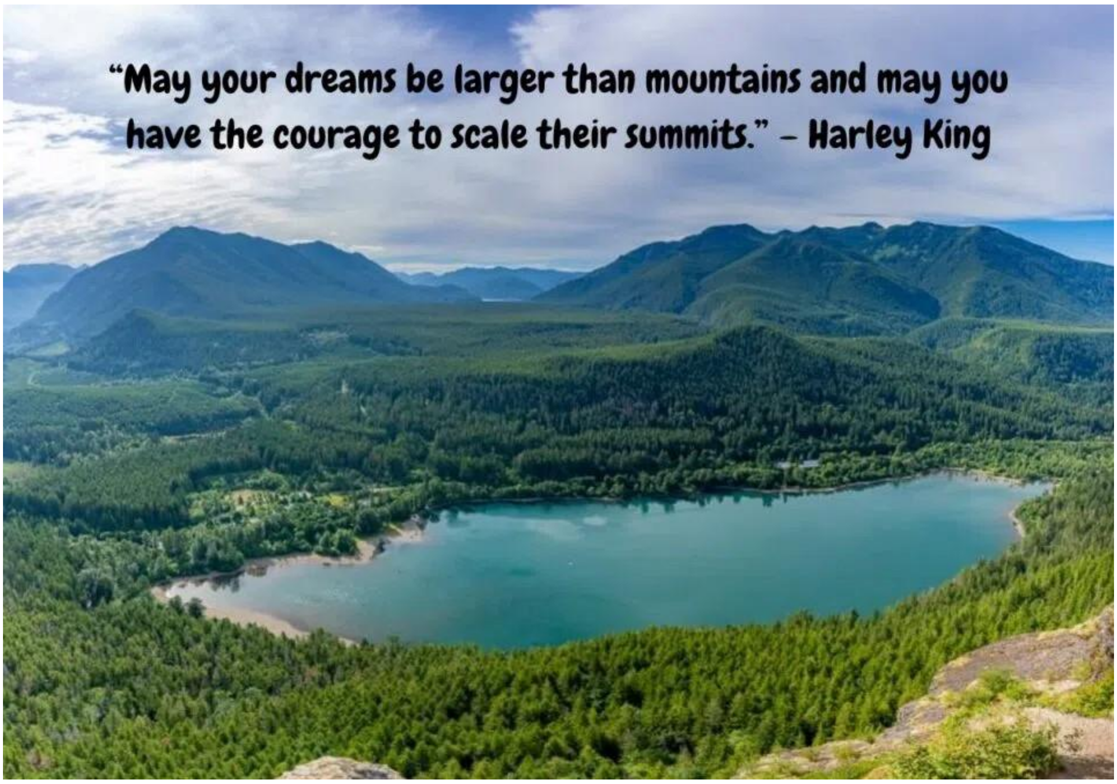
"May your dreams be larger than mountains and may you
have the courage to scale their summits." – Harley King

Chapter 5

Mountain Forests: Challenges and Management

By Hyunshik Moon and Tamirat Solomon

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Mountain Forests: Challenges and Management

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Abstract

Mountain forests are important for their production and protection values. They serve as a home of important timber, wood, and non-wood products in several countries and most importantly they serve in storing water and preventing erosion. They are also hotspots of biodiversity including common indigenous species used for different purposes in society categorized as timber and non-timber forest products (NTFPs). Many mountain forests are playing the role of carbon sinks to mitigate climate change. However, most of the world's mountain communities are strongly influenced by surrounding lowland and urban areas with regard to timber extraction, and expansion of agricultural land to the fertile soils of the forest ecosystem with the addition of forest fire incidences. In a changing climate, human-induced disturbances and lack of awareness are the major threats to mountain ecosystems. For the sustainability of the ecosystem, maintenance and new approaches for the management with special attention and proper actions should be taken to save and maintain the productive, protective, socio-cultural roles of mountain forests which are essential for maximum stability and integrity for the sustainability of the mountain forest ecosystems.

Keywords

Forest disturbance: Participatory forest management: Climate change adaptation

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1. Introduction

Mountains forests make up about 28% or one third of all natural forest cover worldwide (Martin, 2010), which are a living place for 12% of the global inhabitants (Martin, 2003; Glushkova *et al.*, 2020). They are one of the most important ecosystems in the world as they provide numerous important ecological, hydrological, social, and economic values. Mountain forests are important homes of timber, wood, and non-timber forest products in several countries. For instance, the major source of fuel energy for the people living around the mountain in developing countries and to some extent in developed countries is wood. The collected fuel wood from the mountain is used for cooking, heating, drying, preventing insect damage to stored crops, and purifying water and/or sources of economy for both the collectors and the nearby settlements in the foothills of the mountain (Marieke *et al.*, 2015; Nathalie and Martin, 1999). It is commonly accepted that mountain forests assume various functions for society more and more, corresponding to the public utilities (Bugmann *et al.*, 2005), protection of the soils, supply of products for human lives and infrastructures, the purification of air and water, activities linked with tourism and recreation (including hunting), and rural development (through grazing and timber production). Mountain forests are also central elements in natural patrimony and cultural heritage (Gerard, 2002).

Generally, mountains are primarily hotspots of biodiversity (Gratzer and Keeton, 2017; Georg and Bruno, 2011) and common indigenous species that are used for different purposes in society as timber and non-timber forest products (NTFPs). This is due to their vertical expansion which creates different climatic conditions only short distances apart (Georg and Bruno, 2011). And also mountains are global centers of biodiversity; 25 of the 344 global biodiversity hotspots are wholly or partially in mountains (FAO, 2011).

However, most of the world's mountain communities are strongly damaged by surrounding lowland and urban areas with regard to timber extraction, destruction of the watersheds, and often recreation-induced mismanagement (Nathalie and Martin, 1999; Dias and Melo, 2010). Most importantly expansion of agricultural land to the fertile soils of the forest ecosystem is one of the top problems challenging the mountain forests and diversities around, especially in developing countries. This is a result of the question of how much or what fraction of deforestation (emissions) in a country is caused by a specific driver (i.e. expansion of agriculture versus infrastructure) that cannot be answered for many developing countries (Noriko *et al.*, 2012). Even though the mountain ecosystems are very important for life on the earth, attention given to the environment is less than to what it's supposed to be which is evidenced by the scarcity of references and reports from the scientific community in comparison to works on other forest ecosystems. This chapter is intended to address the major challenges of the mountain ecosystem so that scientists and other concerning stakeholders could give more attention to research and scientific works for the sustainability of the ecosystem.

2. Mountain Forests as a Crucial Landscape Resource

In the UN General Assembly (UN, 2015) the Agenda 2030, the importance of mountain ecosystems is clearly recognized in the category of life on land Sustainable Development Goal (SDG 15). It was set as a goal for management by the goal targeting to achieve the year 2020, "to ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains, and dry lands, in line with obligations under international agreements" (goal 15.1); and more specifically "by the year 2030, to ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development" (goal 15.4).

The importance of mountain forests is clearly described by different reports and findings from countries on different continents indicating the roles of mountain forests in influencing the quantity and quality of water, food production, and ecosystem services (FAO, 2011; Georg and Bruno, 2011; Gerard, 2002; Girma, 2006; Harrison *et al.,* 2010; Robert *et al.*, 2013; UN, 2015; Verburg *et al.*, 2009), however, the capacity of mountain ecosystems to provide key services is at risk (Beniston and Stoffel, 2014; Robert *et al.*, 2013). Therefore, as a crucial landscape resource, mountain forests need an integrated management system by the way of integrated forest resource management (IFRM) which is an approach of managing forest resources sustainably by helping forest users, managers, and other stakeholders to achieve their different goals by willfully taking into account, and aiming to reconcile and synergize, their various interests, attitudes, and actions.

3. Challenges of Mountain Forests

3.1 Forest Disturbance

Mountains are fragile and often located in remote areas, whose human populations are often highly vulnerable to environmental, economic, and social changes at all scales from local to global (FAO, 2011; Lexer and Bugmann, 2017). Due to the slope, natural settings, and diversities included, there is an increasing interest in societies for recreation purposes, the mountain environments and forest ecosystem are exposed to changes; specifically disturbances.

A disturbance is a discrete event (volcanic eruption, fire, livestock browsing, tree fall, branch break, etc.) that changes the species composition, the looks (physiognomy/structure) and/or physiological processes and resources, such as light, temperature, and nutrients, in any vegetation system (Frolking *et al.*, 2009; Geldenhuys *et al.*, 2011). As ecosystems are dynamic entities, they are variable across both space and time, and these patterns of variability in ecosystem development are modulated by events or processes known as "disturbances" (Anton *et al.*, 2013).

Land conversion specifically for the purpose of cropland and pasture is widely believed to be one of the main causes of deforestation. Frolking *et al.* (2009) stated that fire, windstorms, logging, and shifting cultivation are dominant disturbances; minor contributors are land conversion, flooding, landslides, and avalanches. However, the influence of land conversion on the forest ecosystem is not simple especially in the developing world, as in most developing economies the decline in forests and woodlands is mainly the result of land conversion, in particular agricultural expansion for crop production (FAO, 1997; FAO, 2003; Gibbs *et al.*, 2010). The influence of agriculture on global deforestation is significant; by considering the importance of both agriculture and forests for the livelihood of humans and sustainability of life on the earth, there is an exigent need to build positive interaction between these two land uses (FAO, 2016).

The perception of disturbances has evolved over time but continues to vary geographically. Sometimes disturbances are seen as beneficial ecological processes and sometimes as catastrophes that threaten the ecosystems they affect. Often they cause substantial concern among the public and policymakers (Kulakowski *et al.*, 2017; Wu *et al.*, 2020; Sánchez *et al.*, 2021). Geldenhuys *et al.* (2011) stated that disturbances at different scales are a natural part of all types of vegetation, and also natural forests and woodlands. They have a benefit for natural processes like distribution of seeds, transportation of seeds from the origin of the sources to other environments v*ia* different agents such as wind, water, animals, and birds and also, on the contrary, they can influence the entire ecosystem depending in the way they happen with mismanagement.

In many regions over the past centuries human activities have strongly influenced forest dynamics, especially following natural disturbances, thus limiting our understanding of natural ecological processes, particularly in densely-settled regions (Bebi *et al.*, 2017). Analysis of the disturbance regime of a forest can be of great value for understanding patterns of structure and composition, as well as being important for defining appropriate management interventions (Adrian, 2007). Characterizing the disturbance regime typically involves assessing the severity, timing, and spatial distribution of the different types of disturbance affecting the forest. It is useful to note the difference between the intensity and severity of disturbance. And also every action in the forest ecosystem specifically in the mountain forest ecosystem needs the care to avoid the distinct effect on the forest environment.

3.2 Climate Change

Our understanding of the magnitude and ecological implications of climatic variation in space and time has greatly developed over the past decades (Bente *et al.*, 2018). Climate change is one of the major disturbing factors which affect the amount and values of forest resources. The impact of climate change on the forest resources is in multidimensional means; such as fluctuation of seasons, altering the frequency, duration, and timing of fire and drought, increasing the intensity of disease incidence, and timing of fire, drought, invasive species, insect and pathogen outbreaks, hurricanes, windstorms, ice storms, or landslides (Kohler *et al.*, 2014; Virginia *et al.*, 2001; Westerling *et al.*, 2006).

Understanding the extent and impact of each disturbance resulting from climate change on the forest provides a background for examining ways to cope with the impacts of climate change (Bente *et al.*, 2001). Forest disturbances are caused by both anthropogenic and natural, influence forest systems by affecting their composition, structure, growth, development, and functional processes.

With a predicted global temperature increase of 2.0–4.5°C until the end of the century (IPCC, 2007), climate change is expected to affect the density and diversity of forest resources and its influence is severe on mountain forests. For instance, Harald *et al.* (2005) stated that in mountain ecosystems, numerous causes are of key importance that may be nearly negligible elsewhere. Examples include the determination of slope angle and aspect for the influence of energy stability, the role of the steep slopes on downhill or water flows, impacts of root systems on slope maintenance, the relationship between high topographic and biotic heterogeneity, the role of forest vegetation on steep slopes for keeping ecosystems, human and infrastructure from natural threats such as avalanches and rock fall.

Changes in climatic conditions strongly alter forest dynamics, particularly disturbance and species assembly, complicating the prediction of the future contribution of forests to climate regulation (Thom *et al.*, 2017).

Table 1: Challenges of mountain forests and the potential impacts

Challenges of mountain forests	*Potential Impacts*	*Sources*
Population pressure & poverty	Reducing production results in dependency on the mountain forests	(Baral *et al.*, 2017; Macchi and ICIMOD, 2010; UN 2002; UNEP, 2002)
Climate change	By changing the climatic parameters, particularly temperature and precipitation	(Fort, 2015; Kohler *et al.*, 2014; Martin, 2003)
The fragile nature of Ecosystem	Complexity of topography that greatly enhanced direct runoff and erosion	(Gabelnick *et al.*, 1997; Martin, 2003; UN, 2002; Wang *et al.*, 2019)
Agricultural expansion	Deforestation and conversion of land use system	(Lindell, 2011; Noriko, 2012; Patru-Stupariu *et al.*, 2020)
Deforestation & forest degradation	Unsustainable extraction of wide ranges of goods and services	(UNEP, 2002; UNEP-WCMC, 2002)

4. Management and Maintenance Mechanism for Mountain Forests

4.1 Participatory Forest Management (PFM)

Mountain forests have a high potential for securing livelihoods by providing opportunities other than timber use because of their beautiful scenery and the associated ecosystem functions (Girma, 2006; Martin, 2003; Gerard, 2002), and they are among the most important ecosystems as they support numerous ecological, hydrological, climatic, social, and economic functions. Mountain ecosystems can only continue to provide all these services in a rapidly changing world if sustainable forest management is implemented and ecosystem services and benefits are considered in forest management at local, landscape and regional scales. The sustainable management of mountain forest can be achieved by the approaches by considering the relationship in between ecosystem and social processes. One of the best methods that can be used to manage the forest resources is participatory forest management (PFM).

PFM is a technique to manage forests and improve the livelihoods of societies who depend and use from them in the process (FAO, 2011). As mountain forest ecosystems provide a wide range of direct and indirect contributions to the people who live in the mountains and surrounding areas (Baral *et al.*, 2017), including nearly 50% of the world's freshwater for direct consumption, agriculture, and energy (Klas, 2011), are originated from mountain forest ecosystems, and mountain tourism accounts for 15-20% of the world's tourism industry, totaling an estimated $US70-90 billion per year. Therefore, the areas are typically exposed to multiple disturbances, damages and hazards. Extreme events such as storms, landslides, avalanches, and rock falls may become more common and intense in mountain areas (Kohler *et al.*, 2019); besides anthropogenic impacts resulting in major changes in the ecosystem.

The socio-cultural values of mountain forests as to the definition given in (Bernue´s *et al.*, 2014; MEA, 2005; Uta *et al.*, 2016) are nonmaterial benefits from mountain forest ecosystems, which include recreational facilities and tourism, aesthetic appreciation, inspiration, a sense of place and educational value (Baral, 2017). However, the socio cultural values of mountain forests result in serious problem in mountain forests mainly forest fire, invasive species, and damage on some specific species and so on.

Trends and experiences over the last decade appear to confirm the general assumption that PFM, when well facilitated, can lead to recovery and/or maintenance of forest quality (Blomley and Ramadhani, 2006), and also, Ameha *et al.* (2016) expressed that participatory management was more successful than government management in making forestry sustainable. In the same ways expressed about the increases in basal area and volume in sites managed under both joint and community-based forest management, and declines in both of these variables in forests under government or open access management (Tom *et al.*, 2008). Therefore, inclusiveness; PFM is a key management method to include the users in management so as to share the responsibility of management with the user group or society.

4.2 Maintenance and Conservation Mechanism for Mountain Forests

Can the use of continuous cover forestry alone maintain mountain forests? Traditional rural activities, such as agriculture, fuel wood collection, charcoal production, livestock grazing and forestry, together with expansion of infrastructures, and tourism and recreation are the major challenges for the mountain communities. Even though there is a difference from place to place and country to country based on the socio-economic and awareness context of each country, such activities are nowadays either declining or in full expansion. Therefore, protection is of vital importance to human populations and activities.

Physical soil and water conservation technologies are the best mechanisms for managing mountain forests. Soil erosion may cause severe loss of topsoil where organic matter and vital nutrients needed by trees for survival. As the land degradation leads to the deterioration of soil quality (Mango *et al.*, 2017), the physical soil and water conservation technologies plays a great role in protection of the soil erosion. For instant, the studies by (Joas, 2015; Kebede *et al.*, 2013) revealed that the use of soil conservation interventions such as traditional stone bunds, terracing and diversion ditches in contributed a significant effect on the reduction of land degradation. More than 80% of land degradation is due to soil erosion; out of which 56% is due to the water-induced soil erosion (Oldema, 1992), therefore, the physical structures are mechanisms to protect the erosion problem.

5. Conclusion

According to the sustainable forest management modules of the food and agricultural organization, the coverage of mountain forests on the world's land surface is about 900 million hectares, which is about 20 percent of forest coverage in the world. Human demands regarding goods and services from the mountain ecosystem globally, although there is a difference in gaining resources from mountain ecosystems based on the developmental level of countries, the mountain ecosystem provides great support to human beings. The followings are the categories of benefits from mountain forest ecosystems to human beings (Figure 1).

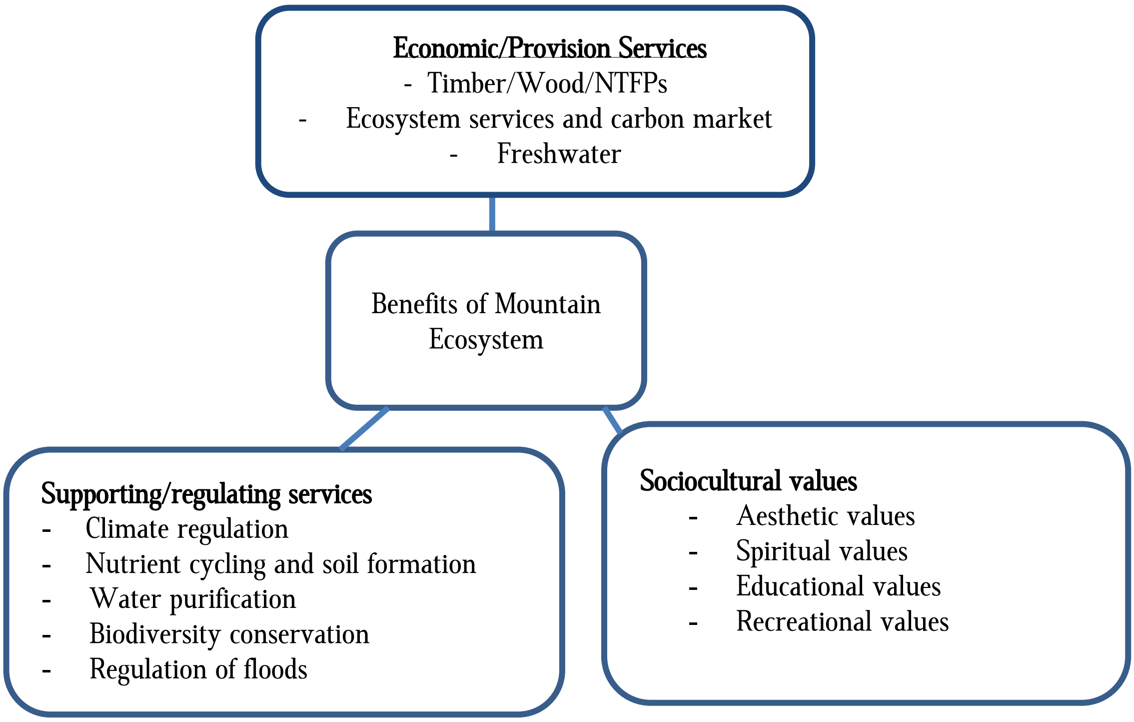

Figure 1: Importance of mountain ecosystems (Baral *et al.*, 2017; Glushkova *et al.*, 2020; Herdis *et al.*, 2017; MEA, 2005; Roberto *et al.*, 2017).

Mountain forests are subject to many forces of changes, in different ways including expansion of agriculture, forest fire, climate change, and mismanagement. Mountain forests are particularly endangered and many mountain forests have been almost completely destroyed. They are threatened by climate change, because of their steep slopes and changing climates and weather conditions, they are fragile ecosystems and also by human use that challenges mainly in the form of disturbances. Forest disturbances, both anthropogenic and natural, influence forest systems by affecting their composition, structure, growth, development, and functional processes.

Generally, as the mountain ecosystems are ecologically fragile and highly vulnerable to disturbance, an integrated approach of management is required by focusing on the nature-based solution through the restoration of degraded mountain areas and reducing deforestation and degradation.

6. References

Adrian, C.N. (2007). *Forest Ecology and Conservation. A Handbook of Techniques*. Oxford: Oxford University Press, p.148.

Ameha, A., Meilby, H. and Feyisa, G.L. (2016). Impacts of participatory forest management on species composition and forest structure in Ethiopia. *International Journal of Biodiversity Science, Ecosystem Services & Management*, 12(1-2): 139-153. DOI: https://doi.org/10.1080/21513732.2015.1112305.

Anton, F., Philip, M. and Ann, C. (2013). Disturbances in deciduous temperate forest ecosystems of the northern hemisphere: their effects on both recent and future forest development. Review paper. *Biodiversity Conservation*, 22(9): 1863-1893. DOI: https://doi.org/10.1007/s10531-013-0525-1.

Baral, H., Jaung, W., Bhatta, L.D., Phuntsho, S., Sharma, S., Paudyal, K., Zarandian, A., Sears, R.R., Sharma, R., Dorji, T. and Artati, Y. (2017). Approaches and tools for assessing mountain forest ecosystem services, Working Paper 235. Bogor, Indonesia: CIFOR. DOI: https://doi.org/10.17528/cifor/006755.

Bebi, P., Seidl, R., Motta, R., Fuhr, M., Firm, D., Krumm, F. and Kulakowski, D. (2017). Changes of forest cover and disturbance regimes in the mountain forests of the Alps. *Forest Ecology and Management*, 388: 43-56. DOI: https://doi.org/10.1016/j.foreco.2016.10.028.

Beniston, M. and Stoffel, M. (2014). Assessing the impacts of climatic change on mountain water resources. *Science of the Total Environment*, 493: 1129-1137. DOI: https://doi.org/10.1016/j.scitotenv.2013.11.122.

Bente, J.G., Vigdis, V., Scott, W.A., Wolf, L.E., Jens-ChS Kristoffer, H., Johan, E., James, D.M.S., Kari, K., Kari A.B., Ann, M., Øystein, H.O., Inger, G.A., Rasmus, E., Hans, H.B., John, B.B., Kristine, B.W., Hilary, H.B. and Jonathan, L. (2018). Stay or go – how topographic complexity influences alpine plant population and community responses to climate change. *Perspectives in Plant Ecology, Evolution and Systematics*, 30: 41-50. DOI: https://doi.org/10.1016/j.ppees.2017.09.008.

Bernue´s, A., Rodrı´guez-OT., Ripoll-B.R. and Alfnes, F. (2014). Socio-Cultural and Economic Valuation of Ecosystem Services Provided by Mediterranean Mountain Agroecosystems. *PLoS ONE*, 9(7): e102479. DOI: https://doi.org/10.1371/journal.pone.0102479.

Blomley, T. and Ramadhani, H. (2006). Going to scale with Participatory Forest Management: early lessons from Tanzania. *International Forestry Review*, 8(1): 93-100. DOI: https://doi.org/10.1505/ifor.8.1.93.

Bugmann, H., Zierl, B. and Schumacher, S. (2005). Projecting the Impacts of Climate Change on Mountain Forests and Landscapes. In: Huber, U.M., Bugmann, H.K.M., Reasoner, M.A. (eds.), *Global Change and Mountain Regions. Advances in Global Change Research*, vol 23. Dordrecht: Springer. DOI: https://doi.org/10.1007/1-4020-3508-X_48.

Dias, E. and Melo, C. (2010). Factors influencing the distribution of Azorean mountain vegetation: implications for nature conservation. *Biodiversity and conservation*, 19(12): 3311-3326. DOI: https://doi.org/10.1007/s10531-010-9894-x.

FAO (1997). State of the World's Forests. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO (2003). State of the World's Forests. Food and Agriculture Organization of the United Nations. Rome, Italy. ISBN 92-5-104865-7.

FAO (2011a). Mountain forests in a changing world. Realize values, addressing challenges. Food and Agriculture Organization of the United Nations, with the support of the Swiss Agency for Development and Cooperation, SDC.

FAO (2011b). Participatory Forest Management in Ethiopia, Practices and Experiences. The sub regional Office for Eastern Africa (SFE), Addis Ababa, Ethiopia, p.58.

FAO (2016). State of the World's Forests 2016. Forests and agriculture: land-use challenges and opportunities. Food and Agriculture Organization of the United Nations, Rome.

Fort, M. (2015). Impact of climate change on mountain environment dynamics. *Journal of Alpine Research*, 103-2. DOI: https://doi.org/10.4000/rga.2877.

Frolking, S., Palace, M.W., Clark, D.B., Chambers, J.Q., Shugart, H.H. and Hurtt, G.C. (2009). Forest disturbance and recovery: A general review in the context of space borne remote sensing of impacts on aboveground biomass and canopy structure. *J. Geophys. Res.*, 114: G00E02. DOI: https://doi.org/10.1029/2008JG00091.

Gabelnick, T., Hogan, D., Okuizumi, K. and Pfeuffer, P. (1997). Managing fragile ecosystems sustainable mountain development: Earth Summit+5 policy analysis and recommendations. 24. Princeton University, USA.

Geldenhuys, C.J., Ham, C. and Ham, H. (2011). Sustainable Forest Management in Africa: Some Solutions to Natural Forest Management Problems in Africa. Proceedings of the Sustainable Forest Management in Africa Symposium. Stellenbosch, South Africa.

Georg, G. and Bruno, M. (2011). *Mountain Regions of the World: Threats and Potentials for Conservation and Sustainable Use. Some expert's opinions*. Vienna: Austrian Academy of Sciences Press.

Gerard, B. (2002). Multipurpose management of mountain forests: which approaches? *Forest Policy and Economics*, 83-87. DOI: https://doi.org/10.1016/S1389-9341(02)00008-4.

Gibbs, H.K., Ruesch, A.S., Achard, F., Clayton, M.K., Holmgren, P., Ramankutty, N. and Foley, J.A. (2010). Tropical forests were the primary sources of new agricultural land in the 1980s and 1990s. Proc. Natl. Acad. Sci. USA 21, 107(38): 16732-16737. DOI: https://doi.org/10.1073/pnas.0910275107.

Girma, A. (2006). Integrated and participatory forest management in the Bale Mountains of Ethiopia. International Symposium towards Sustainable Livelihoods and Ecosystems in Mountainous Regions, 7-9 March 2006, Chiang Mai, Thailand.

Glushkova, M., Zhiyanski, M., Nedkov, S., Yaneva, R. and Stoeva, L. (2020). Ecosystem services from mountain forest ecosystems: conceptual framework, approach and challenges. *Silva Balcanica*, 21(1): 47–68. DOI: https://doi.org/10.3897/silvabalcanica.21.e54628.

Gratzer, G. and Keeton, W.S. (2017). Mountain forests and sustainable development: The potential for achieving the United Nations' 2030 Agenda. *Mountain research and Development*, 37(3): 246-253. DOI: https://doi.org/10.1659/MRD-JOURNAL-D-17-00093.1.

Harald, B., Barbel, Z. and Sabine, S. (2005). Projecting the Impacts of Climate Change on Mountain Forests and Landscapes. *Global Change and Mountain Regions*, 477-487.

Harrison, P.A., Vandewalle, M., Sykes, M.T., Berry, P.M., Bugter, R., de Bello, F., Feld, C.K., Grandin, U., Harrington, R. and Haslett, J.R. 2010. Identifying and prioritizing services in European terrestrial and freshwater ecosystems. *Biodiversity Conservation*, 19: 2791–2821. DOI: https://doi.org/10.1007/s10531-010-9789-x.

Herdis, H., Joar, S. and Sanne, B.H. (2017). Cultural Heritage and Ecosystem Services: A Literature Review. *Conservation and Management of Archaeological Sites*. 19(3): 210-237. DOI: https://doi.org/10.1080/13505033.2017.1342069.

IPCC (2007). Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change Core Writing Team, Pachauri, R.K and Reisinger, A. (Eds.), IPCC, Geneva, Switzerland, 104.

Joas, T. (2015). Effects of Soil and Water Conservation Techniques on Soil Productivity and Bean Grain Yield in Nyamasheke District, Rwanda. M.Sc thesis, Kenyatta University. Kenya.

Kebede, W., Moges, A. and Yimer, F. (2013). Farmers' perception of the effects of soil and water conservation structures on crop production: The case of Bokole watershed, Southern Ethiopia. *African Journal of Environmental Science and Technology*, 7(11): 990-1000. DOI: https://doi.org/10.5897/AJEST2013.1529.

Klas, S. (2011). A view from the top: mountain forests. Development in changing climate, making our future sustainable. The World Bank. Available online at: https://blogs.worldbank.org/climatechange/view-top-mountain-forests [accessed 28 February 2023].

Kohler, T., Wehrli, A. and Jurek, M. (2014). Mountains and climate change: A global concern. Sustainable Mountain Development Series. Bern, Switzerland, Centre for Development and Environment (CDE), Swiss Agency for Development and Cooperation (SDC) and Geographica Bernensia, 136.

Kulakowski, D., Svoboda, M. and Bebi, P. (2017). The central role of disturbances in mountain forests of Europe. *Forest Ecology and Management*. 100(388): 1-2. DOI: https://doi.org/10.1016/j.foreco.2016.07.034.

Lexer, M.J. and Bugmann, H. (2017). Mountain forest management in a changing world. *Eur. J. Forest Res.*, 136: 981–982. DOI: https://doi.org/10.1007/s10342-017-1082-z.

Lindell, L. (2011). Environmental Effects of Agricultural Expansion in the Upper Amazon. A Study of River Basin Geochemistry and Hydrochemistry, and Farmers´ Perceptions, Linnaeus University Dissertations No. 65/2011. ISBN: 978-91-86983- 05-5.

Macchi, M. and ICIMOD (2010). Mountains of the World Ecosystem Services in a Time of Global and Climate Change. Kathmandu: ICIMOD, p.32.

Mango, N., Makate, C., Tamene, L., Mponela, P. and Ndengu, G. (2017). Awareness and adoption of land, soil and water conservation practices in the Chinyanja Triangle, Southern Africa. *International Soil and Water Conservation Research*, 5(2): 122-129. DOI: https://doi.org/10.1016/j.iswcr.2017.04.003.

Marieke, S., Douglas, S. and Ken, E.G. (2015). Fuelwood collection and its impacts on a protected tropical mountain forest in Uganda. *Forest Ecology and Management*, 354: 56-67. DOI: https://doi.org/10.1016/j.foreco.2015.06.037.

Martin, F.P. (2003). Why mountain forests are important? *The Forestry Chronicle*, 79(2): 219.

Martin, S. (2010). Five facts about mountain forests. WWF. Available online at: http://p.dw.com/p/Mnh8. 06.04.2010 [accessed on 29 January 2023].

MEA (2005). *A Report of the Millennium Ecosystem Assessment. Ecosystems and Human Well-Being*. Washington DC: Island Press.

Nathalie, B. and Martin, F.P. (1999). Mountain people, forests, and trees: Strategies for balancing local management and outside interests. A synthesis of an electronic conference of the Mountain Forum. The E-conference report.

Noriko, H., Martin, H., Veronique, D.S., Ruth, S.D.F., Maria, B., Louis, V., Arild, A. and Erika, R. (2012). An assessment of deforestation and forest degradation drivers in developing countries. Environmental Research Letter 7:12. DOI: http://dx.doi.org/10.1088/1748-9326/7/4/044009.

Oldema, L.R. (1992). Global extent of soil degradation. International Soil Reference and Information Centre, Wageningen, The Nertherlands, Available online at: https://19-36.org/10.5558/tfc79219-2 [accessed 23 January 2023].

Patru-Stupariu, I., Alina Hossu, C., Raluca, S., Nita, A., Stupariu, M., Huzui-stoiculescu, A. and Gavrilidis, A.A., (2020). A review of changes in mountain land use and ecosystem

services: from theory to practice. *Land*, 1: 21: DOI: https://doi.org/10.3390/land9090336.
Robert, H., Rigling, A., Bebi, P., Brand, F.S., Briner, S., Buttler, A., Elkin, C., Gillet, F., Grêt-Regamey, A., Hirschi, C., Lischke, H., Scholz, R.W., Seidl, R., Spiegelberger, T., Walz, A., Zimmermann, W. and Bugmann, H. (2013). Sustainable land use in mountain regions under global change: synthesis across scales and disciplines. *Ecology and Society,* 18: 36. DOI: http://dx.doi.org/10.5751/ES-05499-180336.
Roberto, T., Giuseppe, S.M., Catrin, P., Thomas, H., Paolo, A. and Bernhard, W. (2017). Mountain Watersheds and Ecosystem Services: Balancing multiple demands of forest management in head-watersheds. European Forest Institute Yliopistokatu 6, FI-80100 Joensuu Finland.
Sánchez, J.J., Marcos-Martinez, R., Srivastava, L. and Soonsawad, N. (2021). Valuing the impacts of forest disturbances on ecosystem services: An examination of recreation and climate regulation services in U.S. national forests. *Trees, Forests and People*, 5: 100123. DOI: https://doi.org/ 10.1016/j.tfp.2021.100123.
Thom, D., Rammer, W. and Seidl, R. (2017). The impact of future forest dynamics on climate: interactive effects of changing vegetation and disturbance regimes. *Ecological Monographs*, 87(4): 665-684. DOI: https://doi.org/10.1002/ecm.1272.
Tom, B., Kerstin, P., Jaconia, I., Eliakimu, Z., Antje, A. and Neil, B. (2008). Seeing the wood for the trees: an assessment of the impact of participatory forest management on forest condition in Tanzania. *Fauna & Flora International, Oryx*, 42: 380-391. DOI: https://doi.org/10.1017/S0030605308071433.
UN General Assembly (2015). Transforming Our World: The 2030 Agenda for Sustainable Development. A/RES/70/1. Available online at: https://www.un.org/ga/search/view_doc.asp?symbol¼A/RES/70/1&Lang¼E [accessed on 7 May 2020]..
UN (2002). FAO Announces International Year of Mountains in 2002; Sounds Alarm on Degradation of Mountain Environments. Press Release SAG/76.
UNEP (2002). Impact of Global Warming On Mountain Areas Confirmed By Unep-Backed Mountaineers. Environmental issues and sustainable development. UNEP/114.
UNEP-WCMC (2002). Mountain Watch: Environmental change and sustainable development in mountains. UNEP-WCMC Biodiversity Series 12. Cambridge, UK.
Uta, S., Florian, T., Ulrike, T. and Erich, T. (2016). Cultural ecosystem services of mountain regions: Modelling the aesthetic value. *Ecological Indicators*, 69: 78-90. DOI: https://doi.org/10.1016/j.ecolind.2016.04.001.
Verburg, P.H., Van De Steeg, J., Veldkamp, A., Willemen, L. and Veldkamp, A. (2009). From land cover change to land function dynamics: A major challenge to improve land characterization. *J. Environ. Manag.*, 90: 1327–1335. DOI: https://doi.org/10.1016/j.jenvman.2008.08.005.
Virginia, H.D., Linda, A.J., Steve, M., Ronald, P.N., Matthew, P.A., Michael, D.F., Paul, J.H., Lloyd, C.I., Ariel, E.L., Chris, J.P., Daniel, S., Frederick, J.S., Brian, J.S. and Michael, BW. (2001). Climate Change and Forest Disturbances. American Institute of Biological Sciences. *BioScience,* 723-734. DOI: https://doi.org/10.1641/0006-3568(2001)051[0723:CCAFD]2.0.CO;2.
Wang, Y., Wu, N., Kunze, C., Long, R., Perlik, M. (2019). Drivers of Change to Mountain Sustainability in the Hindu Kush Himalaya. In: Wester, P., Mishra, A., Mukherji, A.,

Shrestha, A. (eds.), *The Hindu Kush Himalaya Assessment*. Cham.: Springer. DOI: https://doi.org/10.1007/978-3-319-92288-1_2.

Westerling, A.L., Hidalgo, H.G., Cayan, D.R. and Swetnam, T.W. (2006). Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity. 10.1126/science.1130691.

Wu, S., Chao, C., Huang, B., Luo, M., Duan, X., & Liao, P. (2020). Environmental disturbance in natural forest and the effect of afforestation methods on timber volume increment in Pinus sylvestris L. var. mongolica Litv. *Global Ecology and Conservation*, 24: e01311. DOI: https://doi.org/10.1016/j.gecco.2020.e01311.

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Chapter 6

Dynamics of Grassland Vegetation Composition across different Land-use Types on the Qinghai Tibet Plateau: Implications to Combat Grassland Degradation

By Moses Fayiah, ShiKui Dong, Roberto Xavier Supe Tulcan, Sanjay Singh, Muthu Rajkumar, Sallay Saccoh and Rebecca Bockarie

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Dynamics of Grassland Vegetation Composition across different Land-use Types on the Qinghai Tibet Plateau: Implications to Combat Grassland Degradation

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Abstract

The constant biotic and abiotic interventions on the Qinghai Tibet Plateau (QTP) are seriously degrading the grasslands and, at the same time, restricting the active ecosystem function and grassland vegetation distribution on the plateau. This research analyses the dynamics of grassland vegetation composition across three land uses and counties. The degree of grassland degradation was divided into four land-use types based, i.e., healthy grassland (HG), restored grassland (RG), moderately degraded (MD) grassland, and severely degraded (SD) grassland. About 32 plant species were recorded in Tiebujia county, 28 in Maqin county, and 18 in Maduo county. Results showed *Poa crymophila, Polygonum sibiricum, Leontopodium nanum* and *Oxytropis falcatabunge* as the most abundant grassland species in all land-uses and counties. The richness of species ranged from 8 to 12 species per land-use, suggesting low richness and diversity in restored and degraded grassland. A positive non-significantly mean change ($p<0.05$) was detected for richness and evenness indices while a negative mean change ($p<0.05$) was detected for Simpson and Shannon indices in the alpine meadow and steppe in both Maqin and Maduo county. The results imply that degradation affects grassland vegetation, health, and distribution across the QTP. Plant total cover for the healthy grassland covered far more areas than other land-uses. Urgent mitigation measures to halt grassland degradation and decline in plant vegetation composition on the plateau should be adopted.

Keywords

Grassland; Land-use; Species; Vegetation; Qinghai-Tibet-Plateau

Citation

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1. Introduction

Ecologists and other environmentalists have described the Qinghai Tibet Plateau as the roof of the earth, hot pole, third pole, species differentiation and formation center, highest plateau on earth, and head water station for Asia (Cao *et al.*, 2019; Dong *et al.*, 2019; Dong *et al.*, 2020; Fayiah *et al.*, 2019; Liu *et al.*, 2018; Mipam *et al.*, 2019; Wang *et al.*, 2014; Xiong *et al.*, 2019; Yang *et al.*, 2013). Chinese scholars have referred to the plateau as the center of species formation and differential globally (Zhang *et al.* 2002). The complex biodiversity characteristics of the QTP made some schools of thought to refer to it as a "natural laboratory or the natural museum of floristic evolution" (Hedberg, 1975; Sun, 2002; Sun *et al.*, 2014). The QTP is one of the world's richest biomes with 59.13% of grassland vegetation accounting for 17 grassland types (Weih and Glynn, 2019). Two major types of grassland exist on the QTP; in the north-west, the alpine steppe is the dominant vegetation with *Stipa* (Poaceae family) being the dominant plant species, while in the south-east the alpine meadow vegetation covers the verse majority of the territory with *Kobresia* species (Cyperaceae family) dominating (Mipam *et al.*, 2019; Zhang *et al.*, 2007). The alpine meadow and steppe grasslands account for 44.64% and 28.75%, respectively (Fayiah *et al.*, 2020; Li *et al.*, 2013). Based on Zhang *et al.* (2002) survey of 12,000 plant species belonging to 1,500 genera, 300 rare and endemic species, and 5,000 epiphyte species were found on the QTP (Wu *et al.*, 2008). Sun *et al.* (2014) listed *Meconopsis vig, Pedicularis l, Anaphalis DC, Cremanthodium benth, Primula l, Corydalis DC,* etc. genera of great importance of evolution on the QTP. Based on theoretical evidence, species richness, growth, and diversity vary greatly across the QTP (Fayiah *et al.*, 2019; Sun *et al.*, 2014; Tang *et al.*, 2006; Yang *et al.*, 2013). However, the variation in grassland vegetation and richness is highly connected with the biotic and abiotic processes constantly unveiled on the QTP. Abiotic factors such as climate change, temperature, sunshine duration, precipitation, winter period, drought, flooding, and so on have negatively influenced grassland vegetation on the QTP (Cao *et al.*, 2019; Dong *et al.*, 2019; Dong *et al.*, 2020; Fayiah *et al.*, 2019; Mu *et al.*, 2017; Sun *et al.*, 2014; Sun *et al.*, 2019; Wei and Glynn, 2019; Xiong *et al.*, 2019; Xu *et al.*, 2018; Yang *et al.*, 2013). The biotic activities such as overgrazing, population increase, urbanization and industrialization, crops cultivation and traditional practices, among others, have contributed to the decline in grassland vegetation on the QTP (Fayiah *et al.*, 2020; Sun, Cheng and Li, 2013; Wang, 2009; Wang *et al.*, 2000; Zhang *et al.*, 2019). Scientific evidence has proven that the QTP has richer biodiversity than any other biome across Asia (Sun *et al.*, 2014) and beyond. The scholarly ecologist has confirmed that the plateau host more than 12,000 vascular plant species, 210 mammal species, 5,000 epiphytes species, 115 species of fish, and 532 bird species (Zhang *et al.*, 2002). The complex ecosystem interface on the QTP supports the formation of new species, maintains older species, and provides a safe haven for succession (Zhang *et al.*, 2002).

Globally, the biodiversity/vegetation conservation concept has emerged as the central topic for the sustainable development goals (SDGs) linked with ecosystem sustainability and, by extension, globalization. In this regard, investigating grassland vegetation along land use on the QTP is essential to keep track of vegetation changes occurring due to biotic and abiotic occurrences. Secondly, such investigations should be undertaken constantly because the terrestrial ecosystem on the QTP is very sensitive to environmental and other social disturbances. Many studies have been conducted across the QTP on biodiversity composition and distribution. Still, very little attention is being given to biodiversity in different land-use ecologies. This research intends to bridge this gap and throw light on the vegetation composition and distribution across different land uses on the QTP.

2. Materials and Method

2.1 Study Location

The study was conducted in three Counties on the QTP, namely Tiebujia, Gonghe County (37° 06´82´´N, 99° 55´93´´E), Maqin county (34° 42´48´´N, 100°32´65´´E) and Maduo county (34°84.89´´N 98° 28´92´´E) (Fig.1). The average elevations for these three sites were 3,227 m, 3,803 m and 4,172 m for Tiebujia, Maqin county and Maduo county, respectively. The average annual temperature of the three locations ranges from -0.6 to -24 in January and 18°C in July (Dong *et al.*, 2012; Zhao *et al.*, 2017). As per Ma *et al.* (2002), the alpine grassland of the study areas is separated into (1) "degraded grasslands", (2) "healthy grassland", (3) "restored grassland", and (4) "severely degraded grassland. Tiebujia County is dominated by alpine steppe, Maqin County by alpine meadow, and Maduo County by alpine steppe. In Maduo County, the soil type of the study location is loamy with 40% silt, 40% sand, and 20% clay (Dong *et al.*, 2012). The soil type in Maqin County is classified as subalpine meadow soil (Li *et al.*, 2016), or loam with 40% sand, 20% clay, and 40% silt (Wang *et al.*, 2015; Dong *et al.*, 2012), while Tiebujia County's soil type was described as mostly loam-clay (Zhao *et al.*, 2016).

Table 1: Environmental parameters of the study area

Environmental conditions	*Environmental indicators*	*Study Location*		
		Tiebujia	*Maqin*	*Maduo*
Vegetation type	Grassland	Alpine steppe	Alpine meadow	Alpine Steppe
Land use type	HG, RG, MD, SD	Four (4)	Four (4)	Four (4)
Geographical features	Latitude (N°) Longitude (E°) Altitude (M)	37.06-37.03 99.55-99.32 3,227-3,264	34.42-34.49 100.32-100.22 3,803-3,820	34.84-34.53 98.28-98.12 4,172-4,193
Climatic parameters	Annual precipitation (mm) Annual mean temperature	377 (mm) 0 °C	538.17 0.77°C	358.49 −2.48°C

Notes: Healthy grassland, HG; Restored grassland, RG; Moderately degraded grassland MD; and Severely degraded, SD.

2.2 Sampling Method

Biodiversity parameters, such as species names, abundance, frequency, height, and coverage in a 1 m × 1 m quadrat, were recorded as per Ren's (1998) and Li *et al.*'s (2014) approaches. Proper scientific classification was done either in the field or in the laboratory by a knowledgeable plant taxonomist. In total, 36 replicated quadrats (1 m × 1 m) were enumerated with a distance of at least 30 m from each other. A thorough biodiversity assessment was done and compared among the four land-use grassland types.

2.3 Land Use Selection Criteria

Land use categorization was done as per Ma *et al.* (2002) and Wang *et al.* (2015, 2019) classification methods alongside grazing intensity, fencing, and rodent disturbance. This article incorporated their approach and that of grazing status (freely or moderately grazed), disturbance level, and rodent burrowing activities. The degree of grassland degradation in this study was divided into four land-use types based on the above criteria (Cao *et al.*, 2019), i.e., healthy grassland (HG), restored grassland/cultivated (RG), moderately degraded grassland (MD) and severely degraded grassland (SD).

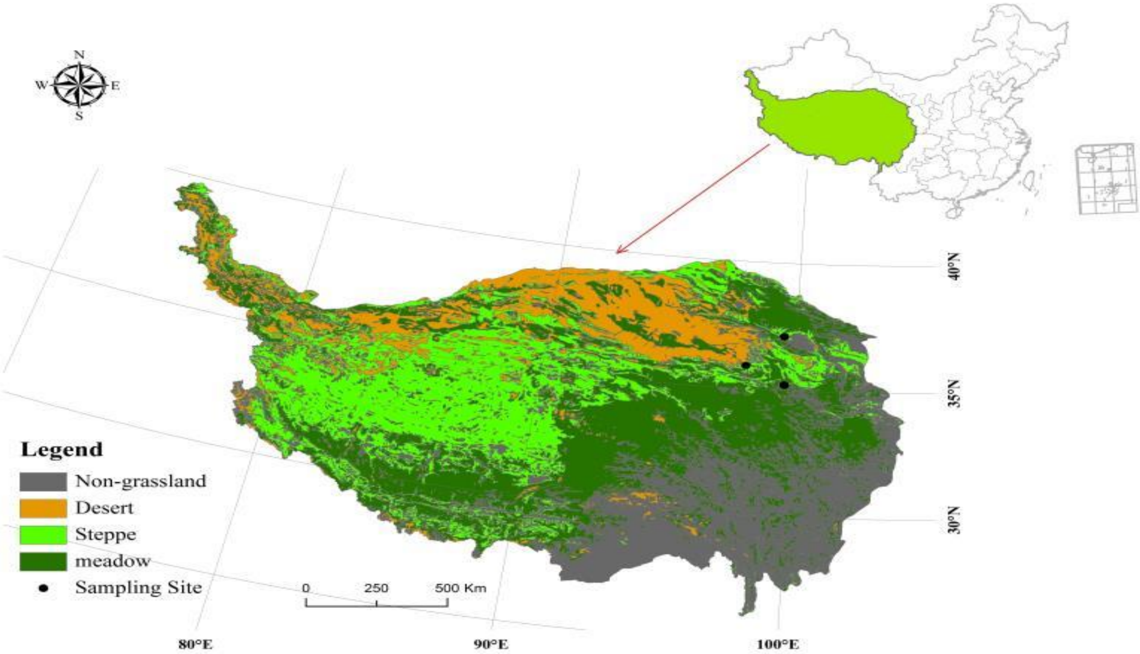

Figure 1: Map showing the study area

Table 2: Land use selection and partition

Degree of Degradation	*Coverage (%)*	*Edible plants proportion (%)*	*Plant height in (cm)*
HG	70-100	90-100	10-40
RG	50-70	70-90	10-37
MD	50-60	40-70	8-14
SD	30-50	0-40	2-4

2.4 Statistical Analysis

All statistical analyses were done using the R software package and IBM-SPSS v.23 Software for Windows. The multi-biodiversity indices like the Simpson diversity index, Shannon-Weiner index, Species richness, and Pielou evenness (Kent and Coker, 1992; Gaines Woodard and Carlson, 1999; Shannon and Weiner, 1963) and soil chemicals parameters were reported as a mean standard error in tables.

Shannon Diversity Index

$$H' = -\sum_{i=1}^{S} P_i \ln P_i$$

Evenness Index

$$J = H'/\ln S$$

Simpson Diversity Index

$$D = 1 - \sum_{i=1}^{s} P_i^2$$

Where N = the number of all plants in the sample community, n_i = the specific number of species I, S = the number of plants in the community, and pi = the specific number of species I in proportion to the aggregate number of plants in the community. The given species number of a particular community is referred to as species richness.

3. Results

The actual number of plant species enumerated in the three grassland types varied greatly. A change in diversity was observed among the different land-use patterns with healthy grassland being the baseline of comparison. For example, 32 plant species were recorded in Tiebujia county, 28 in Maqin county, and 18 in Maduo county (Figure 2). The most abundant plant species across these three study locations were *Poa crymophila, Polygonum sibiricum, Leontopodium nanum* and *Oxytropis falcatabunge* (Table 3). However, the abundance of these species varied across grassland types and land-use in the three counties. The species richness in the different land-use ranged from 5 to 12 species accordingly (Appendix 2). The alpine steppe of Maduo County recorded the lowest plant species richness. The richness of species ranged from 8 to 12 species per land-use with the healthy grassland having higher species richness (Table 3). The species with the most Importance Value Index (IVI) were *Poa crymophyila* (85) for Tiebujia county, *Leontopodium nanum* (75) in Maduo county, and *Poa crymophila* (49) in Maqin county (see Appendix 3, 4 &5).

Table 3: Dominant species, richness and altitude in the three study areas

Type	*Tiebujia Alpine Steppe*			*Maqin Alpine Meadow*			*Maduo Alpine Steppe*		
LU	*Dominant species*	*Richness*	*Alt (m)*	*Dominant species*	*Richness*	*Alt (m)*	*Dominant species*	*Richness*	*Alt (m)*
HG	*Poa crymophila*	10	3,239	*Poa crymophila*	11	3,728	*Leontopodium nanum*	11	4,183
RG	*Poa crymophila*	10	3,230	*Oxytropis falcatabunge*	11	3,806	*Poa crymophila*	5	4,176
MD	*Poa pratensis*	11	3,241	*Leontopodium nanum*	12	3,796	*Polygonum sibiricum*	7	4,173
SD	*Astragalus propinquus*	8	3,234	*Oxytropis falcatabunge*	10	3,810	*Leontopodium nanum*	5	4,179

Notes: LU = Land Use; HG = Healthy Grassland; RG = Restored Grassland; MD = moderately degraded grassland; SD = Severely degraded grassland, and Alt = Altitude (m)

3.1 Plant Height and Total Cover across the Four Land-Uses

Plant height for the four land uses varied, but the restored grassland and healthy grassland dominated in terms of height, especially in Maqin meadow and Maduo alpine steppe (Figure 3). The severely degraded grassland recorded the least height, followed by the moderately degraded grassland. Maduo alpine steppe recorded the least height ($p<0.05$) of plants across all land-uses, especially in the severely degraded grassland (Figure 3). Plant total cover in the healthy grassland was more than other land-uses (Figure 4). The alpine meadows in Margin healthy and restored grassland have more plant total cover than other land-uses in Tiebujia and Maduo county. This was followed by the alpine steppe in Tiebujia and the alpine steppe in Maduo respectively (Figure 4). In particular, the severely degraded grassland reported less plant total coverage followed by the moderately degraded grassland. However, the alpine steppe in Maduo reported the least total coverage area, especially with severely degraded grasslands (Figure 4).

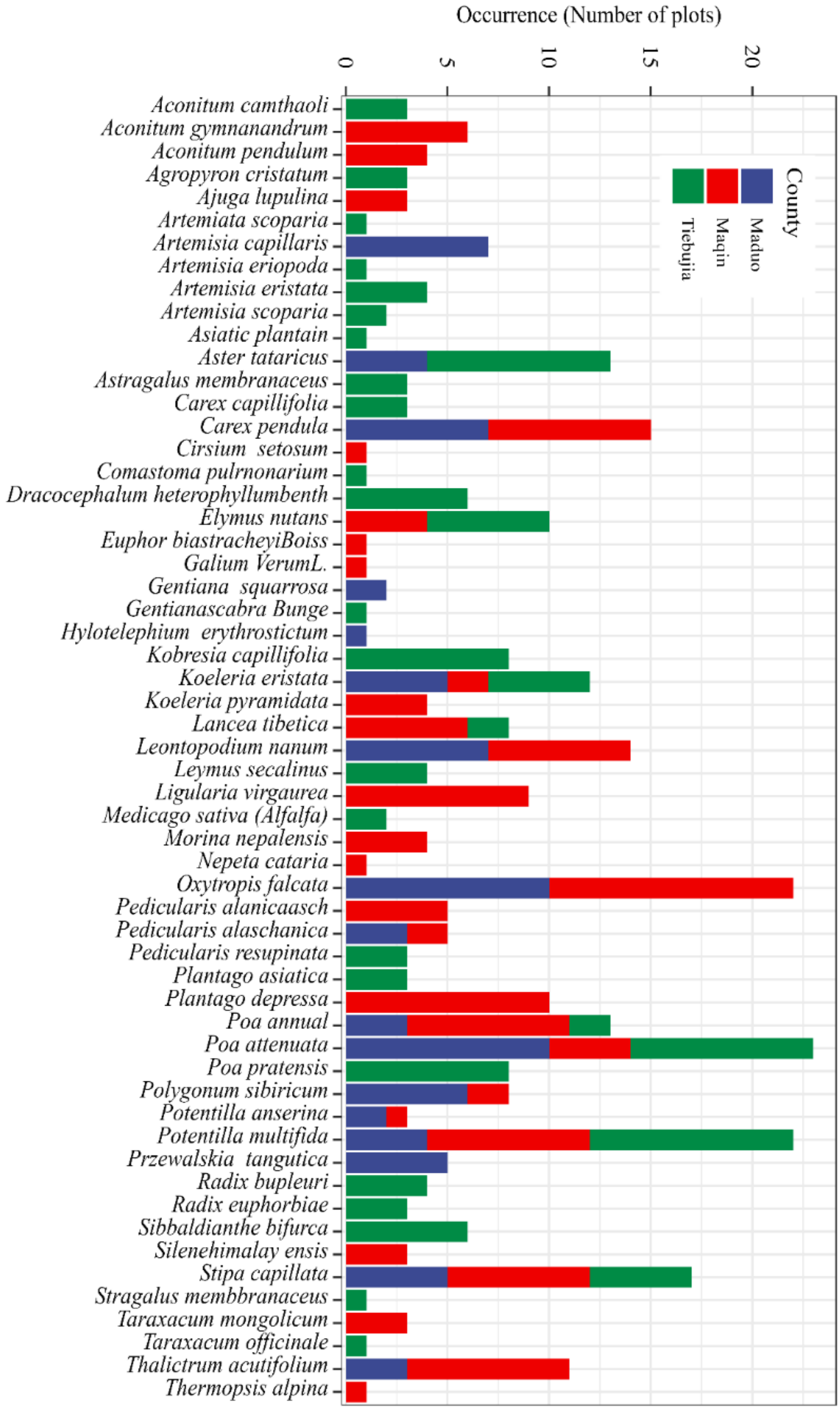

Figure 2: Species abundance according to grassland type

Most plant species in (Figure 2) were detected in all the three counties and their land-uses, while some were only found at particular locations and in land-uses. About 21 plant species were found in Tiebujia county, while 14 and 5 plant species were found in Margin and Maduo County, respectively.

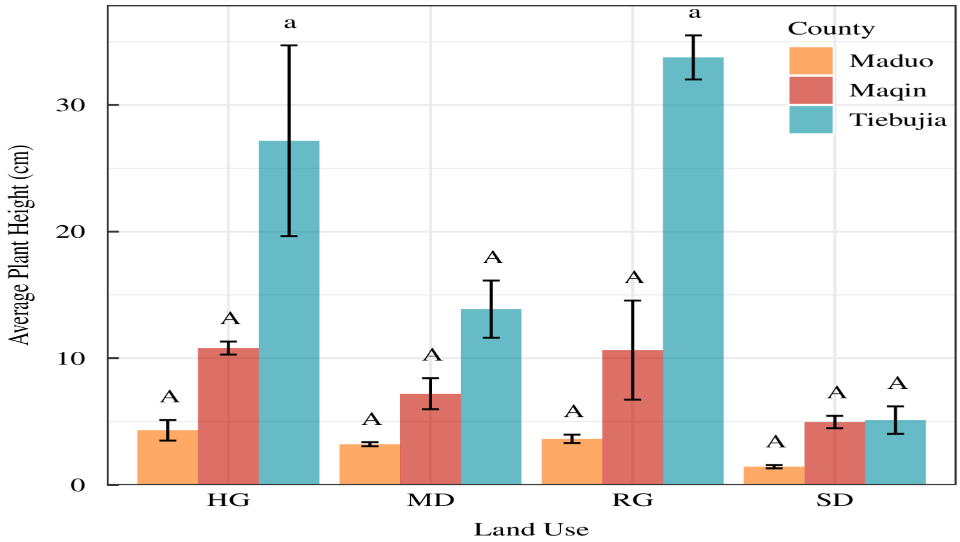

Figure 3: Average plant heights in the four land-uses. The significant differences among diverse land-use are depicted by different alphabetical letters ($p < 0.05$)

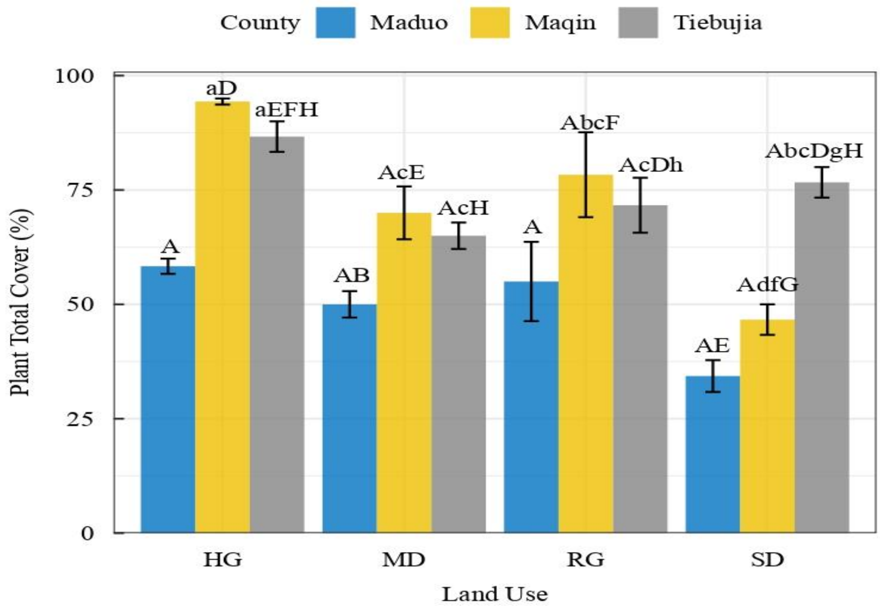

Figure 4: Total plant coverage across four land use. The significant differences among different land use are depicted by different alphabetical letters ($p < 0.05$)

3.2 Mean Change of Multi-Diversity Indices across the Three Grassland Types and Land-Uses

The healthy grassland was used as the baseline to compare the mean change percentage of plant diversity indices across the different grassland types and land use (Figure 5). A significantly positive mean change in the moderately degraded grassland ($p<0.05$) was observed for all plant diversity indices in the alpine steppe in Tiebujia County. In contrast, a positive non-significantly mean change percentage was detected for richness and evenness indices for the alpine meadow in Maqin county and the alpine steppe in Maduo county. In Maqin and Maduo county, the Simpson diversity index and Shannon Weiner indices showed a negative mean change ($p<0.05$) in the moderately degraded grassland.

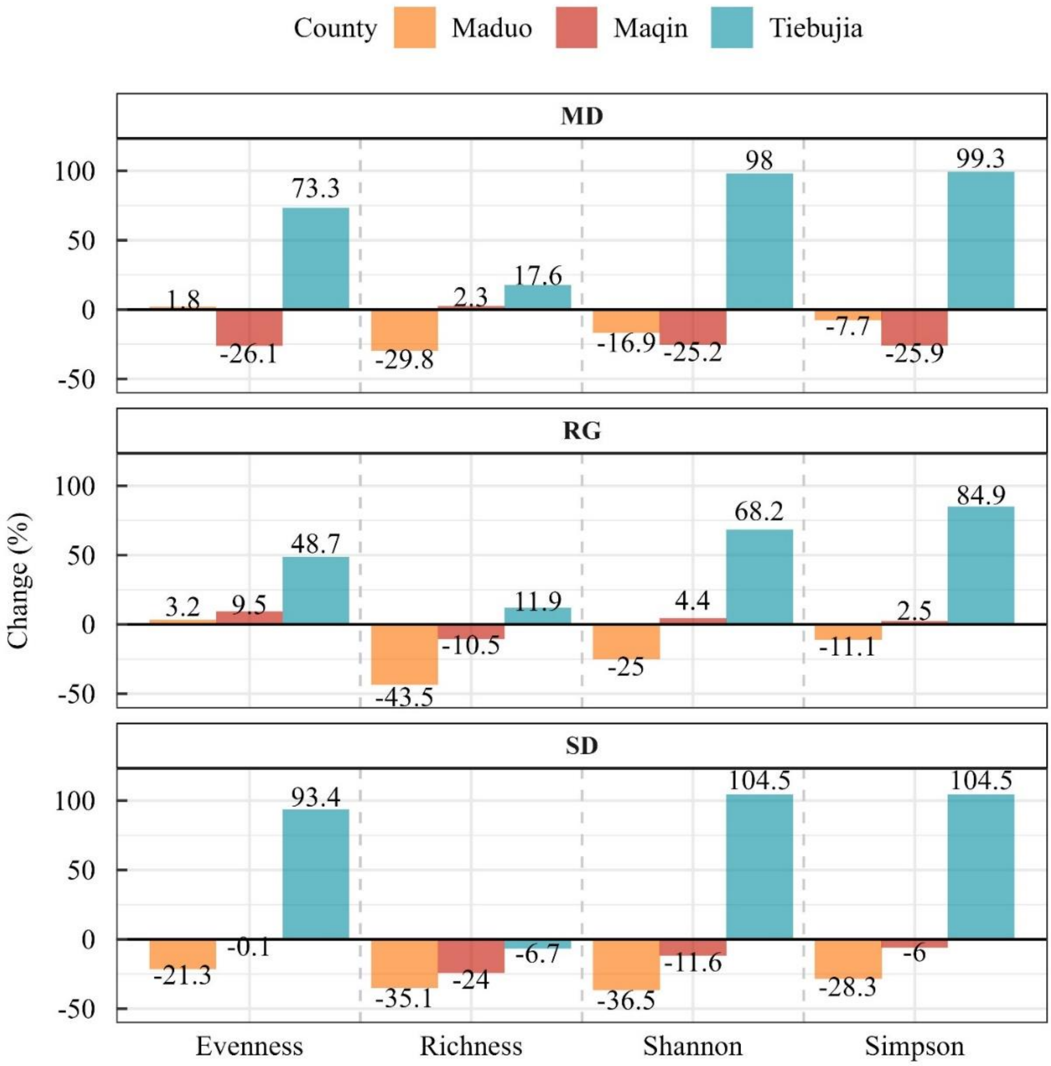

Figure 5: Mean change percentage of plant diversity indices in MD; RG and SD base of comparison with HG on the QTP

4. Discussion

The QTP is known to host and harbor greater plant biodiversity (Wu, 2008) as compared to surrounding lowland ecologies and is considered an ideal ecology for studying plant species composition, adaptation and abundance under harsh environments under climate change impacts (Sun *et al.*, 2014). Understanding grassland vegetation composition and abundance on different grassland ecologies is fundamental in protecting degraded grassland ecosystems and plant vegetation composition. The relationships that exist between plant diversity and plant abundance, productivity, etc. in degraded ecosystems such as QTP grasslands, have attracted rigorous debate among scholarly ecologists in recent years (Li *et* *al.*, 2018; Chen *et al.*, 2019; Fraser *et al.*, 2015; Oba, Vetaas and Stenseth 2001; Maron *et al.*, 2011; Fox, 2003). The natural grassland biomes on the QTP are experiencing diverse environmental conditions like temperature, wind, precipitation, and soil nutrients (Zhu, Lin and Yangjian, 2016). These adverse conditions affect plant vegetation composition and its distribution pattern across different land-use in three counties on the QTP. Plant species enumerated across the three grassland types showed variation and change with healthy grassland being used as a comparison baseline for other land uses. Sun *et al.* (2014) concluded that QTP is rich in plant diversity and composition, and hosts nearly 12,000 species of 1,500 genera (Wu, 2008). Across the three study counties, Tiebujia county recorded 32 plant species, while Maqin and Maduo counties recorded 28 and 18 plant species, respectively. The most abundant plant species across the three study locations were *Poa crymophila, Polygonum sibiricum, Leontopodium nanum* and *Oxytropis falcatabunge* (Table 3).

Table 4: Standard error of multi-biodiversity indices, plant coverage and height

Land use		*HG*		*RG*		*MD*		*SD*	
Grassland Type Location	*Indicators*	*Mean*	*Std Error*	*Mean*	*Std Error*	*Mean*	*Std Error*	*Mean*	*Std Error*
Tiebujia Alpine Steppe	Shannon	1.449	0.482	1.621	0.040	1.969	0.034	1.864	0.154
	Simpson	0.603	0.198	0.749	0.010	0.823	0.007	0.816	0.024
	Evenness	0.605	0.174	0.697	0.010	0.823	0.026	0.893	0.017
	Richness	10.333	2.028	10.333	0.882	11.000	0.577	8.333	1.453
	Plant height	27.167	7.539	33.754	1.741	13.881	2.256	5.116	1.082
	Plant Cover	86.667	3.333	71.667	6.009	65.000	2.887	76.667	3.333
Maqin Alpine Meadow	Shannon	1.893	0.044	1.978	0.193	1.426	0.318	1.671	0.022
	Simpson	0.802	0.006	0.823	0.038	0.594	0.127	0.754	0.012
	Evenness	0.766	0.022	0.835	0.059	0.569	0.083	0.764	0.033
	Richness	12.000	1.155	10.667	0.882	12.333	3.180	9.000	0.577
	Plant height	10.804	0.513	10.647	3.911	7.197	1.226	4.963	0.493
	Plant Cover	94.333	0.667	78.333	9.280	70.000	5.774	46.667	3.333
Maduo Alpine Meadow	Shannon	1.646	0.106	1.310	0.054	1.646	0.106	1.064	0.156
	Simpson	0.769	0.028	0.693	0.023	0.769	0.028	0.553	0.085
	Evenness	0.828	0.015	0.854	0.009	0.828	0.015	0.638	0.100
	Richness	7.333	0.667	4.667	0.333	7.333	0.667	5.333	0.333
	Plant height	4.313	0.814	3.636	0.332	3.209	0.159	1.440	0.131
	Plant Cover	58.333	1.667	55.000	8.660	50.000	2.887	34.333	3.480

Notes: Std = Standard, Er = Error, SD = Severely degraded grassland, HG = healthy grassland, MD = moderately degraded, RG = restored grassland. The mean standard error was given for HG, RG, MD and SD grassland across the three counties and their land-uses.

The variation in plant species could be connected with elevation, land-use practices, and the degradation level of county grassland ecologies. Grazing and rainfall intensity could also be factors determining the plant vegetation composition of each land-use. Another reason may be ascribed to the outcome of the environmental gradient being less diverse due to intense grazing by livestock. Other factors that may affect grassland vegetation composition and distribution across the QTP are light, temperature, topography, climate change, fire, fertilizer application, and grazing (Guo, 2008). Based on Cao *et al.*'s (2019) review, small mammals, climate change, overgrazing, harsh environmental conditions, privatization, and fragile soil may be the sources of degradation and, by extension, affects plant vegetation composition. However, overgrazing on the QTP is the main culprit causing the decline of plant diversity, vegetation composition, total coverage, above- and below-ground biomass, soil nutrient, and richness resulting in degradation (Chai *et al*., 2017; Schleuss *et al*., 2015; Zhang *et al*., 2016). Alternately, Harris (2015) noted that plant species in most land-use on the QTP have developed tolerance mechanisms to withstand periodic and intensity grazing consequences on plant species composition. Similarly, Bertness and Callaway (1994) and Sun *et al.* (2014) suggest that plant-plant interaction strongly impacts plant vegetation composition and the dynamics of plant vegetation composition on the QTP.

Plant species coverage and height vary greatly along different land-use on the QTP. Degraded land use recorded fewer plant species and lesser plant coverage area than restored and healthy grassland. The alpine steppe in Maduo county recorded fewer plant species and was the most degraded grassland across all land-uses. This may be attributed to the harsh environmental conditions coupled with grazing and climate change impacts (Cao *et al*., 2019). Similarly, the total plant coverage varies across counties and land-uses and the variation could be attributed to harsh environmental conditions. The alpine meadow of Maqin county covered more areas in the healthy, restored, moderate, and severely degraded land-use than those in Tiebujia and Maduo counties combined. This difference in vegetation coverage among the different counties may be attributed to human disturbance, population growth, climate change, and elevation (Sun *et al*., 2014). The higher plant species coverage and height in Maqin county could be attributed to higher nitrogen availability in the soil (Wang *et al*., 2015).

The mean change percentage of plant diversity indices of the different land-uses and grassland types with the healthy grassland used as the baseline was investigated. Both significantly positive and negative mean change at ($P<0.05$) was detected across the different land-uses across the three counties. A positive mean change was detected for richness and evenness indices. In contrast, a negative trend was seen for Simpson and Shannon Weiner indices in the alpine meadow and alpine steppe in Maqin and Maduo County, respectively. The reason for this difference in plant diversity could be due to the long fallow period and livestock exclusion practice that is in place at the three study sites. The possible explanation for the mean change decline in species richness and evenness in both restored grassland and moderately degraded grassland of alpine meadow and steppe in Maqin and Maduo counties could be attributed to human and natural factors (Cai *et al*., 2015; Liu *et al*., 2018; Sun, Cheng and Li., 2013; Wang *et al*., 2000; Yang *et al*., 2006) interplay on the plateau. Andrade *et al.* (2015) observed that livestock grazing and land-use change, among others, contribute to biodiversity decline on grasslands. The soil pH, high elevation, extreme temperature, grazing, and nutrient level may also be essential factors responsible for reduced species richness in the counties. A negative trend in the severely degraded grassland was detected for plant diversity, evenness, and species richness. This might be attributed to the very nature of our land-use selection criteria.

5. Conclusion

The QTP terrestrial ecosystem is extremely fragile, complex and is sensitive to biotic and abiotic interventions. Based on this, the plateau has experienced enormous changes in its environmental conditions and plant vegetation composition. Plant biodiversity and plant coverage are two crucial indicators in determining ecosystem function and vegetation distribution on grasslands. This study proved that plant diversity indices, cover, abundance, and height are being influenced by harsh environmental uncertainties like climate change, extreme temperature, and drought, among others. There was a statistically significant alteration between land-use and Counties and variables such as richness, evenness, Simpson index, plant height, and plant total coverage. Land-use changes on the QTP have affected the plateau's potential vegetation composition and services provision ability. The HG displays satisfactory plant diversity, plant total cover, and height indicators across the three counties. However, the SD, MD and RG grasslands lag in displaying these indicators meaning land-uses affect plant vegetation distribution and composition. Across all land-uses, SD land use was associated with poor vegetation composition. For example, the plant biodiversity indices values were low on the SD grassland compared to other forms of land uses. The average species richness species in the SD grassland was 8, 10 and 5, respectively, for Tiebujia, Maqin and Maduo Counties grasslands. Similarly, restored grasslands accounted for a lower species richness as compared to HG and MD grasslands. The constant biotic and abiotic interventions on the QTP seriously degrade the grasslands while halting the active ecosystem function and plant vegetation distribution on the plateau. The alpine steppe in Maduo County is the most affected grassland type among the three counties studied. Critical mitigation actions to reduce/stop grassland degradation and deterioration of plant composition and vegetation on the plateau should be enforced.

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7. References

Andrade, B.O., Koch, C., Boldrini, I.I., Vélez-Martin, E., Hasenack, H., Hermann, J.M. and Overbeck, G.E. (2015). Grassland degradation and restoration: a conceptual framework of stages and thresholds illustrated by southern Brazilian grasslands. *Natureza & Conservação*, 13(2): 95–104. DOI: https://doi.org/10.1016/j.ncon.2015.08.002.

Bertness, M.D. and Callaway, R. (1994). Positive interactions in communities. *Trends in Ecology and Evolution*, 9-(5): 191–193. DOI: https://doi.org/10.1016/0169-5347(94)90088-4.

Cao, J., Adamowski, J.F., Deo, R.C., Xu, X., Gong, Y. and Feng, Q. (2019). Grassland Degradation on the Qinghai-Tibetan Plateau: Reevaluation of Causative Factors. *Rangeland Ecology & Management*, 72-(6): 988-995. DOI: https://doi.org/10.1016/j.rama.2019.06.001.

Chai, L., Hou, F., Bowatte, S. and Cheng, Y. (2017). Effects of Yak grazing on plant community characteristics of meadow grasslands in the Qinghai-Tibetan Plateau, China. EGU General Assembly Conference 19, 23-28 April 2017, Vienna, Austria, p.3461. Available online at: https://meetingorganizer.copernicus.org/EGU2017/EGU2017-3461.pdf / & https://ui.adsabs.harvard.edu/abs/2017EGUGA.19.3461C/abstract [Accessed on 23 October 2021].

Chen, C., Chen, H.Y.H., Chen, X. and Huang, Z. (2019). Meta-analysis shows positive effects of plant diversity on microbial biomass and respiration. *Nature Communication*, 10: 1332. DOI: https://doi.org/10.1038/s41467-019-09258-y1.

Chen, S., Wang, W., Xu, W., Wang, Y., Wan, H., Chen, D. and Bai, Y. (2018). Plant diversity enhances productivity and soil carbon storage. *Proc. Natl. Acad. Sci. U.S.A.*, 115-(16): 4027–4032. DOI: https://doi.org/10.1073/pnas.1700298114.

Dong, S., Lassoie, J.P., Wen, L., Zhu, L., Li, X., Li, J., and Li, Y. (2012). Degradation of rangeland ecosystems in the developing world: tragedy of breaking coupled human-natural systems. International *Journal of Sustainable Society*, 4-(4): 357–371. Available online at: https://uknowledge.uky.edu/igc [Accessed on 11 November 2021].

Dong, S.K., Shang, Z.H., Gao, J.X. and Boone, R. (2020). Enhancing sustainability of grassland ecosystems through ecological restoration and grazing management in an era of climate change on Qinghai-Tibetan Plateau. *Agriculture Ecosystem & Environment*, 287: 106684. DOI: https://doi.org/10.1016/j.agee.2019.106684.

Dong, S.K., Zhang, J., Li, Y.Y., Liu, S.L., Dong, Q.M., Zhou, H.K., Yeomans, J., Li, S. and Gao, X.X. (2019). Effects of grassland degradation on aggregate-associated soil organic carbon of alpine grassland ecosystems in Qinghai-Tibetan Plateau. *European Journal Soil Science*, 71-(1): 69-79. DOI: https://doi.org/10.1111/ejss.12835.

Fayiah, M., Dong, S., Khomera, S.W., Ur Rehman, S.A., Yang, M. and Xiao, J. (2020). Status and Challenges of Qinghai–Tibet Plateau's Grasslands: An Analysis of Causes, Mitigation Measures, and Way Forward. *Sustainability*, 12(3): 1099. DOI: https://doi.org/10.3390/su12031099.

Fayiah, M., Dong, S.K., Li, Y., Xu, Y., Gao, Li, S., Shen, H., Xiao J., Yang, Y. and Wessel, K. (2019). The relationships between plant diversity, plant cover, plant biomass and soil fertility vary with grassland type on Qinghai-Tibetan Plateau. *Agriculture, Ecosystems and Environment*, 286: 106659. DOI: https://doi.org/10.1016/j.agee.2019.106659.

Fox, J.W. (2003). The long-term relationship between plant diversity and total plant biomass depends on the mechanism maintaining diversity. *Oikos*, 102: 630–640. Available online at: https://www.jstor.org/stable/3547946 [Accessed on 10 October 2021].

Fraser, L.H., Pither, J., Jentsch, A., Sternberg, M., Zobel, M., Askarizadeh, D., Bartha, S., Beierkuhnlein, C., Bennett, J.A. and Bittel, A. (2015). Worldwide evidence of a unimodal relationship between productivity and plant species richness. *Science*, 349: 302–305. DOI: https://doi.org/10.1126/science.aab3916.

Gaines, P., Woodard, C.T. and Carlson, J.R. (1999). An enhancer trap line identifies the Drosophila homolog of the L37a ribosomal protein. *Genetics*, 239: 137-143. DOI: https://doi.org/10.1016/s0378-1119(99)00363-7.

Gao, T., Xu, B., Yang, X., Jin, Y., Ma, H. and Li, J. (2012). Review of research on biomass carbon Stock in grassland ecosystem of Qinghai-Tibetan Plateau. *Progress in Geography*, 31: 1724–1731. DOI: https://doi.org/10.11820/dlkxjz.2012.12.019.

Guo, Q.F. (2008). The diversity-biomass-productivity relationships in grassland management and restoration. Basic. *Applied Ecology*, 8: 199–208. DOI: https://doi.org/10.1016/j.baae.2006.02.005.

Guo, Q. F. and Berry, W.L. (1998). Species richness and biomass: dissection of the humped shaped relationship. *Ecology*, 79: 2555–2559. DOI: https://doi.org/10.1890/0012-9658(1998)079[2555:SRABDO]2.0.CO;2.

Harris, R.B., Wang, W., Badinqiuying, A., Smith, A.T. and Bedunah, D.J. (2015). Herbivory and competition of Tibetan steppe vegetation in winter pasture: effects of livestock exclosure and plateau pika reduction. *Plos One*, 24: 10-(7). DOI: https://doi.org/10.1371/journal.pone.0132897.

Hedberg, O. (1975). Adaptive evolution in a tropical alpine environment. In: Heywood VH ed. Taxonomy and ecology. New York: Academic Press, pp.71–93. Available online at: http://institucional.us.es/revistas/lagascalia/19/Progress%20Hedberg.pdf [Accessed on 20 August 2021].

Kent, M. and Coker, P. (1992). Vegetation description and analysis, a practical approach. *The Geographical Journal*, 159(2): 237. DOI: https://doi.org/10.2307/3451427.

Li, S., Lang, X., Liu, W., Ou, G., Xu, H. and Su, J. (2018). The relationship between species richness and aboveground biomass in a primary *Pinus kesiya* Forest of Yunnan, southwestern China. *PLoS One*, 13(1): e0191140. DOI: https://doi.org/10.1371/journal.pone.0191140.

Li, X., Gao, J., Brierley, G.J., Qiao, Y., Zhang, J., and Yang, Y. (2013). Rangeland Degradation on the Qinghai-Tibet Plateau: Implications for Rehabilitation. *Land Degradation & Development*, 24: 72-80. DOI: https://doi.org/10.1002/ldr.1108.

Li, Y., Wang, S., Jiang, L., Zhang, L., Cui, S., Meng, F., Wang, Q., Li X. and Zhou, Y. (2016). Changes of soil microbial community under different degraded gradients of alpine meadow. *Agriculture, Ecosystems and Environment*, 222: 213–222. DOI: https://doi.org/10.1016/j.agee.2016.02.020.

Li, Y.Y., Dong, S.K., Liu, S.L., Wang, X.X., Wen, L. and Wu Y. (2014). The interaction between poisonous plants and soil quality in response to grassland degradation in the alpine region of the Qinghai-Tibetan Plateau. *Plant Ecology*, 215: 809–819. DOI: https://www.jstor.org/stable/24553769.

Liu, S., Zamanianb, K., Schleussa, P., Zarebanadkoukic, M. and Kuzyakova, Y. (2018). Degradation of Tibetan grasslands Consequences for carbon and nutrient cycles. *Agriculture Ecosystem and Environment*, 252: 93–104. DOI: https://doi.org/10.1016/j.agee.2017.10.011.

Ma, Y.S., Lang, B.N., Li, Q.Y., Shi, J.J and Dong, Q.M. (2002). Study on rehabilitating and rebuilding technologies for degenerated alpine meadow in the Yangtze and Yellow River source region. *Pratacultural Science*, 19-(9): 1-5. DOI: https://doi.org/7697525aaa982a6c81176fb509dce99e37f633.

Maron, J.L., Marler, M., Klironomos, J.N. and Cleveland, C.C. (2011). Soil fungal pathogens and the relationship between plant diversity and productivity. *Ecological Letters*, 14: 36—41. DOI: https://doi.org/10.1111/j.1461-0248.2010.01547.x.

Mipam, T.D., Zhong, L.L., Liu, J.Q., Miehe, G. and Tian, L.M. (2019). Productive Overcompensation of Alpine Meadows in Response to Yak Grazing in the Eastern Qinghai-Tibet Plateau. *Frontiers in Plant Science*, 10: 925. DOI: https://doi.org/10.3389/fpls.2019.00925.

Mu, C.C., Abbott, B.W., Zhao, Q., Su, H., Wang, S.F., Wu, Q.B., Zhang, T.J. and Wu, X.D. (2017). Permafrost collapse shifts alpine tundra to a carbon source but reduces N_2O and CH_4 release on the northern Qinghai-Tibetan Plateau. *Geophysical Research Letters*, 44: 8945-8952. DOI: https://doi.org/10.1002/2017GL074338.

Oba, G., Vetaas, O.R. and Stenseth, N.C. (2001). Relationships between biomass and plant species richness in arid zone grazing lands. *Journal of Applied Ecology*, 38-(4): 836–845. DOI: https://www.jstor.org/stable/827323.

Ren, J.Z. (1998). *Research Methods of Grassland Science*. Beijing: China Agricultural Press [In Chinese]. Available online at: https://www.publish.csiro.au/rj/rj08002 [Accessed on 5 October 2021].

Schleuss, P.M., Heitkamp, F., Sun, Y., Miehe, G., Xu, X. and Kuzyakov, Y. (2015). Nitrogenuptake in an alpine kobresia, pasture on the Tibetan Plateau: localization by 15N labeling and implications for a vulnerable ecosystem. *Ecosystems*, 18: 946-957. DOI: https://doi.org/10.1007/s10021-015-9874-9.

Shannon, C.E. and Wiener, W. (1963). The Mathematical theory of communication. Urbana: University of Juionis Press, p.117. Available online at: https://www.worldcat.org/title/mathematical-theory-of-communication/oclc/13553507 [Accessed 20 August 2022].

Sun, H. (2002). Tethys retreat and Himalayas-Hengduanshan Mountains uplift and their significance on the origin and development of the Sino-Himalayan elements and alpine flora. *Acta Botanica Yunnanica*, 24: 273–288. DOI: https://en.cnki.com.cn/Article_en/CJFDTotal-YOKE200203000.htm.

Sun, H., Niu, Y., Chen, Y. S., Song, B., Liu, C. Q., Peng, D. L., Chen, J. G., and Yang, Y. (2014). Survival and reproduction of plant species in the Qinghai-Tibet Plateau. *Journal of Systematics and Evolution*, 52-(3): 378–396. DOI: https://doi.org/10.1111/jse.12092.

Sun, J., Cheng, G.W. and Li, W.P. (2013). Meta-analysis of relationships between environmental factors and aboveground biomass in the alpine grassland on the Tibetan Plateau. *Biogeosciences*, 10: 1707-1715. DOI: https://doi.org/10.5194/bg-10-1707-2013.

Sun, J., Hou, G., Liu, M., Fu, G., Zhan, T., Zhou, H. and Haregeweyn, N. (2019). Effects of climatic and grazing changes on desertification of alpine grasslands, Northern Tibet. *Ecological Indicators*, 107: 105647. DOI: https://doi.org/10.1016/j.ecolind.2019.105647.

Tang, Z.Y., Wang, Z.H., Zheng, C.Y. and Fang, J.Y. (2006). Biodiversity in China's mountains. *Frontiers in Ecology and Environment*, 4: 347–352. DOI: https://doi.org/10.1890/1540-9295(2006)004[0347:BICM]2.0.CO;2.

Wang, C., Wei, M., Wu, B., Wang, S. and Jiang, K. (2019). Alpine grassland degradation reduced plant species diversity and stability of plant communities in the Northern Tibet Plateau. *Acta Oecologica*, 98- (301): 25–29. DOI: https://doi.org/10.1016/j.actao.2019.05.005.

Wang, G.X. and Cheng, G.D. (2000). Eco-environmental changes and causative analysis in the source regions of the Yangtze and Yellow Rivers, China. *Environmentalist*, 20: 221–232 (In Chinese). DOI: https://doi.org/10.1023/A:1006703831018.

Wang, Q. (2009). Prevention of Tibetan eco-environmental degradation caused by traditional use of biomass. *Renewable and Sustainable Energy Review*, 13: 2562–2570. DOI: https://doi.org/10.1016/j.rser.2009.06.013.

Wang, X., Dong, S., Sherman, R., Liu, Q., Liu, S., Li, Y. and Wu. Y. (2014). A comparison of biodiversity-ecosystem function relationships in alpine grasslands across a degradation gradient on the Qinghai–Tibetan Plateau. *The Rangeland Journal*, 37(1): 45–55. DOI: https://doi.org/10.1071/RJ14081.

Wang, X., Dong, S.K., Gao, Q., Zhou, H., Liu, S., Su, X. and Li, Y. (2013). Effects of short-term and long-term warming on soil nutrients, microbial biomass and enzyme activities in an alpine meadow on the Qinghai-Tibet Plateau of China. *Soil Biology & Biochemistry*, 76: 140-153 DOI: https://doi.org/10.1016/j.soilbio.2014.05.014.

Wang, X., Wiegand, T., Swenson, N.G., Wolf, A.T., Howe, R.W., Hao, Z. and Yuan, Z. (2015). Mechanisms underlying local functional and phylogenetic beta diversity in two temperate forests. *Ecology*, 96-(4): 1062–1073. DOI: https://doi.org/10.1890/14-0392.1.

Weih, M. and Glynn, C. (2019). Willow Short-Rotation Coppice as Model System for Exploring Ecological Theory on Biodiversity–Ecosystem Function. *Diversity*, 11(8): 125. DOI: https://doi.org/10.3390/d11080125.

Wu, Y.H. (2008). The vascular plants and their ecogeographical distribution of the Qinghai-Tibetan Plateau. Beijing: Chinese Corporation for Promotion of Humanities Science Press p.1369 Available online at: https://www.nhbs.com/en/the-vascular-plants-and-their-eco-geographical-distribution-of-the-qinghai-tibetan-plateau-chinese-book [Accessed on 20 August 2021].

Xiong, Q., Xiao, Y., Halmy, M.W., Dakhil, M.A., Liang, P., Liu, C., Zhang, L., Pandey, B., Pan, K., El Kafraway, S.B., and Chen, J. (2019). Monitoring the impact of climate change and human activities on grassland vegetation dynamics in the northeastern Qinghai-Tibet Plateau of China during 2000–2015. *Journal of Arid Land*, 11: 637-651. DOI: https://doi.org/10.1007/s40333-019-0061-2.

Xu, W., Zhu, M., Zhang, Z., Ma, Z., Liu, H., Chen, L., Cao, G., Zhao, X., Schmid, B., and He, J. (2018). Experimentally simulating warmer and wetter climate additively improves rangeland quality on the Tibetan Plateau. *Journal of Applied Ecology*, 55: 1486-1497. DOI: https://doi.org/10.1111/1365-2664.13066.

Yang, H.J., Jiang, L., Li, L.H., Li, A., Wu, M.Y. and Wan, S.Q. (2012). Diversity–dependent stability under mowing and nutrient addition: evidence from a 7–year grassland experiment. *Ecological Letters*, 15: 619–626. DOI: https://doi.org/10.1111/j.1461-0248.2012.01778.x.

Yang, Y., Feng, Z., Liu., D. and Zhang, J. (2006). The Spatial-temporal Change of Grassland in Qinghai-Tibet Plateau, 2006 IEEE International Symposium on Geoscience and Remote Sensing, 2006, pp. 3099-3102. DOI: https://doi.org/10.1109/IGARSS.2006.795.

Zhang, B., Dong, C.X., Li, B.L. and Yao, Y.H. (2002). Biodiversity and conservation in the Tibetan Plateau. *Chinese Geography and Science*, 12: 135–143. DOI: https://doi.org/10.1007/BF02837467.

Zhang, X., Sun, S., Yong, S., Zhou, Z., and Wang, R. (2007). *Vegetation map of the People's Republic of China 1:1 000 000.* Beijing: The Geological Publishing House (GPH). Available online at: http://english.ib.cas.cn/Research/Achievements/200904/t20090403_1447.html [Accessed 25 September 2021].

Zhang, Y., Dong, S., Gao, Q., Ganjurjav, H., Wang, X. and Geng, W. (2019). Rare biosphere plays important roles in regulating soil available nitrogen and plant biomass in alpine grassland ecosystems under climate changes. *Agriculture Ecosystem and Environment*, 279: 187-193. DOI: https://doi.org/10.1016/j.agee.2018.11.025.

Zhang, Y., Gao, Q., Dong, S., Liu, S., Wang, X., Su, X., Li, Y., Tang, L., Wu, X., and Zhao, H. (2015). Effects of grazing and climate warming on plant diversity, productivity and living state in the alpine rangelands and cultivated grasslands of the Qinghai-Tibetan Plateau. *Rangeland Journal*, 37(1): 57-65. DOI: https://doi.org/10.1071/RJ14080.

Zhao, Z., Sandhu, H.S., Ouyang, F. and Ge, F. (2016). Landscape changes have greater effects than climate changes on six insect pests in China. *Science China: Life Sciences*, 59: 627–633. DOI: https://doi.org/10.1007/s11427-015-4918-0.

Zhao, Z., Dong, S., Jiang, X., Liu, S., Ji, H., Li, Y., Han, Y. and Sha, W. (2017). Effects of warming and nitrogen deposition on CH4, CO2 and N2O emissions in alpine grassland ecosystems of the Qinghai-Tibetan Plateau. *Science of the Total Environment*, 592: 565–572. DOI: https://doi.org/10.1016/j.scitotenv.2017.03.082.

Zhu, J., Lin, J. and Yangjian, Z. (2016). Relationships between functional diversity and aboveground biomass production in the Northern Tibetan alpine grasslands. *Science Report*, 6: 34105. DOI: https://doi.org/10.1038/srep34105.

8. Appendices

Appendix 1: Pairwise beta diversity (Whittaker)

Land	*1HG*	*1MD*	*1RG*	*1SD*	*2HG*	*2MD*	*2RG*	*2SD*	*3HG*	*3MD*	*3RG*	*3SD*
1HG	0.00											
1MD	0.28	0.00										
1RG	0.36	0.58	0.00									
1SD	0.36	0.37	0.50	0.00								
2HG	0.67	0.63	0.75	0.67	0.00							
2MD	0.58	0.60	0.85	0.70	0.37	0.00						
2RG	0.53	0.56	0.83	0.67	0.38	0.14	0.00					
2SD	0.55	0.43	0.84	0.68	0.58	0.33	0.27	0.00				
3HG	0.69	0.79	0.77	0.77	0.71	0.78	0.71	0.77	0.00			
3MD	0.71	0.84	0.73	0.73	0.73	0.82	0.73	0.81	0.31	0.00		
3RG	0.79	0.85	0.83	0.74	0.87	0.88	0.87	0.81	0.39	0.38	0.00	
3SD	0.77	0.91	0.80	0.80	0.71	0.74	0.64	0.79	0.67	0.69	0.85	0.00

Appendix 2: Bray-curtis distance between communities

Land	*1HG*	*1MD*	*1RG*	*1SD*	*2HG*	*2MD*	*2RG*	*2SD*	*3HG*	*3MD*	*3RG*	*3SD*
1HG	1.00											
1MD	0.51	1.00										
1RG	0.53	0.29	1.00									
1SD	0.58	0.26	0.49	1.00								
2HG	0.61	0.41	0.86	0.55	1.00							
2MD	0.49	0.20	0.64	0.75	0.53	1.00						
2RG	0.59	0.28	0.63	0.38	0.45	0.43	1.00					
2SD	0.23	0.63	0.16	0.09	0.28	0.17	0.44	1.00				
3HG	0.37	0.21	0.43	0.28	0.51	0.26	0.35	0.08	1.00			
3MD	0.39	0.94	0.67	0.85	0.60	0.38	0.32	0.27	0.52	1.00		
3RG	0.61	0.43	0.78	0.41	0.77	0.14	0.30	0.13	0.59	0.68	1.00	
3SD	0.75	0.30	0.44	0.55	0.35	0.29	0.50	0.50	0.48	0.49	0.18	1.00

Appendix 3: Importance Value Index for plant species

Tiebujia	*Q1*	*Q2*	*Q3*	*QT*	*Dens*	*Freq*	*Abun*	*RD*	*RF*	*RA*	*IVI*
Aster tataricus	143	26		169	56	67	85	6	6	7	19
Astragalus membranaceus	76			76	25	33	76	3	3	6	12
Comastoma pulrnonarium	12			12	4	33	12	0	3	1	5
Dracocephalum heterophyllum	2	75	2	79	26	100	26	3	10	2	15
Elymus nutans		28	62	90	30	67	45	3	6	4	13
Gentiana scabra		19		19	6	33	19	1	3	2	5
Kobresia capillfolia	56	64		120	40	67	60	4	6	5	16
Koleria cristata	27	21		48	16	67	24	2	6	2	10
Lancea tibettica	104			104	35	33	104	4	3	8	15
Leymus secalinus			11	11	4	33	11	0	3	1	5
Poa annua			14	14	5	33	14	1	3	1	5
Poa crymophila	30	244	900	1174	391	100	391	44	10	31	85
Poa pratensis	327	155		482	161	67	241	18	6	19	44
Potentilla bifurca	151		3	154	51	67	77	6	6	6	18
Potentilla multifida	15	13	22	50	17	100	17	2	10	1	13
Radix bupleuri	47			47	16	33	47	2	3	4	9
Radix euphorbiae	2			2	1	33	2	0	3	0	3
Stipa capillata	13	7		20	7	67	10	1	6	1	8
	1005	652	1014	2671	890	1033	1261	100	100	100	300

Appendix 4: Importance Value Index for plant species

Maqin (HG)	*Q1*	*Q2*	*Q3*	*QT*	*Dens*	*Freq*	*Abun*	*RD*	*RF*	*RA*	*IVI*
Aconitum pendulum	12	9		21	7	67	11	1	6	1	8
Ajuga lupulina		22	38	60	20	67	30	3	6	3	12
Carex myosuroides	150	121		271	90	67	136	13	6	15	33
Elymus dahuricus		60		60	20	33	60	3	3	7	12
Elymus nutans	142		79	221	74	67	111	10	6	12	28
Koleria cristata	4	8	246	258	86	100	86	12	9	10	30
Ligularia virgaurea	4			4	1	33	4	0	3	0	3
Oxytropis falcatabunge	57	56	29	142	47	100	47	7	9	5	20
Pedicularis alaschanica		25		25	8	33	25	1	3	3	7
Plantago depressa	4	10	175	189	63	100	63	9	9	7	24
Poa annua	12	7	50	69	23	100	23	3	9	3	14
Poa crymophila	227	226	34	487	162	100	162	23	9	18	49
Potentilla multifida	134	117	18	269	90	100	90	12	9	10	31

Maqin (HG)	*Q1*	*Q2*	*Q3*	*QT*	*Dens*	*Freq*	*Abun*	*RD*	*RF*	*RA*	*IVI*
Silene himalayensis	22	3		25	8	67	13	1	6	1	8
Taraxacum mongolicum	6	14	16	36	12	100	12	2	9	1	12
Thermopsis alpina			22	22	7	33	22	1	3	2	6
Total	774	678	707	2159	720	1167	893	100	100	100	300

Appendix 5: Importance Value Index for plant species

Maduo	*Q1*	*Q2*	*Q3*	*QT*	*Dens*	*Freq*	*Abun*	*RD*	*RF*	*RA*	*IVI*
Artemisia capillaries	48	26	22	96	32	100	32	5	9	4	19
Aster tataricus	7			7	2	33	7	0	3	1	4
Carex myosuroides	22	19		41	14	67	21	2	6	3	11
Gentiana spuarrosa	5	12		17	6	67	9	1	6	1	8
Koleria cristata	17	37		54	18	67	27	3	6	4	13
Leontopodium nanum	166	292	190	648	216	100	216	35	9	30	75
Oxytropis falcatabunge	27	36	19	82	27	100	27	4	9	4	18
Poa annua		62	7	69	23	67	35	4	6	5	15
Poa crymophila	42	85	161	288	96	100	96	16	9	13	38
Polygonum sibiricum	4		205	209	70	67	105	11	6	15	32
Potentilla multifida			19	19	6	33	19	1	3	3	7
Przewalskia tangutica	23	56		79	26	67	40	4	6	6	16
Stipa capillata	71	47	62	180	60	100	60	10	9	8	28
Thalictrum aquilegifolium	23	23	16	62	21	100	21	3	9	3	16
Total	455	695	701		617	1067	713	100	100	100	300

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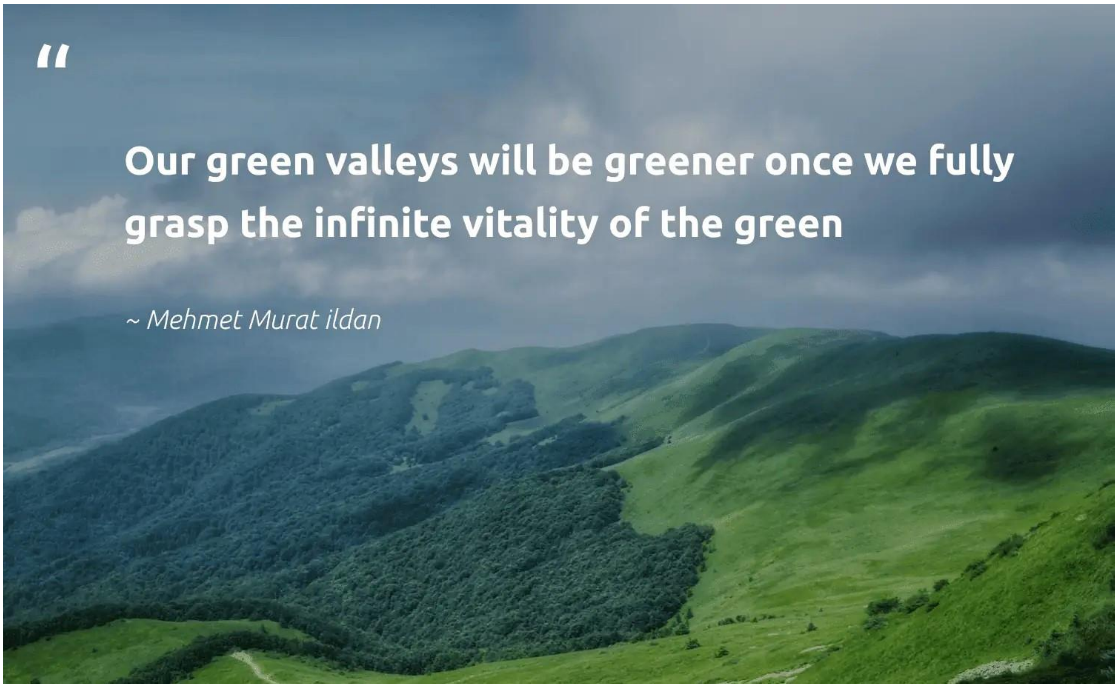
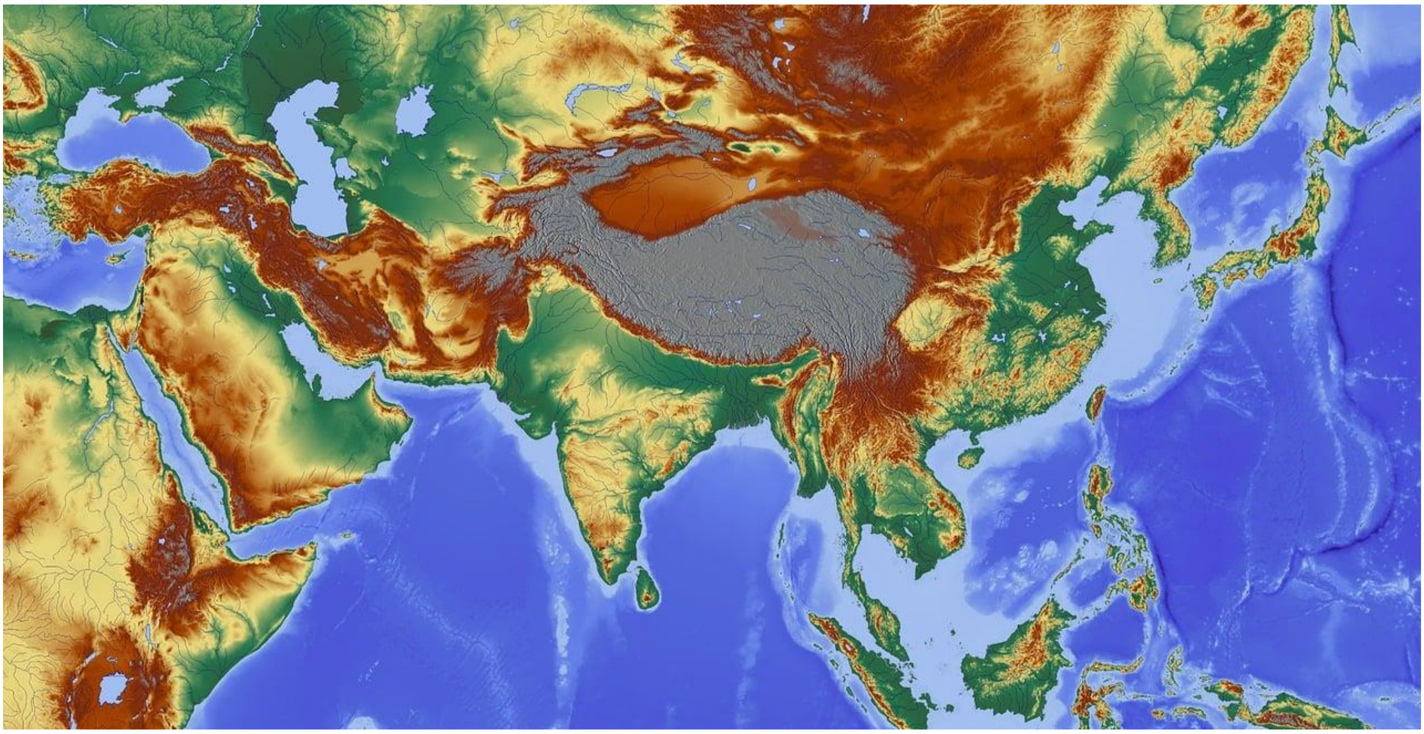

"
Our green valleys will be greener once we fully grasp the infinite vitality of the green
~ Mehmet Murat ildan

Chapter 7

Understanding the Nexus of Climate Change and Migration: A Case of Dhye Peoples from Upper Mustang, Nepal

By Pragya Sherchan



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Understanding the Nexus of Climate Change and Migration: A Case of Dhye Peoples from Upper Mustang, Nepal

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Abstract

People of Dhye village are recognized as the Nepal's first climate refugees. Historical records show that mass migration of people from Dhye village has occurred for three times, with latest one attributed to the climate change. This article aims to explore and understand the underlying causes of the Dhye people's migration, and to analyze the land suitability for their relocation. The article discusses that people of Dhye have migrated mainly to look for livelihood options, water availability and land for cultivation. As of now, more than two dozen water ponds have dried completely, and the only community reservoir serves as main source of irrigation water. This led to a decrease in cultivated area by one-fourth within last 40 years. The livestock farming has also been decreasing year by year with only one yak herder left in the entire Dhye village. The temperature trend is positive, whereas precipitation trend is negative. The land suitability analysis done by using Multi-Criteria Decision Analysis (MCDA) shows that Thangchung Chawale village is more suitable location than Dhye village in terms of cultivation area, water availability, and distance to health-post and transportation facilities.

Keywords

Climate change; Land suitability; Dhye; Climate refugee

Citation

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1. Introduction

The high-altitude cold deserts of greater Himalayan region or Trans-Himalayan region are among the most vulnerable ecosystems to climatic changes (Christensen and Heilmann, 2009; Sharma and Tshering, 2009). According to IPCC (2007), the adverse effects of changing weather patterns and climate have extended beyond crop cultivation and, thus, influence livelihoods of people. Mustang is an ancient isolated kingdom located in the Trans-Himalaya region of north-western Nepal with very low population density and arid cold climate. The region hosts a range of human societies whose main source of livelihood is livestock farming and agriculture. Like other high mountains, Mustang also represents fragile ecosystem, and inhabitant communities try to balance their livelihood with available resources. Mustang is divided into two regions: Upper Mustang and Lower Mustang. Lo-pa (Upper Mustang) falls under rain-shadow zone of Nepal. Upper Mustang is also known for its severe winter and is one of the coldest regions of Nepal, as the temperature drops down to -20^{o} to -30^{o} Celsius in winter. In summer, the temperature remains between 0º C to 10º C (Dhungel, 2002). Life and livelihood in many mountain settlements in Nepal are under stress from desertification, drought and water scarcity (Shrestha, 2016).

Human migration is not a new phenomenon occurring due mainly to the poverty and environmental shocks. There are many pulling and pushing factors for human displacement. The migration decision is taken by families and households rather than the individuals alone, to maximize expected earnings and reduce the risk of consumption failure by diversifying income sources across sectors or agro-zones (Jha *et al.*, 2018). Scheffran, Marmer and Snow (2012) expressed that the human migration is not only a response to poverty and social deprivation, but it is also an adaptive response to changing climate. The communities from some of the Trans-Himalayan settlements such as Dhye, Samjong and Yara have expressed their sufferings owing to water scarcity, particularly during the dry season. These three communities are situated in the upper Mustang area of Mustang district. Reportedly, communities from Dhye (4000 masl) are ready to move to Thangchung Chawale (3500 masl), located north-west at the bank of Dhye Khola tributary that later joins the Kali Gandaki river. They had migrated from Nakkali-Damodarkunda to Zhong, and to Dhye (Devkota, 2013).

2. Study Area

Mustang district is one of the 77 districts of Nepal. Mustang district lies on Dhaulagiri Zone of Western Development Region of Nepal, which is divided into two regions: lower Mustang and upper Mustang. The headquarter is Jomsom, which covers an area of 3,573 km^2 and has population of 13,452 (2011). Dhye village is from Lo-pa (Upper Mustang), lies in Lo-Ghekar Damodarkunda Rural Municipality of ward no. 5. This village is located at 29º2'30" North and 083º5' 92" East and lies at 3860 masl (Figure 1). It consists of 26 households with a population of 163 people. Due to low access to water, they grow wheat, naked barley and maize that need little water. They practice animal husbandry, mostly mountain goat, sheep, and high-altitude cattle like yak. The yak has thick fur and can withstand severe cold and drought because it can thrive on thorny plants (Shrestha, 2016). The climate varies from alpine to tundra type where temperature ranges from 10°C to 26°C, and annual mean precipitation ranges from 3.25 ml to 13 ml (LAPA, 2016).

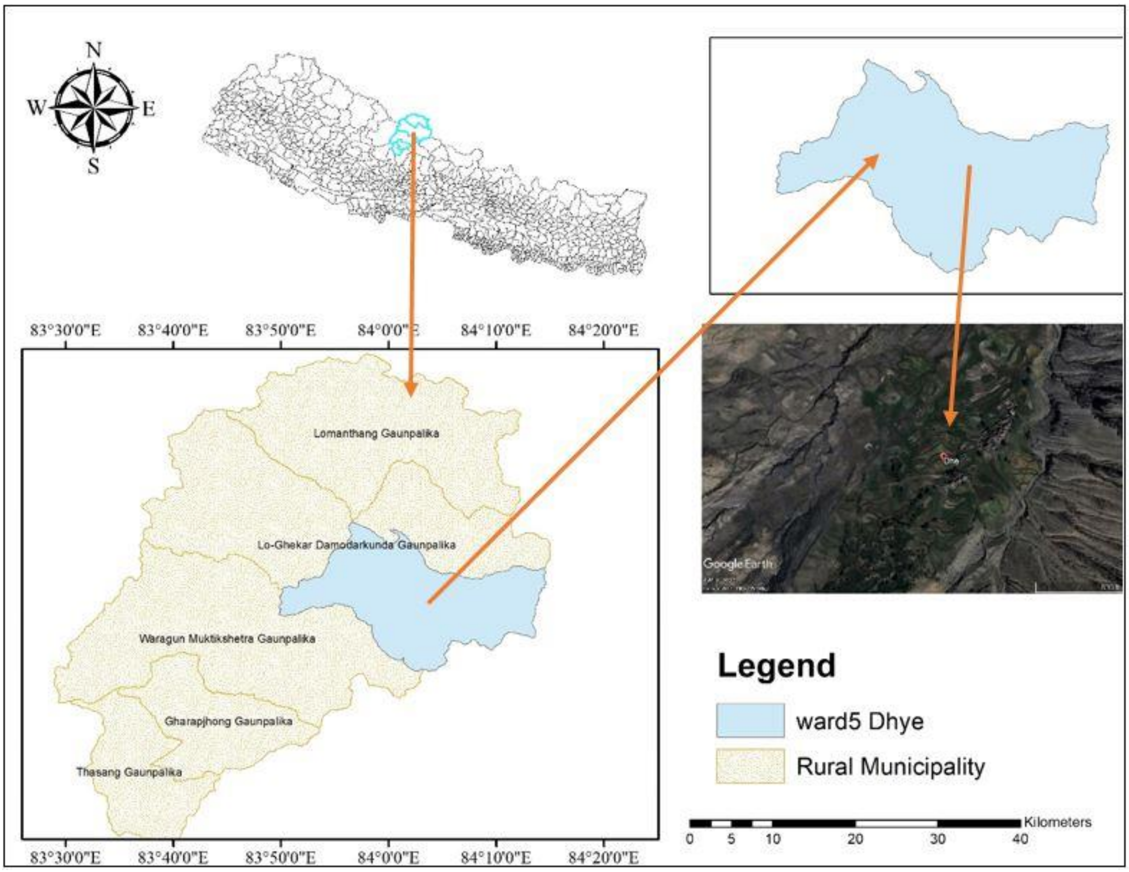


Figure 1: Map of Study Area (*Source:* Nepal Department of Survey, 2017)

3. Materials and Methods

The present chapter is based on the study relying on both primary and secondary data sources. Field data was collected in October 2018 covering both qualitative and quantitative techniques.

The household survey was conducted to gather basic information on socio-economic status, possible causes of migrations in different places, people's perception on climate change and natural hazard ranking. Only 23 household were present at the site, so the respondents were purposively selected. The semi-structured questionnaires were used to collect quality information. Similarly, KII (Key Informant Interview) was used to find in-depth information from 5 key persons: representatives of Lo-Ghekar Damodarkunda Rural Municipality, Annapurna Conservation Area, Mukhiya, chairman of club and chairman of resettlement committee. Field observation of all the migratory sites was also done for the validation of the household survey's information. The secondary data were collected from Department of Hydrology and Meteorology (DHM), District Agriculture Development Office (DADO) and Central Bureau of Statistics. The MS Excel, Mann Kendall Correlation (SPSS), GPS and Google Earth Pro were used to analyze data. The Digital Elevation Model (DEM) of 30×30 resolution was extracted from SRTM (Shuttle Radar Topography Mission) and the study area layer was digitized from Geo-Eye Satellite image from Google Earth Pro. The land use and soil data were collected from Department of Irrigation. River data and transportations data were collected from Survey Department of Nepal. The land suitability criteria such as agriculture, soil erosion, flood and livelihood were extracted from the possible causes of migration in different migratory sites and from the natural hazard ranking. For the hazard ranking, at an initial step, all the hazards that occurred in Dhye and Thangchung Chawale were listed by involving the villagers. In the second step, each of the listed hazards was compared in pairs and the hazards that had more impact on the villagers were noted. Finally, all the noted hazards were counted, and highest number scored hazard was ranked as 1st and then 2nd, 3rd and so on. Higher the number scored higher is the rank.

All the methods were conducted for comparison between two sites – Dhye and Thangchung Chawale – designated for resettlement. Then the criteria were divided into sub-criteria as required and respective data were collected from different data sources as shown in Figure 2. After acquiring data, an analysis was done using ArcGIS and thematic maps produced for criteria and sub-criteria. The thematic maps were reclassified into suitable, moderately suitable and unsuitable to prepare thematic land suitability map. Thereafter, a comparison between all the criteria and sub-criteria was done in pairs using MCDA and score was given from -1 to +1. The high scoring site was concluded as more suitable land for resettlement.

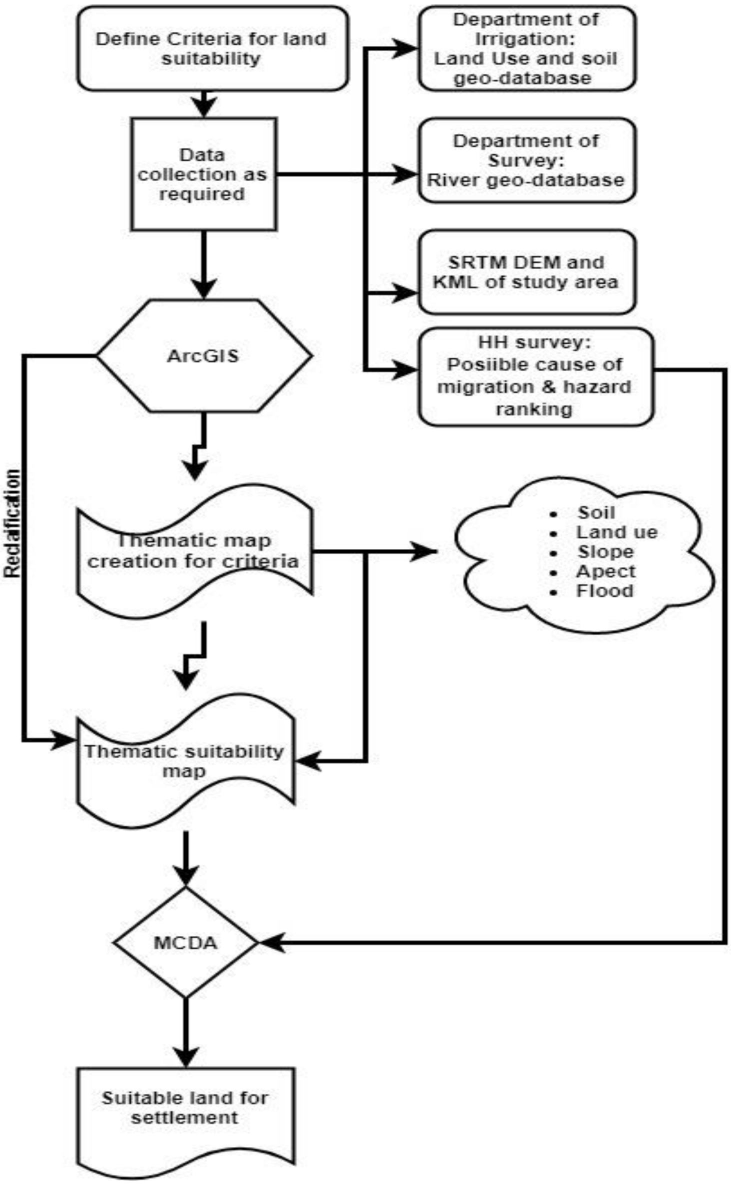


Figure 2: Procedure for land suitability analysis

4. Results

4.1 Demography

There are 26 households with a population size of 163 people (88 male and 75 female) in Dhye village (study area). All the villagers were of same clan "Gurung" and follow Buddhism religion. The education status of the male population was higher than that of the females and most of the villagers have obtained primary education. Their main occupation was agriculture and livestock farming. They cultivate barley, naked barley, potato, radish, spinach, cabbage, cauliflower, mustard, apple, peach, apricot, etc.

4.2 Migration Pattern

In the history, the people of Dhye have migrated from Ghayu/ Ghayul at about 5000 masl. Ghayu is the local name. "Gha" means mountain, and "yul" means village; a village at the base of mountain. Ghayul is located at the base of Bhrikuti mountain and is also known as "Nakkali Damodarkunda". Nowadays, it is also known as "Ghayu kharka", a name given by Sherpa guide as it is a trekking trail for Damodarkunda (religious Lake) and for Nilgiri summit. Even today, one can see the remnants of a settlement, cultivated land and irrigation cannels at Ghayu.

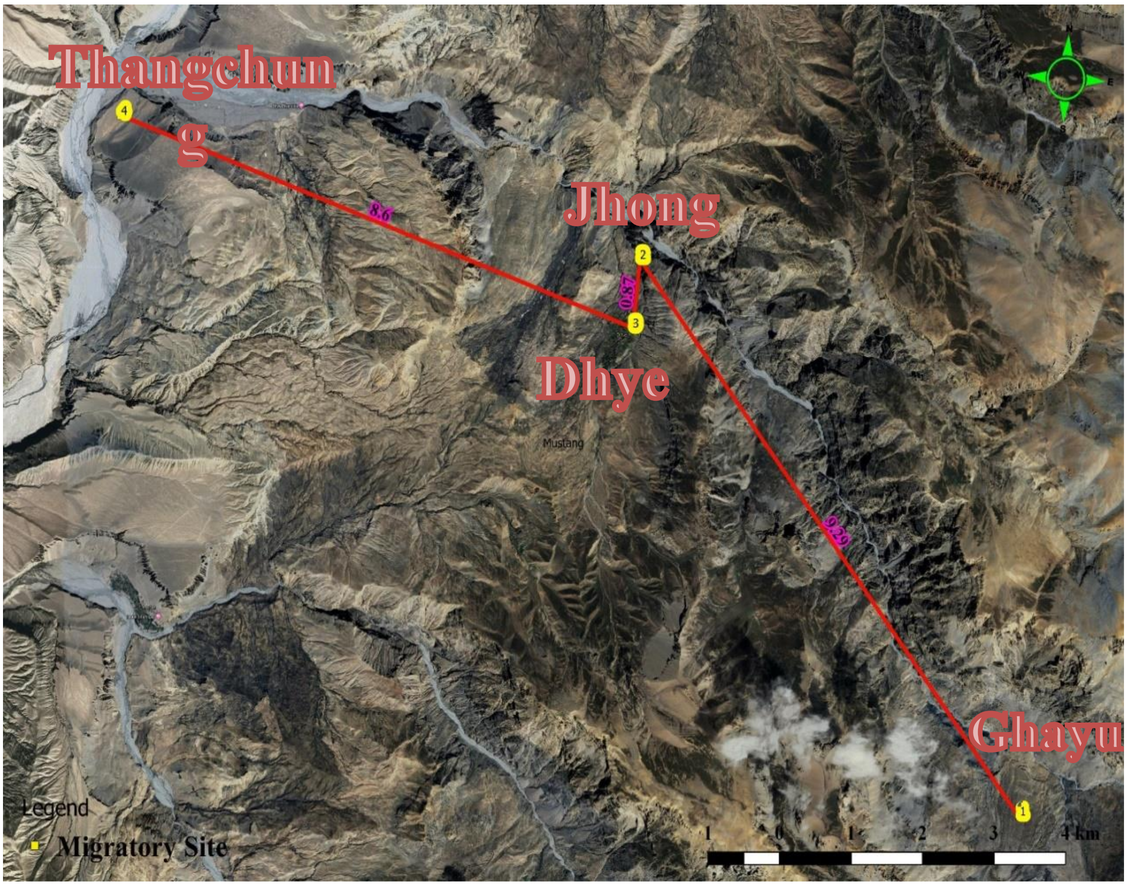


Figure 3: Different migratory sites of Dhye people (*Source:* USGS, Geo-Eye Satellite image)

From Ghayu they had migrated to Jhong, located at about 3800 masl. Jhong is also the local name that means "cave". It is at a walking distance of about 0.87 km from Dhye village downhill. From Jhong, they had migrated to Dhye village, their current place of living located at about 4000 masl (refer Figure 3). It is a beautiful place. Dhye seems to be the only place where human settlement was possible among these three villages. Causes of migration of these people are highlighted in the table 1.

Table 1: Possible causes for migration in different places and their livelihood options

S.N.	*Place name (migrated from)*	*Approximate time (years before)*	*Distance from Dhye*	*Livelihood options*	*Reasons for migration (from/to)*
1.	Ghayu to Jhong	Approximately 500-1000 years back	9.29 km	Livestock cultivation and hunting	Soil erosion, weather, deficient agricultural land, no irrigation due to soil erosion, avalanche and safety
2.	Jhong to Dhye		0.87 km	Livestock and cultivation	Enough agricultural land, water availability, enough irrigation, and pasture land
3.	Dhyey to Thangchung Chawale	350 to 400 years	8.6 km	Livestock and cultivation	Decrease in agricultural production due to drought, deficiency of water, lack of health facilities, inadequate education

4.3 Occupation

The major occupation or source of livelihood of the people of Dhye village is agriculture, livestock, hotel and government jobs. There is now change in number of people having livestock, which is shown in the figure below:

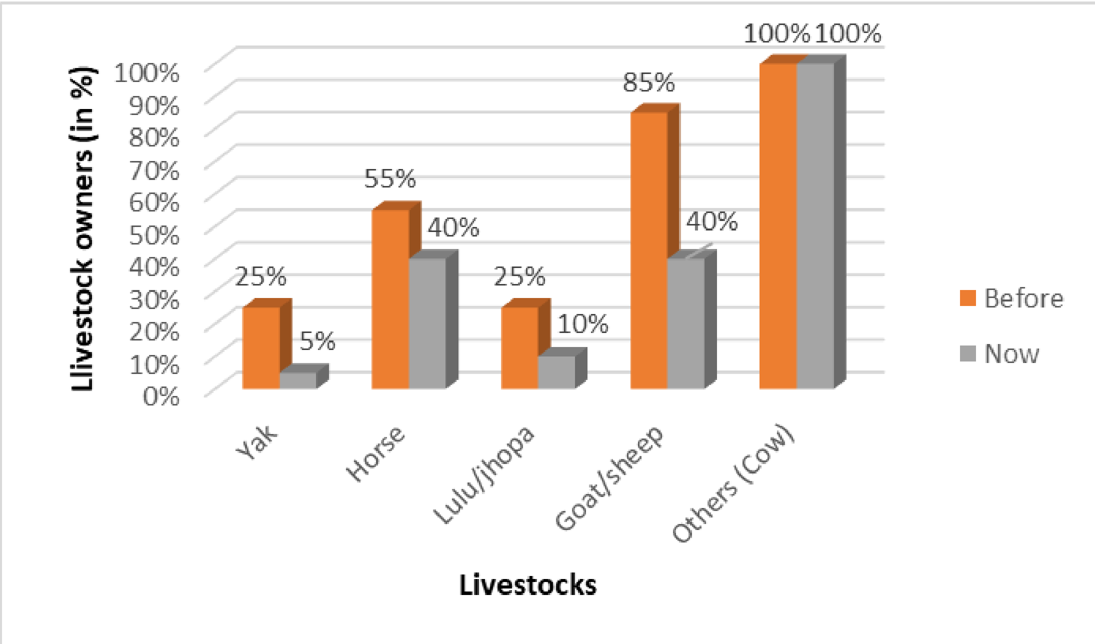


Figure 4: Change in number of people having livestock

25% of the respondents were raising yak before, but yak raising decreased to 5%, i.e. only one person is rearing yak in the whole village. Mr. Kunsang Rinzin Gurung is the last yak herder of the Dhye village. Similarly, there is decrease in all the livestock except cow, i.e. 100% respondents. The horse rearing has decreased from 55% to 40%. Similarly, 25% to

10% and 85% to 40% decrease in lulu/jhopa[1] and goat/sheep, respectively, due to the degrading grazing lands (Figure 4).

4.4 Changes in Climate

The maximum number of respondents, i.e.18, said that there is change in temperature. The temperature has been increasing over past few decades. 100% respondents said that there is change in time, duration and intensity of rainfall and snow fall. There is change in amount, intensity and time of precipitation, which ultimately affected the agricultural practices and condition of pasture lands. Hailstorm does not occur in the study area. 11 respondents said that there was change in wind speed and time, whereas 5 respondents negated, and 4 respondents affirmed the same answer (Figure 5).

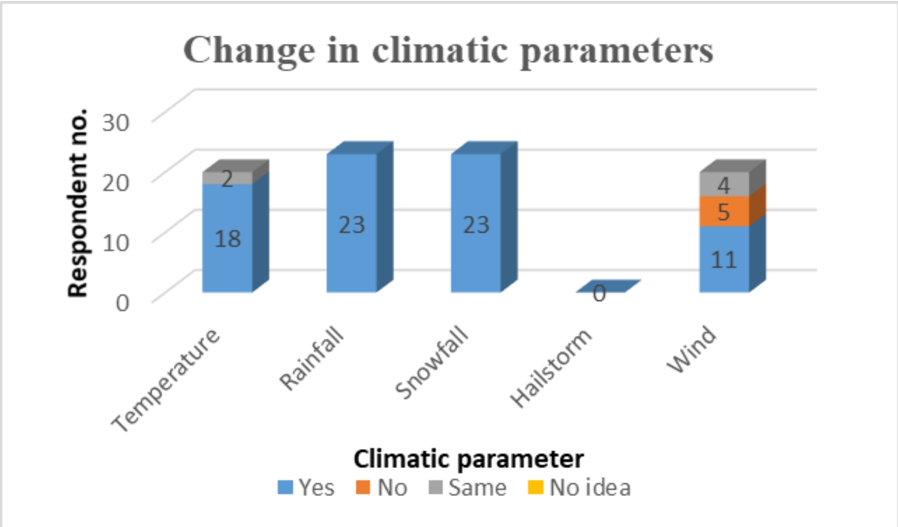
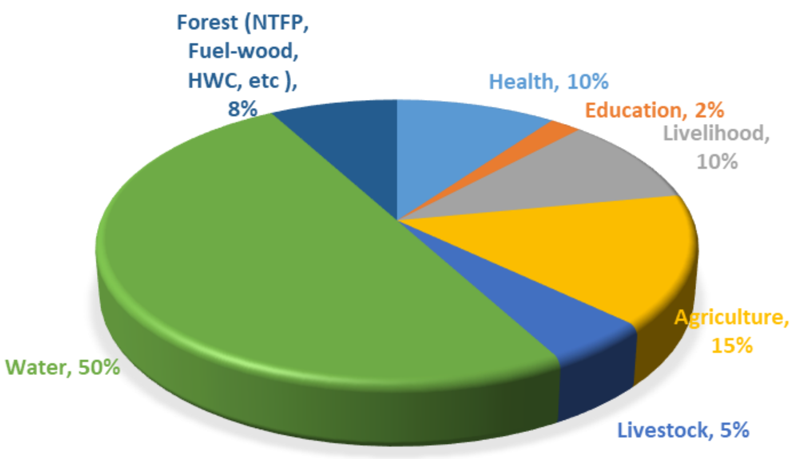


Figure 5: Change in climatic parameters

The water is the most affected sector (50%) as a consequence of climatic variations. It is followed by agriculture, health and livelihood, forest, livestock and education sectors (Figure 6).

Figure 6: Different sectors affected due to change in climatic parameters



[1] Cross breed of yak and cow

Narration in Table 2 highlights problems caused by climate change and some suggested options.

Table 2: Major problems and their adaptation options for different sectors

S.N.	*Different sectors*	*Major problems*	*Adapting options*
1.	Health	No health facilities, lack of awareness about health and sanitation	Amchi practices[2], salt tea for water contain in body
2.	Education	School is closed due to lack of students and teacher	Children are sent to lower regions (Jomsom, Tsarang), Pokhara, Kathmandu, India for education facility
3.	Livelihood	Less cultivating practices, insufficient water for irrigation and drinking, not enough fuel sources, insufficient pasture lands, decrease in livestock numbers, no transportation facilities	Solar lights and mill, water mill, improved cooking stove, tap water, new variety and hybrid seed of crops and vegetables, migration
4.	Agriculture	Insufficient water for irrigation, drought	Use of new species, use of improved variety of crops, rotational irrigation, greenhouse and stopped cultivating land
5.	Livestock	Insufficient pasture land	Stopped raising livestock, practicing cultivating green vegetables
6.	Water	Water sources (springs and ponds) are drying up	Artificial pond reservoir, rotational irrigation, plantation of bhotepipal (*Populus ciliate*) and bains (*Salix folia*)
7.	Forest (NTFP[3], fuelwood, HWC[4], etc.)	not enough forest, very far from settlement, not enough grazing land, jimbu (*Allium hypsistum*) (NTFP) has been extinct	Improved cooking stove, use of cow, goat and yak dung as a fuel, use of gas stove, plantation of bhotepipal (*Populus ciliate*) and bains (*Salix folia*)

[2] In general, amchi medical practice is also identified by the name sowa rigpa, which means "science of healing" in classical Tibetan as well as in regional Himalayan and Central Asian languages and dialects. The word amchi means "doctor". This system of medicine is a spiritual practice, a science, and an art that dates back thousands of years. Aspects of this medicine system were transmitted from India to Tibet between the 7th and 12th centuries, during the first and second dissemination of Buddhism. This system combines the profound work of Sangye Menla, the Medicine Buddha, with indigenous Tibetan traditions such as Bön, and was shaped into sowa rigpa as it is known today (Source: http://www.drokpa.org/amchi.html).

[3] Non-Timber Forest Products

[4] Human Wildlife Conflict

4.5 Types of Crops Cultivated in Dhye-Chawale

The major crops are wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), pea (*Pisum sativum*), buckwheat (*Fagopyrum esculentum*), mustard (*Brassica compestris*), potato (*Solanum tuberosum*), spinach (*Spinacia oleracea*), cauliflower (*Brassica oleracea* var. botrytis), cabbage (*Brassica oleracea* var. capitata), apple (*Malus domestica*), etc. Fruits cultivation was not practiced earlier. However, of late, they have started cultivating fruits, mostly apple. In the year 2011, they formed a cooperative organization called "Dhye Thangjung Agricultural Cooperative Organization" with a mandate to develop fruits cultivation for sustenance. They have used 132 hectares of government land at Chawale and started plantation of 8000 apple plants, 200 walnut (Juglans regia), 200 apricot (Prunus armeniaca) and 200 peach (*Prunus persica*) plants. It has been 8 years now, and they have started harvesting apples, apricot and peach to earn revenue. Walnut has not started fruiting yet.

According to the District Agricultural Development Office, apple can be cultivated on elevation ranging from 2000 to 3000 masl. However, now apples are also being grown above this altitude range. Chawale is at about 3500 masl and these people are cultivating and harvesting apples since 2015. The people of Dhye can only cultivate crops once a year, which is not enough for them to survive round the year. According to the villagers, they are cultivating cereals every year; however, within the last 30 to 40 years almost 75% of the land is left uncultivated due to water scarcity for irrigation. The Upper Mustang people had started cultivating green vegetables after the Care Nepal trained them 30 years ago. It is said that the Lo people used to have meats and cereals they grew. But now it has changed, and they are cultivating green vegetables.

4.6 Status of Water Sources

In the study area, five water sources were spotted: Napromo, Puchhumi, Phungmukere and Hyulu for irrigation purpose and Nhamo for drinking purpose. Figure 7 shows that most of the respondents said that the condition of water sources has been decreasing everywhere except Nhamo (Figure 7). These water sources used to be more than 2 dozen private and community ponds. Nowadays, due to the decreased water volume, the villagers are collecting water in only one artificial pond for irrigation (red area). It is a matter of concern that these water sources completely dry up during the winter season. There are two water taps constructed by Care Nepal in the village; they run for just six months. During

Picture 1: Only remaining artificial community pond

rest six months (from October to March) they run completely dry. Similarly, the artificial ponds also get dried up for three months (from November to January).

It was learnt that the condition of the pasture lands used to be very good earlier. However, with the passage of time, due to erratic rainfall, snowfall, and seasonal changes in terms of intensity and duration, the pasture lands have been degrading by years. The following table represents the pasture land conditions based on the responses from the respondents.

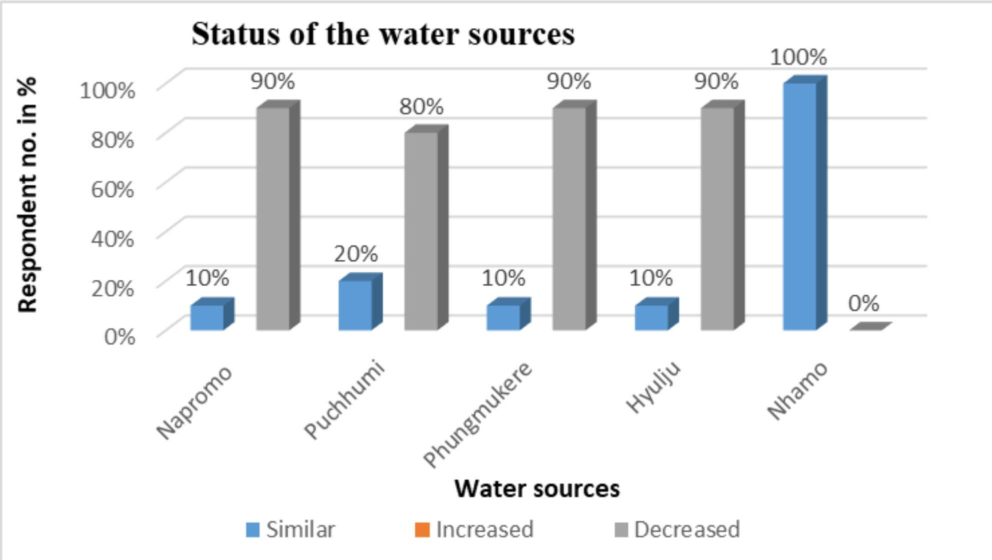


Figure 7: Status of water sources of Dhye village

Table 3: Status of the pasture lands

S.N.	*Name of pasture land*	*Pasture land condition*		*Remarks*
		Before	*Now*	
1.	Ghayu	Very good	Good	Pasture lands are degrading due to the decrease in rainfall and changes in snowfall pattern and time (unseasonal)
2.	Ghoma	Very good	Very bad	
3.	Kya	Very good	Good	
4.	Jhotang	Very good	Good	
5.	Nihmalokchu	Very good	Good	
6.	Tsathang	Very good	Good	
7.	Nakti	Excellent	Very good	
8.	Chawale	Excellent	Very good	
9.	Ghomar	Very good	Good	
10.	Kripchyu	Very good	Good	
11.	Thotang	Excellent	Good	

4.7 Mann Kendall Correlation Coefficient (Tau-b test) for Climate Data Analysis

Data in Table 4 shows that there is significant relationship between maximum temperature (Tmax) and mean temperature with year 1988-2017. As the significant p values for Tmax and mean temperature (0.02 and 0.03) are less than 0.05, the correlation is significant at the 0.05 level. Along with that, there is positive correlation between them, as the correlation coefficient is same i.e. 0.29 for both. There is no significant relationship between minimum temperature (Tmin) and year 1988-2017. As the significant p value for Tmin 0.36 is greater than 0.05, there is positive correlation between them, as the correlation coefficient is 0.12.

Table 4: Mann Kendall Correlation between Year (1988-2017) and Temperature, Jomsom

Variables	*Correlation coefficient (r) value*	*Significance (p) value*
Tmax and year	0.29	0.02
Tmin and year	0.12	0.36
Mean Temp	0.29	0.03

Table 5: Mann Kendall Correlation between Year (1988-2017) and Precipitation

Variables	*Correlation coefficient (r) value*	*Significance (p) value*
Mean ppt and year (Jomsom, year (1988-2017)	0.337	0.009
Mean ppt and year (Ghami, year (1983-2012)	-0.190	0.155

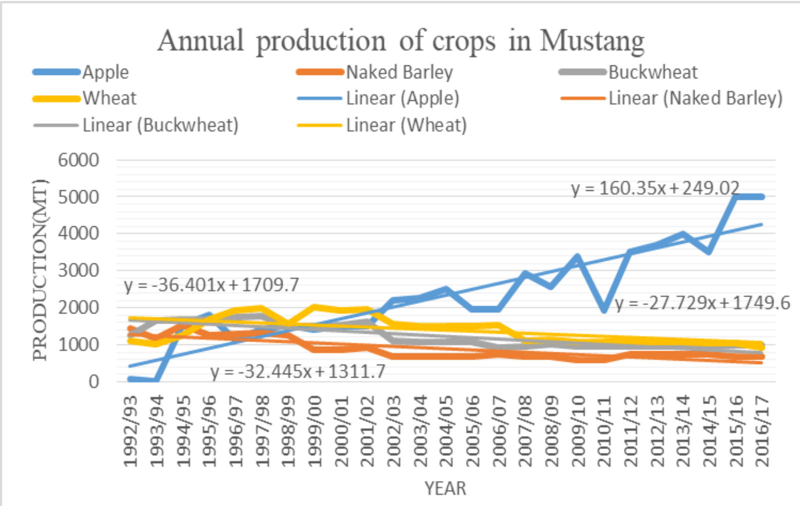


Figure 8: Crops production trend in Mustang

Table 5 shows that here is significant relationship between mean precipitation and year (1988-2017) for Jomsom. As the significant p value for mean precipitation is 0.009, which is less than 0.01. Hence, the correlation is significant at the 0.01 level. Along with that, there is positive correlation between them, as the correlation coefficient is 0.337. There is no significant relationship between mean precipitation and year (1983-2012) for Ghami. As the significant p value 0.155 is greater than 0.05, there is negative correlation between them, as the correlation coefficient is -0.190.

4.8 Crops Production and Population Trend Analysis

The Figure 8 depicts the production trend of all the crops such as naked barley, buckwheat and wheat. It is in decreasing trend. The production trend of apple is dramatically increased (160.35 mt/year). The drastic change is seen after year 1993/94.

The population census is only available for five decades from 1971 to 2011 for study area and for Mustang district. The Figure 9 shows decreasing population trend for both Mustang district as well as for Surkhang. It seems that the present population of Mustang is half of the population number of 1971. Similarly, the population of Surkhang is less than 1/4th population of 1971.

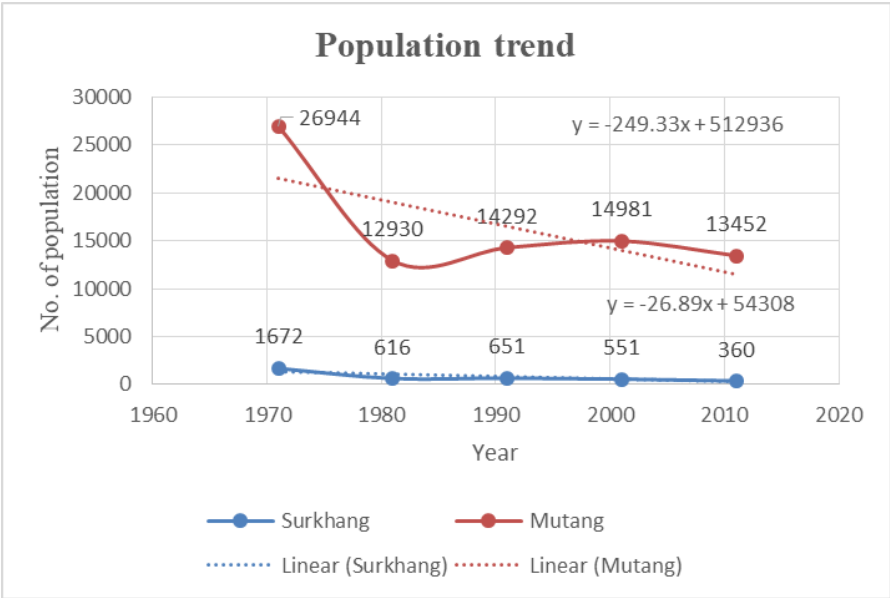


Figure 9: Population trend analysis

4.9 Land Suitability Analysis for Thangchung Chawale and Dhye

The Figure 10 exhibits that there is only one type of soil class for both the settlements i.e., Aridosol, which is a soil of arid climate and is common in the desert regions. They often have accumulations of lime ($CaCO_3$), sodium or salts. Water deficiency is the dominant

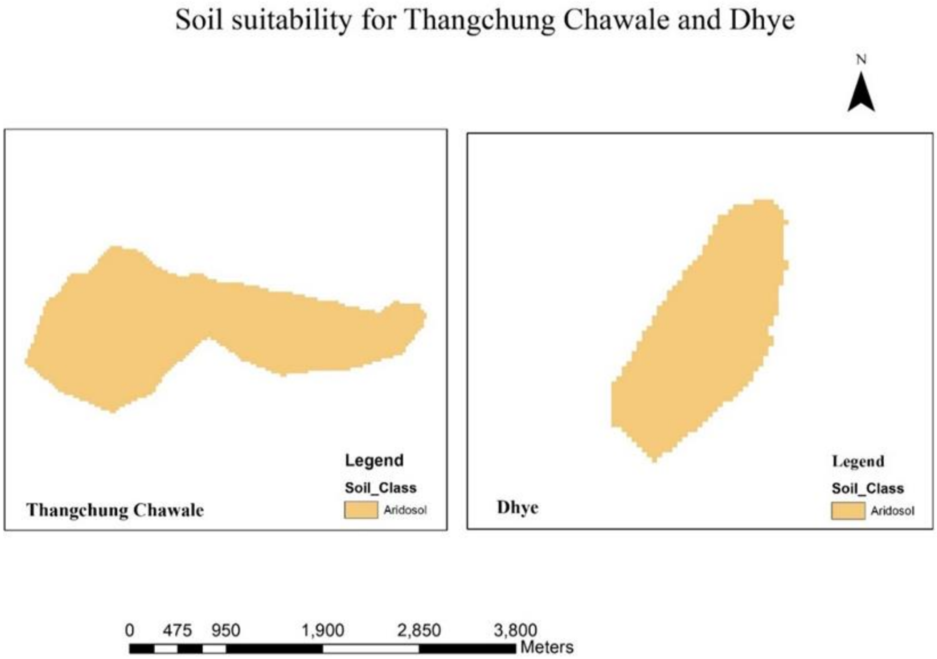


Figure 10: Land suitability maps for soil

characteristics of Aridosol. Productivity of Aridosol is generally low and there is potential for land degradation due to overgrazing by livestock (Ruben, Garcia and Frankentein, 2015).

But if the irrigation is made available then they can be made productive through the use of fertilizers and proper management practices. The Figure 11 exhibits land use suitability for agriculture, which is classified into 3 classes as highly suitable, moderately suitable and not suitable. The result shows that at the resettlement area, i.e., Thangchung Chawale, 106.21 ha area is moderately suitable (barren land) and 225.81 ha area is unsuitable (sand, gravel and boulders). In the Dhye village, 15.84 ha area is suitable (agriculture valley) and 72.99 ha area is moderately suitable (shrub land/grassland and barren land).

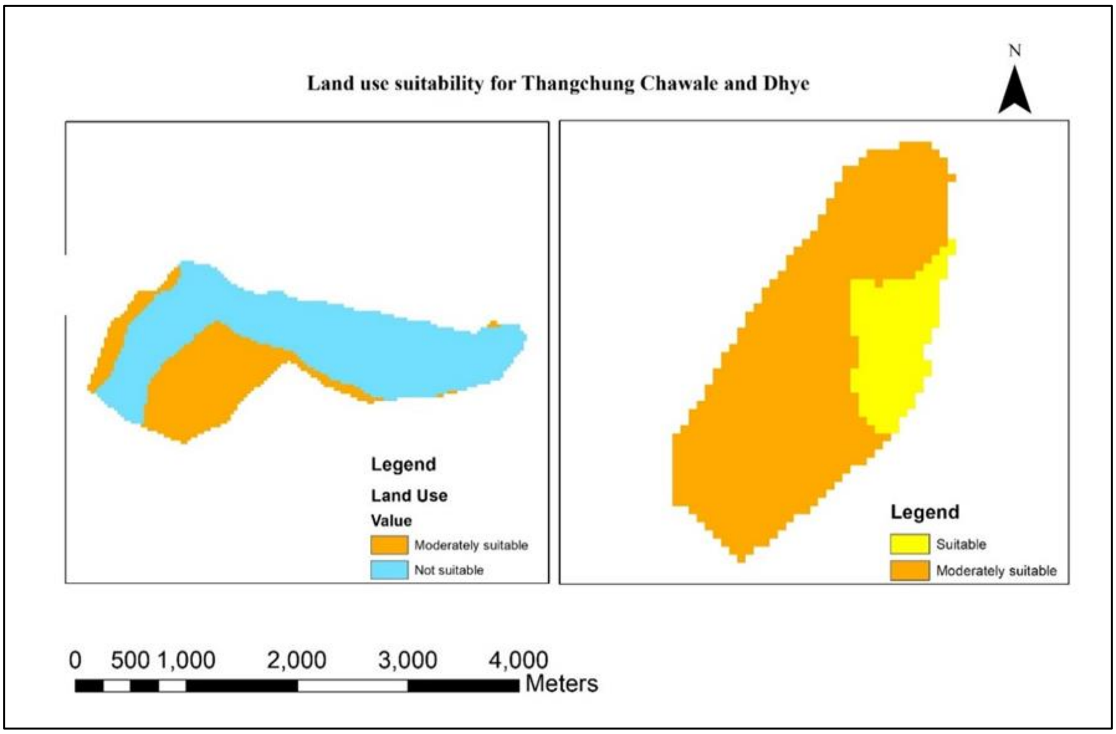


Figure 11: Land suitability maps for land use

The Figure 12 illustrates land suitability for slope, which was calculated according to the guideline of FAO into 7 slope classes in percent. In the resettlement area, 110.7 ha area of land is suitable that includes flat and gently sloping relief. Similarly, 168.21 ha and 38.7 ha area are moderately suitable (includes sloping and hilly relief) and unsuitable (includes mountainous to very steep mountainous relief), respectively. On the other hand, in Dhye, 14.31 ha is suitable, and 64.17 ha and 10.35 ha area are moderately suitable and unsuitable, respectively.

The Figure 13 exhibits that entire area of both the resettlement sites has soil erosion hazard, which is severe due to their geographical location and climate.

The Figure 14 exhibits that, in the Thangchung Chawale, 54.63 ha area is suitable, and 178.92 ha and 98.46 ha area are moderately suitable and unsuitable, respectively. Contrarily, only 52.47 ha area is suitable, and 29.7 ha and 6.66 ha area are moderately suitable and unsuitable, respectively, in Dhye.

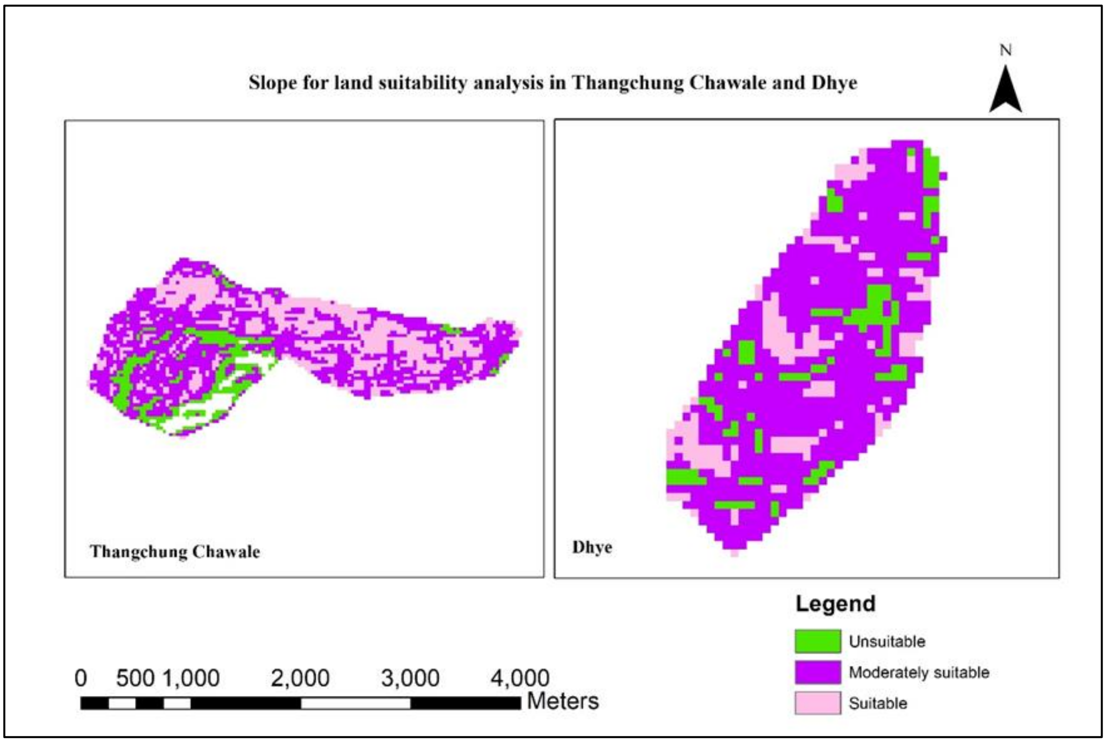


Figure 12: Land Suitability maps for Slope

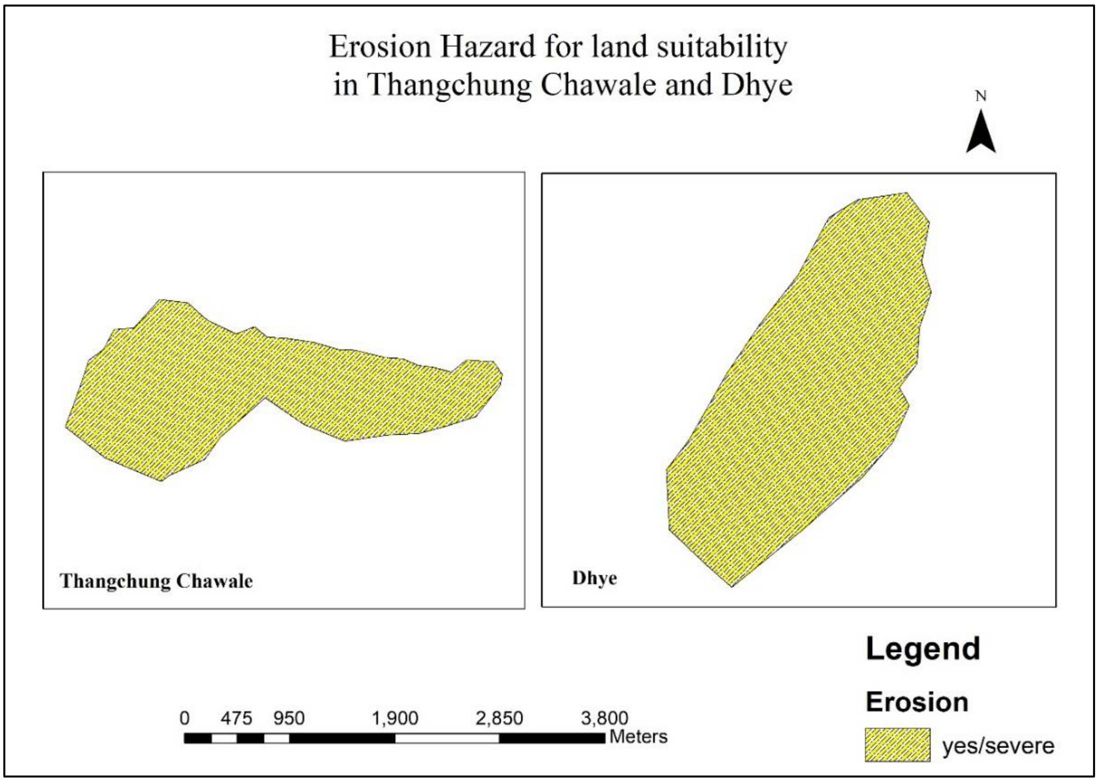


Figure 13: Land Suitability maps for Erosion

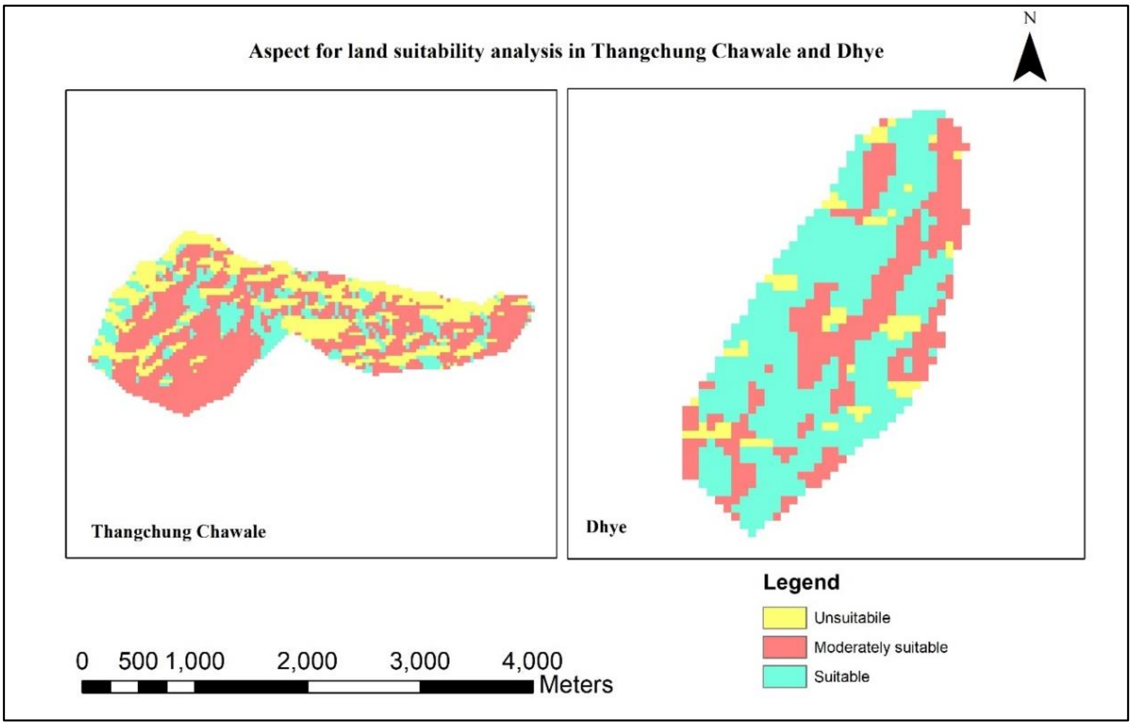


Figure 14: Land suitability maps for aspect

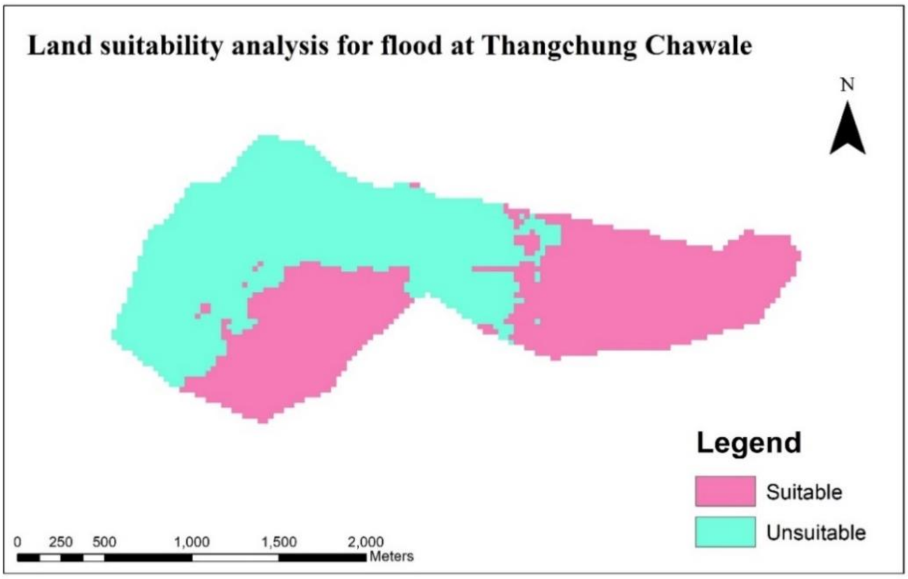


Figure 15: Land Suitability maps for Flood

The flood risk analysis is only done for the new settlement area as it lies at the confluence of the Kali Gandaki river, Dhye Khola and Tsarang Khola. The flood had occurred from Dhye Khola in the past. The Figure 15 shows that 165.51 ha area is suitable, and 166.5 ha area is unsuitable land in the Thangchung Chawale.

4.10 Pairwise Comparison Between Two Sites for Land Suitability

The Figure 16 shows the pairwise comparison done between all the sub-criteria of Thangchung Chawale and Dhye. All the scoring is given in percent, according to the weightage given to the criteria's importance. Finally, the maximum number is scored by

Thangchung Chawale i.e. 0.7585, and Dhye has scored 0.3048 as shown in Table 6 below. The Thangchung Chawale is better than Dhye, as it has more area or land for cultivation. Water is available throughout the year. The slope suitability to construct buildings and cultivate land is more. The distance to the nearest health post is short and transportation access is available. Hence, these factors make the Thangchung Chawale suitable for resettlement.

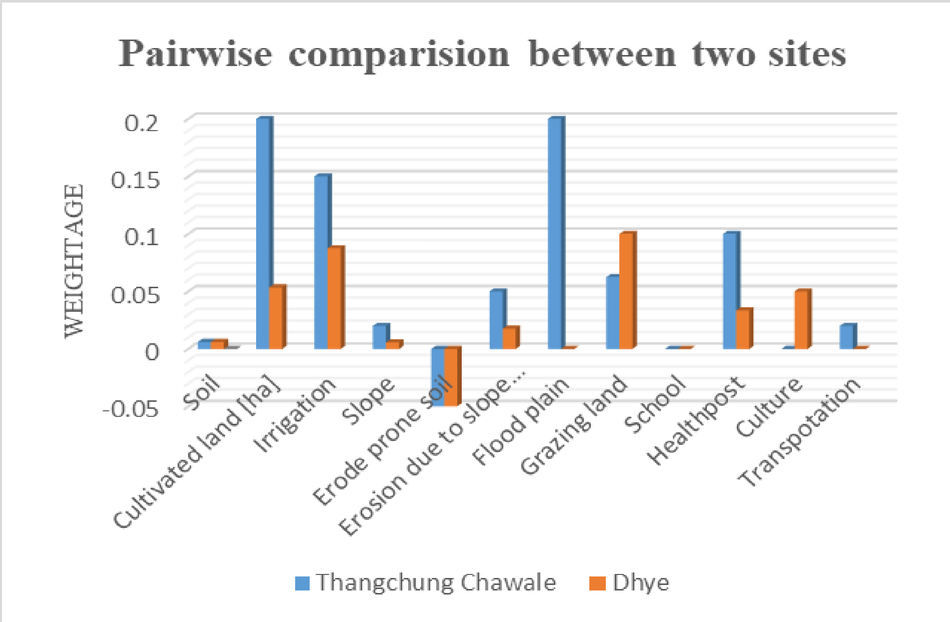


Figure 16: Pairwise comparison between two sites for land suitability

Summary of effect is shown in Table 6 highlighting the importance given in percentage for each criterion and weightage/score given between -1 to +1 to analyze the suitability for resettlement.

Table 6: Final land suitability analysis for resettlement

Criteria	*Subcriteria*	*Thang-chung Chawale*	*Dhye*	*Thang-chung Chawale*	*Dhye*	*Weigh-tage 1*	*Weigh-tage 2*	*Thangchung Chawale*	*Dhye*
Agriculture	Soil	Aridisol	Aridisol	0.2	0.2	40%	3%	0.006	0.006
	Cultivated land [ha]	332.19	88.83	1	0.26741		20%	0.2	0.05348
	Irrigation	12 months	7 months	1	0.58333		15%	0.15	0.0875
	Slope	278.91	78.48	1	0.28138		2%	0.02	0.00563
Erosion	Erode prone soil	Yes/severe	Yes/ severe	-1	-1	10%	5%	-0.05	-0.05
	Erosion due to slope aspect	233.55	81.94	1	0.35085		5%	0.05	0.01754
Flood	Flood plain	166.5 ha area is prone to flooding	No flood	1	0	20%	20%	0.2	0
Livelihood	Grazing land	8hrs	5hrs	0.625	1	30%	10%	0.0625	0.1

Criteria	*Subcriteria*	*Thang-chung Chawale*	*Dhye*	*Thang-chung Chawale*	*Dhye*	*Weigh-tage 1*	*Weigh-tage 2*	*Thangchung Chawale*	*Dhye*
	School		Closed	0	0		3%	0	0
	Health post	1hr	3hrs	1	0.33333		10%	0.1	0.03333
	Culture	Obstacle	Easy	0	1		5%	0	0.05
	Transportation	yes	No	1	0		2%	0.02	0
Total							100%	0.7585	0.30348

5. Discussion

The migration in Mustang is not a new phenomenon. Viewing the history of the people of Mustang, they had migrated from Tibet to Mustang and the population of Upper Mustang used to speak Tibetan language as their mother tongue (Devkota, 2013). Their main job/occupation was rearing livestock such as yak, sheep/goat and horses. So, they usually led a nomadic life with cattle grazing on pasture lands. Now, the situation has changed. The people are living in community and cultivating the crops in addition to rearing livestock for survival. They had started cultivating green vegetables after the training given by Care Nepal about 30 years ago. The annual mean temperature of Jomsom has increased by 0.024°C during the period from 1986 to 2017. People's perception on temperature matches the trend analyzed scientifically. This result is also similar to that inferred by NTNC (2012) and LAPA (2016). Similarly, the annual precipitation for all season is in increasing trend for Jomsom (1988-2017), while it is decreasing for Ghami (1983-2012). It is similar as reported in DHM (2017) and LAPA (2016) stating that higher the elevation, lower the precipitation trend.

When analyzing the reasons for multiple number of migrations of the people of Dhye, there seem to be only the push factors. As far as migration from Ghayu and Jhong is concerned, the reasons appear to be the harsh climatic conditions - cold weather, water and agricultural deficits, soil erosion, etc. At the same time, the pull factors such as enough water, agricultural land and grazing land attracted them to migrate to Dhye. They were living there happily for nearly 300-400 years. However, as per the crops production trend analysis, the annual production of crops is decreasing except that of apples. According to the household survey and key informant interview, they do not cultivate in 75% of the land from almost 40 years. Wild herb Jimbu is getting extinct and the climatic condition seems to be becoming conducive for apple farming in the higher altitude (Rana *et al*., 2011; RAD, 2015). This might be due to the changes in climatic pattern (NTNC, 2012). The rise in temperature has increased the apple production pattern in Upper Mustang (Regmi, Paudyal and Bordoni, 2009; Gurung, 2015).

6. Conclusion

The people of Dhye have been migrating at different time intervals and places because of both push factors and pull factors. They migrated from Ghayu and Jhong due to push factor in search of new opportunities for their livelihood options. Then they found Dhye village with enough settlement space, water and grazing land. These factors pulled them to resettle in Dhye village 500-1000 years ago. There was no correlation between climate change and migration at that time. According to DHM (2017) and other researches and from household survey and key informants, it seems the temperature is increasing, and precipitation trend is changing (seasonal, duration, intensity and volume) leading to drought. The drying of water resources has degraded grazing lands and crop production has reduced drastically. As a result, people have migrated to nearby places, even to foreign countries, looking for better lives for themselves and for their families. Therefore, it is apparent that their third migration from Dhye to Thangchung Chawale was happened due to the adverse impact of climate change during the last 40 years. As they were forced to move from Dhye due to drought and water scarcity leading to low productivity, they have been tagged "climate refugee" and migration became their adaptation strategy to cope with climate change. The people of Dhye having experiences of three migrations, have not only faced hardships related to social and economic resources but have also faced difficulties in maintaining their cultural values, indigenous practices and ancestral heritages.

The land suitability analysis indicates that the Thangchung Chawale has scored high rank and has become more suitable for Dhye people in terms of cultivated land, water availability, distance to the nearest health-post and transportation. This result supports the decision of the Dhye people to relocate to that place.

7. Recommendations

- Now it's a high time to establish this community as a climate smart/resilient village community so that they do not need to migrate again and again.
- As Thangchung Chawale lies in flood plain, all the mitigation and prevention options must be adapted.
- Chawale lies on flood debris and other crops can't be cultivated. Cash/tree crops such as apple, walnut and other fruits and bhotepipal and bains can be planted to make the area less prone to flood events.
- Although the Dhye Khola water stream is available throughout the year, its quality is not good for drinking purpose. So, appropriate interventions for water treatment with advance technologies must be installed to purify the water.
- Awareness program about climate change and their mitigation and adaptation measures can be promoted to combat the adverse impact of climate change.
- The cultivation of apple and some other crops is happening new in this place, and result is very positive. So, the cultivation of new species can be promoted to enhance their socio-economic conditions.

8. Acknowledgement

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9. References

Christensen, M. and Heilmann, C.J. (2009). Forest Biodiversity Gradients and the Human Imapct in Annapurna Conservation Area, Nepal. *Biodivers Conserv*, 18: 2205-2221.

Devkota, F. (2013). Climate Change and its Socio-cultural Impact in the Himalayan Region of Nepal. A Visual Documentation. *Anthrovision. Vaneasa Online Journal*, (1.2).
DHM (2017). Observed Climate Trend Analysis in the Districts and Physiographic Regions of Nepal (1971-2014). Kathmandu, Nepal: Department of Hydrology and Meteorology.
Dhungel, R.K. (2002). The Kingdom of Lo (Mustang): A Historical Study. Kathmandu: Tashi Gephel Foundation.
Gurung, G.S. (2015). Increasing Vulnerability of Mustang: *A Personal Account*. Meeteri, Vol.4.
IPCC (2007). Climate Change 2007: *The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. New York: University of Cambridge.
Jha, C.K., Gupta, V., Chattopadhyay, U. and Sreeraman, B.A. (2018). Migration as Adaptation Strategy to Cope with Climate Change: A study of farmers' migration in rural India. *International Journal of Climate Change Strategies and Management,* 10(1): 121-141. DOI: https://doi.org/10.1108/IJCCSM-03-2017-0059.
LAPA (2016). *Climate Change Local Adaptation Plan for Action:* Conservation Area Management Committee, Surkhang Village Development Committee, Mustang. Government of Nepal.
NTNC (2012). Climate Change Impact on Livelihood and Natural Resources of Upper Mustang. Kathmandu, Nepal: Forestry Nepal. Available online at: https://www.eldis.org/document/A63845 [accessed on 11 December 2022].
RAD (2015). Statistical Information of Apple Farming. Ministry of Agricultural Development, Nepal Government, Kathmandu.
Rana, R.S., Bhagat, R., Kalia, V. and Lal, H. (2011). The Impact of Climate Change on a Shift of the Apple Belt in Himachal Pradesh: *Handbook of Climate Change and India.* Chapter 3, pp 12. Available online at: https://www.taylorfrancis.com/books/e/9780203153284/chapters/10.4324/9780203153284-13 [accessed on 11 December 2022].
Regmi, B.R., Paudyal, A. and Bordoni, P. (2009). *Climate Change and Agro biodiversity in Nepal: Opportunities to Include Agrobiodiversity Maintenance to Support Nepal's National Adaptation Programme of Action (NAPA)*. Pokhara, Nepal: LI-BIRD.
Ruben, A., Garcia, G. and Frankentein, S. (2015). USCS and the USDA Soil Classification System: Development of a Mapping Scheme. *Cold Regions Rsearch and Engineering Laboratory*: ERDC/CRREL TR-15-4.
Scheffran, J., Marmer, E. and Snow, P. (2012). Migration as a Contribution to Resilience and Innovation in Climate Adaptation: Social Networks and Co-development in Noerthwest Africa. *Applied Geography*, 33: 119-127.
Sharma, E. and Tsering, K. (2009). Climate Change in the Himalayas: The Vulnerability of Biodiversity. *Sustain Mt. Dev*, 55: 10-12.
Shrestha, H.K. (2016). Preventing More Climate Refugees in Npal: *Building Knowledge for Climate Resilience in Nepal*. Nepal Academy of Science and Technology, pp.5

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If you really think that the environment is less important than the economy, try holding your breath while you count your money.
- Guy McPherson

Chapter 8

Integrated Management of Land, Water and Bioresources for Sustainable Agriculture in North Eastern Region of India

By Sanjay-Swami

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Integrated Management of Land, Water and Bioresources for Sustainable Agriculture in North Eastern Region of India

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Abstract

The ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. There is no single way to implement the ecosystem approach, as it depends on local, provincial, national, regional or global conditions. The North Eastern Region (NER) of India represents three geographies (East Himalayas, Brahmaputra Valley, and North East Hills) and covers about 7.7 percent of the total geographic area of India. Around 56 percent of the cultivated area of the NER is under low altitude (valley or lowland), 33 percent under mid-altitude (flat upland), and the rest under high altitude (upland terrace). The environment, local conditions, socio-economic and socio-cultural life of different tribal communities and the rituals associated with agricultural practices have developed many Indigenous farming systems, which have in-built eco-friendly systems for conservation, preservation and utilization of natural resources. However, with the passage of time, some of these practices have been further refined and modified to cater the location specific present day needs for conservation of natural resources, particularly soil and water resources. The present article is to discuss some important ecosystem approaches/traditional practices followed in the North Eastern Region with recent innovations to make agriculture more efficient and more sustainable.

Keywords

Ecosystem approach; North Eastern region; Integrated management of resources; Sustainable agriculture

Citation

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1. Introduction

The challenges arising from global economic and population growth, pervasive rural poverty, degrading natural resources in agricultural land use, and climate change are forcing ecological sustainability elements to be integrated into agricultural production intensification. Chemo-centric technological advancement during Green Revolution period boosted the production potential and provided food security to the nation. However, over a period of time, this production system has started exhibiting its carrying capacity as reflected by production plateau in green revolution belt (Sanjay-Swami, 2017). This version of agriculture wherein the soil structure, soil life and organic matter are mechanically destroyed every season, and the soil has no organic cover, is no longer adequate to meet the agricultural and rural resource management needs and demands of the 21st century (Kassam and Friedrich, 2012). The future farming must be multifunctional, and, at the same time, ecologically, economically and socially sustainable, so that it can deliver ecosystem goods and services as well as livelihoods to producers and society. The farming needs to address effectively the local, national and international challenges. These challenges include food, water and energy insecurity, climate change, pervasive rural poverty, and degradation of natural resources. All these challenges can be addressed by adopting integrated management of land, water and bioresources.

The ecosystem approach is a strategy for the integrated management of land, water and bioresources that promotes conservation and sustainable use in an equitable way. It is based on the application of appropriate scientific methodologies focused on levels of biological organization, which encompasses the essential structure, processes, functions and interactions among organisms and their environment. It recognizes that humans, with their cultural diversity, are an integral component of many ecosystems. During its fourth meeting of Conference of the Parties (COP4) in Bratislava in May 1998, the Convention on Biological Diversity (CBD) acknowledged the need for a workable description and further elaboration of the ecosystem approach, and requested the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) to develop principles and other guidance on the ecosystem approach. Based on the work of SBSTTA, which had a mandate of operationalizing the ecosystem approach, the fifth meeting of the members of the Conference of the Parties (COP-MOP5) endorsed a description of the ecosystem approach and recommended 12 principles for application of the ecosystem approach. It also suggested 5-points operational guidance for the ecosystem approach (SCBD, 2004).

2. Methodology

Both primary and secondary data were used to document some important ecosystem approaches/traditional practices followed in the North Eastern Region of India along with the recent innovative modifications to make these practices more efficient in the present agricultural scenario. The primary data/observation/pictures were collected during multiple field visits/survey, whereas the secondary data were collected from relevant research papers published in various journals, articles, books and searching Google search engine with the appropriate key words like ecosystem approach, traditional practices, North Eastern Region of India, etc.

3. North Eastern India's Regional Perspective

India's North Eastern Region (NER) represents three geographical entities (East Himalayas, Brahmaputra Valley, and North East Hills) and covers about 7.7 percent of the total geographic area of India. Around 56 percent of the cultivated area of the NER is under low altitude (valley or lowland), 33 percent under mid-altitude (flat upland), and the rest under high altitude (upland terrace) (Sanjay-Swami, 2019a). Nearly 22 percent land area is under crop cultivation in the region leaving 78 percent without cultivation. Majority of the fields in the region are situated across the hilly slopes (Sanjay-Swami, 2019a). Traditionally, farmers in both upland terrace and valleys practice mono-cropping under rainfed agriculture, where rice (*Oryza sativa*) is the major crop occupying more than 80 percent of the cultivated area followed by maize (*Zea mays*). The cropping intensity of the NER is 130 percent. The "slash and burn" agriculture (shifting cultivation or *Jhum*) is practiced on about 0.88 million ha. Soil health/fertility is the most crucial factor in deciding the agricultural productivity. Approximately, 84 per cent of the soils in the NER are acidic in nature, having low available phosphorus and zinc with toxicity of iron and aluminum.

The region has several unique features: fertile land, abundant water resources, evergreen dense forests, high and dependable rainfall, mega biodiversity and agriculture-friendly climate, yet it failed to convert its strengths optimally into growth opportunities for the well-being of the people. It has diversity in cropping pattern, livestock management and diversity in culture and socio-economic life. The size of land holdings is small that varies with state to state within the region. The mainstay of livelihood is only the agriculture, which is predominantly traditional and CDR (complex, diverse and risk prone), with a very backward industrial sector. The environment, local conditions, socio-economic and socio-cultural life of different tribal communities and the rituals associated with agricultural practices have developed many Indigenous farming systems, which have in-built eco-friendly systems for conservation, preservation and utilization of natural resources. However, with the passage of time, some of these practices have been further refined and modified to cater the location specific present day needs for conservation of natural resources, particularly soil and water resources (Sanjay-Swami, 2019a).

The following sections deal with some important ecosystem approaches/traditional practices followed in the North Eastern Region along with recent innovations to make agriculture more efficient, more sustainable.

3.1 Shifting Cultivation

The agricultural system, which is characterized by a rotation of fields rather than of crops, by short period of cropping (one to three years) alternating with long fallow periods (up to 20 or more years, but often as short as 6-8 years) and clearing of forest by means of slash and burn is known as "slash and burn" agriculture or shifting cultivation or *jhum*. This system involves cultivation of crops on steep slopes. Land is cleared by cutting of forests, bushes, etc. up to the stump level during December-January months leaving the cut plant materials for drying and final burning to make the land ready for sowing of seeds of different crops before the onset of rains. Upland rice is the main crop grown in mixtures with maize, finger millet, foxtail millet, beans, tapioca, yam, banana, sweet potato, ginger, chilies, sesame and vegetables. All these crops are grown as rainfed without tilling the land. Harvesting starts from August onwards. Maize and cucurbits are first available for consumption. Rice harvesting starts with maturity of panicles, which are picked up in time, leaving behind stubbles in the *jhum* field to decompose. The *jhum* practice has an in-built mechanism of sustenance, conservation and renewable system of resource management (Sanjay-Swami, 2018).

Traditionally, *jhum* cultivation was productive and sustainable. However, over the past four decades, due to increasing human population, the *jhuming* cycle in the same land, which extended to 20-30 years in older days, has now been reduced to 3-6 years (Sanjay-Swami, 2018). Deforestation and biomass burning in *jhum* aggravate soil erosion and ecosystem degradation. Annual soil erosion on steep slopes (44-53%) under shifting cultivation can be as much as 40.9 Mg/ha along with attendant losses (in kg/ha) of 702.9 of soil organic carbon (SOC), 63.5 of phosphorus (P) and 5.9 of potassium (K). Soil erosion, during the 1st and 2nd years on the abandoned land has been estimated at 147, 170, and 30 Mg/ha, respectively (Saha, Mishra and Khan, 2011). Similar observation was also made by Ray *et al.* (2020) who reported that shifting cultivation is the primary source of livelihood for farmers in the hilly tracts of North East India. However, the *jhumias'* (farmers involved in shifting cultivation) livelihoods are at stake due to low productivity and low profit due to detrimental effects of soil erosion, loss of soil nutrients and biodiversity. Steep slopes, cultivation along the slope, with negligible nutrient replacement and high rainfall are among the major causes of land degradation in Meghalaya state. The annual soil loss and carbon content in different land use systems are presented in table 1.

Table 1: Soil loss and carbon content in different land use systems

S. No.	*Land use system*	*Soil loss (ton/ha/yr)*	*Organic carbon (%)*
1.	Shifting cultivation	30.20-170.20	1.24-2.54
2.	Agriculture	5.10-68.20	1.96-2.70
3.	Livestock based land use system	0.88-14.28	1.80-2.94
4.	Natural fallow	0.37-1.83	2.84-3.25
5.	Agri-horti-silvi-pastoral	0.38-1.22	2.01-3.22
6.	Natural forest	0.04-0.52	2.92-3.05

Source: Saha, Mishra and Khan (2011)

3.2 Modified Shifting Cultivation Ensuring Soil Conservation

Bun cultivation is a modification of shifting cultivation and is mostly followed in the Meghalaya plateau for last four decades. In this system, the crops are grown on a series of raised beds of 0.15-0.30 m height having 0.75-1.0 m width with almost equal width under sunken area made along the slopes, locally referred to as "Bun". While preparing buns, biomass is burnt under the soil, and the land is abandoned after two or three years. It provides an improved production system, helps conserve soil moisture, and prevents land degradation and soil erosion. In this system, bench terraces are built on the hill slopes running across the slopes. The gap between each bun is levelled using the cut and fill method. The vertical break between each terrace is 1 meter. Such measures help in preventing erosion and retaining maximum rainwater within the slopes. It also helps in safely disposing-off the additional runoff from the slopes to the lower areas.

3.3 Bamboo Drip Irrigation System

Meghalaya is well-known for having the highest rainfall in the world with about 11,500 mm rainfall recorded annually (Sanjay-Swami, 2021). This makes Meghalaya the wettest places on Earth. Though, the state gets plenty of rainfall during the monsoon season, a well-managed irrigation system is required during the dry spell. Hill farming is subject to a number of serious constraints such as undulating topography, steep-slopes, poor and shallow soils (prone to erosion). Majority of the fields in the region are situated across the hilly slopes. Therefore, the water-retention capacity of the terrain is poor and bringing water from distant water sources to the fields is a big challenge for the farmers in the rural areas. Ground channeling is also impractical due to the harsh landscape. Confronted with such adverse conditions for irrigation, the traditional farmers of Meghalaya have come up with an innovative way. The farmers of the Jaintia and Khasi hills have developed unique bamboo drip irrigation system of trapping springs and stream water normally to irrigate the betel leaf or black pepper crops planted in areca nut orchards or in mixed orchards (Sanjay-Swami, 2021).

Figure 1: Burning of hill side for *jhum* cultivation
Source: Field trip, 2014

Figure 2: Making bunds to reduce soil loss
Source: Field trip, 2014

Figure 3: View of *jhum* field after germination
Source: Field trip, 2014

The bamboo drip irrigation system is based on gravity and the steep slopes that facilitate in implementing it. Water from an uphill source is trapped and brought to the plantation by a main bamboo channel. Usually, these water sources are far off from the plantations and the main bamboo channel runs hundreds of meters - in some cases even few kilometers. The water is then regulated through a complex bamboo network of secondary and tertiary channels to all the parts and corners of a plantation, right up to the bottom of the hill.

Bamboos of varying diameters are used to build the channels, support structures, diversion pipes and strips. Channels are held above the ground by bamboo or wooden *Y* shaped sticks. About a third of the outer casing in length and internodes of bamboo pieces have to be removed while fabricating the system. One stretch of channel is lashed to another by thin bamboo strips. Indigenous tools like a *dao*, a type of local axe, and chisels of various shapes and design are used to build the bamboo network. Two labourers can construct a network covering 1 hectare of land in 15 days. They are built with such skill that water wastage by leakage is minimal. The construction is based on a simple thumb rule that the ratio of diameter of primary channel to tertiary channel determines the quantity of water which will reach the trees. It is a subtle skill that comes with years of observation and experience. It is so perfect that about 18-20 litres of water entering the bamboo pipe system per minute gets transported over several hundred metres and finally gets reduced to 20-80 drops per minute at the site of the plant (Sanjay-Swami, 2021).

Figure 4: Buns ready for sowing
Source: Field trip, 2019

Figure 5: Vegetable cultivation on buns
Source: Field trip, 2019

Figure 6: Larger view of bun cultivation
Source: Field trip, 2019

The cost involved in building the system is minimal. Bamboo is available freely in this region. Usually, the farmer himself sets up the system in his plantation with some help from 1 or 2 labourers (Sanjay-Swami, 2021). The region gets heavy rain and, as a result, each installation lasts for about 2-3 years. After the rainy season the undergrowth is cleared, and reinforcements are provided. Old bamboo is left to rot, which, over the time, returns to the soil as humus. Cooperatives are formed and each farmer provides his skill and labour to build and maintain the system. The distribution of water from one plantation to another is done by diverting water at fixed timings. This avoids the occurrence of conflicts between various farmers. By this method, the whole community works harmoniously sharing the limited resources judiciously (Sanjay-Swami, 2019b).

3.4 Modified Bamboo Drip Irrigation System

The bamboo drip irrigation system, traditionally used for irrigating plantation crops from stream water, has been further refined and modified to increase water use efficiency and to irrigate field crops apart from plantation crops. Since the region faces lot of water scarcity during dry period, and as most of the crops are cultivated on upland topography, water harvesting tanks (*Jalkunds)* at the top of the hills can be the solution for water scarcity (Sanjay-Swami, 2019b). During wet period, water can be collected by making small ponds or tanks and can be saved for dry spell. Since water in bamboo drip irrigation is actually conveyed from higher elevation to the downstream with the help of gravity up to plantation crops, water harvesting tank should also be constructed at the top of the hills or above the cultivated crops so that water can easily be transported through bamboo.

Bamboos are laid down from the water source, which is the mainline, and from there lateral line bamboos are connected. Bamboos are laid just above the properly spaced crop plants. Bamboo has a hole above the plant so that water can just drip on the particular plant only. The height of bamboo placed above the plant should be enough for the farmers to move under it for inter-culture operations like manual weeding. The end of the mainline should be closed. Holes in the mainline convey the water to the laterals. The laterals also consist of small holes just above the individual plant to drip water. For efficient utilization of water, tying of some woolen thread with the cap in the holes of the laterals is also recommended to manage the speed of drip or to irrigate only the desired crop area. If the wetting is completed, it can be pulled down for seizing the flow of water for its efficient utilization. In the mainline, holes can be either closed with the help of mud or thread just like in the laterals for seizing the flow with respect to particular plant. It leads to better utilization of rainwater which would have been washed out if not harvested during rainy season. It has also been observed that about 25-30% water can be saved by modified bamboo drip irrigation followed by straw mulching, although it is cost effective only for cash crops like potato, capsicum, tomato, strawberry, etc., which are grown with definite spacing (Sanjay-Swami, 2019b).

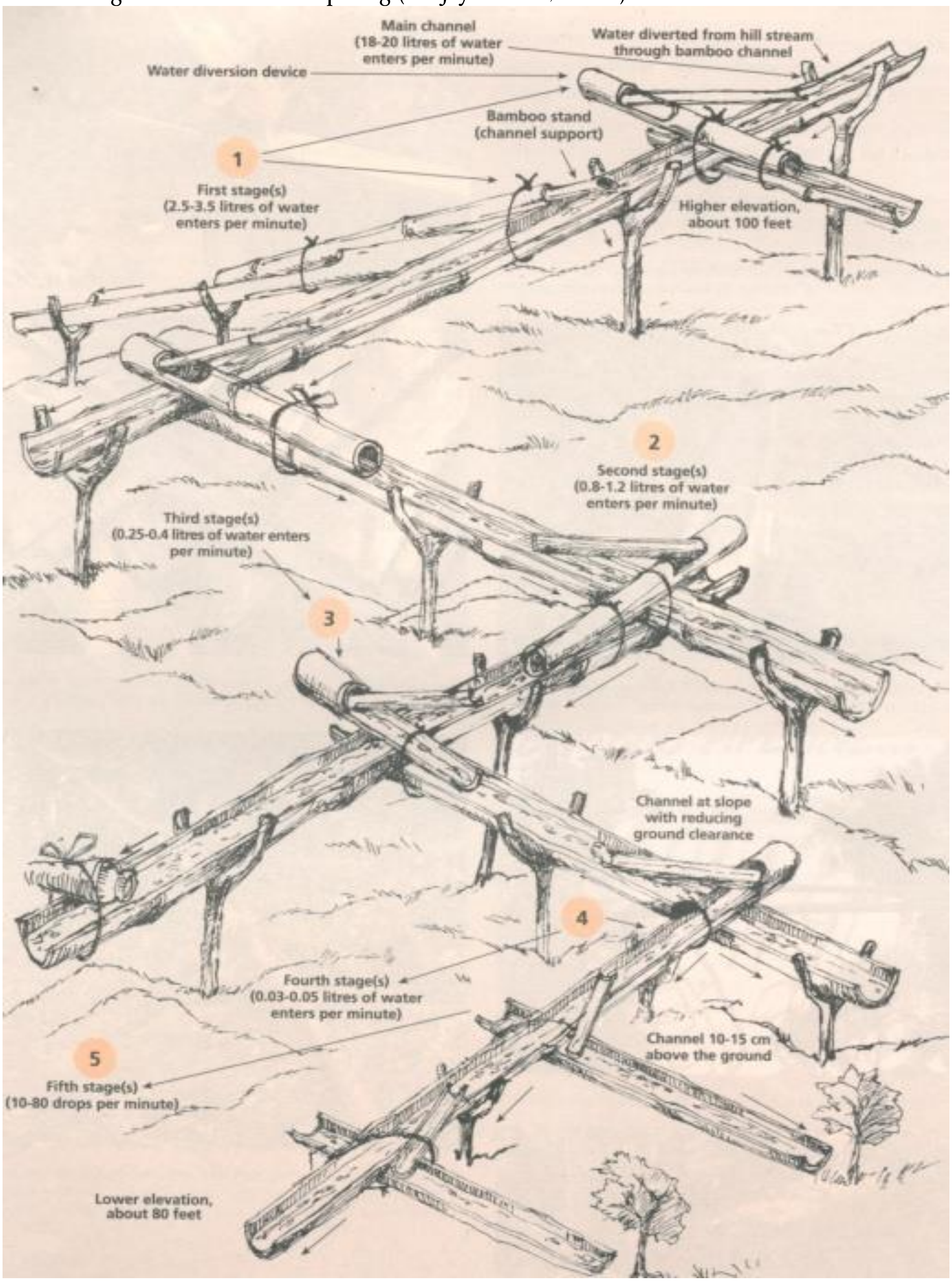

Figure 7: Different stages of water distribution in bamboo drip irrigation system. *Source:* CSE (2021)

3.5 Rice-Fish System of Apatani Plateau

It is a multipurpose water management system, which integrates land, water and farming system by protecting soil erosion, conserving water for irrigation and paddy-cum-fish culture. It has been practiced in a flat land of about 30 km^2 located at an altitude of about 1,525 m above m.s.l. in the humid tropic climate of Lower Subansiri district of Arunachal Pradesh. Local tribe "Apatani" who developed this system dominates the area; every stream rising from the hill is trapped soon after it emerges from forest, canalized at the rim of valley and diverted by network of primary, secondary and tertiary channels. The first diversion from the stream takes off at a short distance above the terraces. Central irrigation channel of 0.61 x 0.61 m size and embankment of the same size in each of the paddy plots are constructed. The water into the plots is drawn from irrigation channel and

Figure 8: Modified bamboo drip irrigation system suitable for field crops.
Source: ICAR Research Complex for NEH Region (2018)

has a check gate made of bamboo splits (huburs) at the inlet for regulation of entry and exit of water through the outlet. The farmers drawn off the water from the rice fields twice, once during flowering and finally at maturity on an average 10 cm water level is maintained in the plots by adjusting the height of outlet pipes. For fish culture, a vertical pit is dug in the middle of the plot, so that the water remains in these pits even when it drains away from the surrounding fields. To prevent trashes or migration of fish, a semicircular wooden/bamboo net is installed at the inlet to reduce beating action of flowing water regulating in soil erosion; wooden strikes or planks are put at the outlet. The huburs are installed about 15 cm x 25 cm above the bed level. They are made of plank or pine tree trunk or bamboo stem of different diameters. The water from terraces is finally drained into the river, which flows in the middle of valley.

Figure 9: Rice-fish system of Apatani plateau

3.6 ZABO System of Farming

"Zabo" is an Indigenous farming system of Nagaland state. This system has its origin in Kikruma village of Phek district of Nagaland, located at an altitude of 1,270 m above m.s.l. The word "Zabo" means impounding of water. It has a combination of forest, agriculture and animal husbandry with well-founded soil and water conservation base. It has protected forest land towards the top of hill, water harvesting tanks in the middle and cattle yard and paddy fields for storage for the crops as well as for irrigation during the crop period. Special techniques for seepage control in the paddy plots are followed. Paddy husk is used on shoulder bunds and puddling is done thoroughly.

3.7 Alder Based Farming

In some pockets of Nagaland, the farmers use *Alnus nepalensis* (alder) tree for agriculture. In this system, the alder seedlings are planted on the sloppy land intended for cultivation and the alder grows fast till it attains 6-10 years age. At this stage, initially the trees are pollarded, the leaves and twigs are burnt, and ash is mixed with soil to prepare it for raising crops. Subsequently, pollarding is done once every 4-6 years. Under this process, coppice is cut except 5-6 on top of the main trunk and crop schedule is followed including fallow period of 2-4 years. The bigger branches stripped of leaves are used for firewood, while the root of the tree develops nodules (colonies of *Frankia*) increasing the fertility of soil. Spreading nature of the roots helps in preventing soil erosion on slopes. Nitrogen fixation in *Alnus nepalensis* takes place through a symbiotic relationship between *Alnus* with nitrogen fixing actinomycetes of the genus *Frankia* and is, therefore, able to improve degraded *jhum* lands. The symbiotic microorganism *Frankia* (Actinomycetes) is located in specialized structures, or nodules, along the root system of the host plants. The root nodules are analogous to those induced by *Rhizobium* in legumes, and they provide an environment where *Frankia* can grow and prosper, while providing the host plant with fixed atmospheric nitrogen. Unlike the *Rhizobium*-legume symbiosis, where most of the host plants belong to a single large family, *Frankia* can form root nodules in symbiosis with actinorhizal plants. The ability of the alder trees to develop and retain fertility of the soil has been fully utilized by farmers in Angami, Chakhesang, Chang, Yimchunger and Konyak area in Nagaland at varying altitudes.

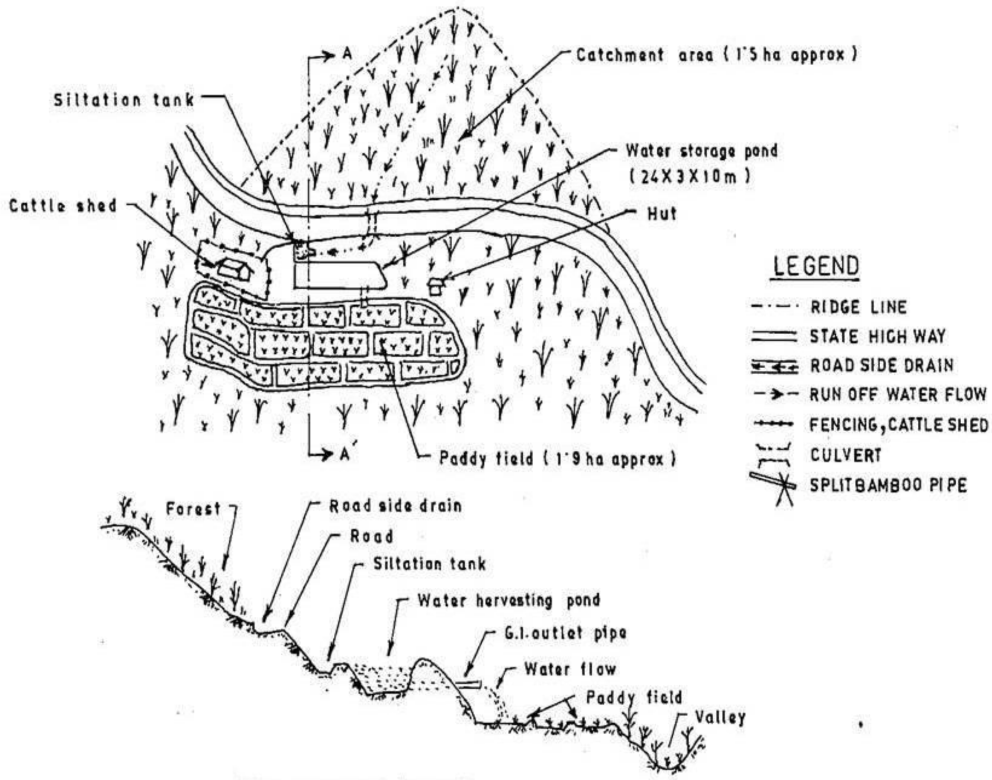

Figure 10: Land management under Zabo farming system. *Source:* Sanjay-Swami *et al.* (2021)

3.8 Organic Cultivation

The concept of organic cultivation/farming builds on the idea of efficient use of locally available resources as well as the usage of adapted technologies e.g., soil fertility management, closing of nutrient cycles as far as possible, control of pests and diseases through management and natural antagonists. It is based on a system-oriented approach and can be a promising option for sustainable agricultural intensification, as it may offer several potential benefits such as: (i) a greater yield stability, especially in risk-prone tropical ecosystems, (ii) higher yields and incomes in traditional farming systems, once they are improved and the adapted technologies are introduced, (iii) an improved soil fertility and long-term sustainability of farming systems, (iv) a reduced dependence of farmers on external inputs, (v) the restoration of degraded or abandoned land, (vi) the access to attractive markets through certified products, and (vii) new partnerships within the whole value chain, as well as a strengthened self-confidence and autonomy of farmers.

The organic farming is based on following four basic principles:

Principle of Health: Organic agriculture should sustain and enhance the health of soil, plant, animal and human as one and indivisible entity.

Principle of Ecology: Organic agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them.

Principle of Fairness: Organic agriculture should build on relationships that ensure fairness regarding the common environment and life opportunities.

Principle of Care: Organic agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment.

Figure 11: Alder based farming in *Jhum* land

Figure 12: Field after crop harvest

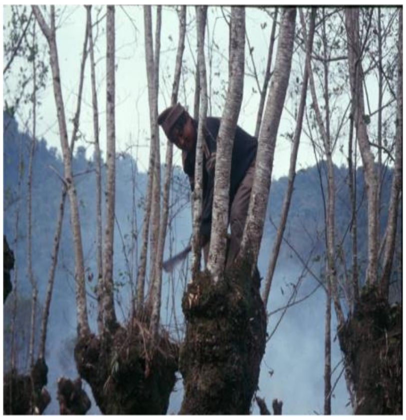

Figure 13: Pollarding of alder tree

These basic principles provide organic farming with a platform for ensuring the health of environment for sustainable development, even though the sustainable development of mankind is not directly specified in the principles (Sowmya, 2014).

The NER has much strength for organic farming. The region is home to many niche crops like large cardamom, ginger, turmeric, Assam lemon, Joha rice, medicinal rice, Naga chilly (Bhoot Jolkiya), areca nut and passion fruit with high market demands. Farmers can fetch premium prices for organic produce along with conserving local crops, which are common for farmers in their localities as local crops are more resistance to biotic and abiotic stresses (Sanjay-Swami, 2017). Sikkim has become the first state in India to go fully organic in terms of production and consumption of food. The changeover is already apparent in local markets where organic produce seems to be trumping non-organic. Approximately, 75,000 acres of chemically fertilized farmland have been converted to organic farming in Sikkim state. NER is the fourth largest producer of oranges in India. Best quality ginger (low fibre content) is produced in this region and an Agri-Export Zone (AEZ) for ginger is established in Sikkim. Sikkim is the largest producer of large cardamom (54 percent share) in the world.

Meghalaya, being organic by default, provides an ample scope for expanding and exploiting the potential for this sector in right direction. The new policy of the state government also aims at building brand Organic Meghalaya, which will produce organic certified food and products, link organic food to ecotourism, cleaner and greener environment through lower carbon regime and build consumer awareness and demand for safe and healthy food. Meghalaya Department of Agriculture has successfully initiated pilots during 2010, which began with tea and, thereafter, cauliflower in Ri-Bhoi and East Khasi Hills district. "MEG" Tea is presently marketed as Organic Certified Tea and is available in three variants - Green, Oolong and Black Tea. All the organic tea variants are USDA and NPOP certified, which were certified by M/s Control Union India. In Garo Hills, organic certification of pineapple and cashew nut are ongoing and are presently in C_1 and C_2 stage (Shabong, 2015).

Organic farming, without doubt, is one of the fastest growing sectors of agriculture production in Meghalaya. The Meghalaya state aims to convert at least 200,000 hectares into organic farmland by 2020 (Shabong, 2015). The process to convert a portion of agricultural land to become fit for organic cultivation takes at least three years. The agricultural land is being selected area wise to be converted into organic farmland, and the land is put under observation for three years. After the third-year conversion period, the land is certified as fit for organic farming or not. So far 1,410 hectares of agricultural land have been certified for organic farming in the Meghalaya. The agricultural land, in which some crops have been organically cultivated, includes 150 hectares for tea plantation, 380 hectares for cashew nut and 80 hectares for turmeric. The process to convert around 16 hectares land under ginger cultivation has entered its second year (Sanjay-Swami, 2019b).

3.9 Biochar for Soil Acidity Management

Approximately, 84 per cent of the soils in the North Eastern Hill (NEH) region of India are acidic having low available phosphorus (P) and zinc (Zn) and toxicity of iron and aluminum (Lyngdoh and Sanjay-Swami, 2018). To overcome the problem of soil acidity, farmers adopt variety of soil amendments like ash, manures, lime, compost and bio-sorbents. Although, liming is good practice to overcome the soil acidity problem, yet the latest, cheap and good organic source is biochar as the availability of biomass is much more in NEH region (Yadav and Sanjay-Swami, 2018). The usefulness of biochar increases when it is applied in combination with organic manures like farm yard manure (FYM), vermicompost, poultry manure, pig manure, etc. (Yadav and Sanjay-Swami, 2019).

Meghalaya is known for a large array of vegetables, both sub-tropical and temperate. Tomato (*Lycopersicon esculentum* Mill.) is one of the most important vegetable crops supporting the livelihood of many vegetable growers. Hence, for optimization of biochar dose with vermicompost and recommended dose of fertilizers to maximize the yield of tomato in acid soil, a field experiment was conducted at School of Natural Resource Management, College of Postgraduate Studies in Agricultural Sciences, Umiam, Meghalaya during winter season of 2017. Tomato cv. Megha tomato-2 was used as test crop with three doses of biochar (B) @ 2, 3 and 4 t/ha, vermicompost (VC) @ 2.5 t/ha and two graded recommended doses of NPK fertilizers (RDF) @ 75 and 100%. Sixteen combination of treatments as T_1 - Control, T_2 - B @ 2 t/ha, T_3 - B @ 3 t/ha, T_4 - B @ 4 t/ha, T_5 - 75% RDF + B @ 2 t/ha, T_6 - 75% RDF + B @ 3 t/ha, T_7 - 75% RDF + B @ 4 t/ha, T_8 - 75% RDF + B @ 2 t/ha + VC @ 2.5 t/ha, T_9 - 75% RDF + B @ 3 t/ha + VC @ 2.5 t/ha, T_{10} -75% RDF + B @ 4 t/ha + VC @ 2.5 t/ha, T_{11} - 100% RDF + B @ 2 t/ha, T_{12} - 100% RDF + B @ 3 t/ha, T_{13} - 100% RDF + B @ 4 t/ha, T_{14} - 100% RDF + B @ 2 t/ha + VC @ 2.5 t/ha, T_{15} - 100% RDF + B @ 3 t/ha + VC @ 2.5 t/ha, T_{16} - 100% RDF + B @ 4 t/ha+ VC @ 2.5 t/ha were tested. The trial was laid out in RBD and replicated thrice. The results indicated that plant height, number of fruits/plant, fruit size and fruit yield of tomato was superior with the application of biochar @ 4 t/ha with vermicompost @ 2.5 t/ha and 100% RDF and the soil pH also improved significantly over control. Hence, the combined application of biochar @ 4 t/ha with vermicompost @ 2.5 t/ha and 100% RDF may be recommended for Meghalaya farmers to enhance tomato productivity coupled with managing their acidic soils (Sanjay-Swami *et al.*, 2018).

Figure 14: Biochar *Source:* ICAR Research Complex for NEH Region, 2017

Figure 15: Application of biochar in experimental field. *Source:* Experimental Plot, 2017

Figure 16: Mixing of biochar in soil for managing acidity problem. *Source:* Experimental Plot, 2017

Das *et al.* (2012) also attempted to document the various indigenous techniques of soil and water conservation in the North-eastern region of India linked with traditional farming practices like Alder (*Alnus nepalensis*) based farming system, *Zabo* farming, *Panikheti* in hills and pond based farming system in plains of the region developed by local farmers using their ingenuity and skills over the centuries and reported that some components of these farming systems have good scientific base for resource conservation like nutrient cycling through *in situ* residue management, green leaf manuring, soil and water conservation and maintenance of forestry whereas there are few components like burning of biomass in *jhuming* needs a relook.

Figure17: Experimental plots with different treatments. *Source:* Experimental Plot, 2018

Figure 18: Fruiting stage of tomato *Source:* Experimental Plot, 2018

4. Conclusion

The future farming must be multifunctional and, at the same time, ecologically, economically and socially sustainable so that it can deliver ecosystem goods and services as well as livelihoods to producers and society. The environment, local conditions, socio-economic and socio-cultural life of different tribal communities of the North Eastern Region of India, and their rituals associated with agricultural practices have developed many

Indigenous farming systems, which have in-built eco-friendly systems for conservation, preservation and utilization of natural resources. Shifting cultivation or *jhum,* bun cultivation, bamboo drip irrigation system, modified bamboo drip irrigation system, rice-fish system of Apatani tribe, ZABO system of farming in Nagaland, alder-based farming, organic cultivation, and use of ash, manure, composts, biochar, etc. for managing soil acidity are just some of the hundreds of traditional eco-friendly practices performed by the farmers of North Eastern Region. The uniqueness of these practices is their suitability to the local conditions, their economic feasibility and easy implementation.

5. References

CSE (2021). Bamboo drip irrigation. Centre for Science and Environment, India. Available online: https://www.cseindia.org/bamboo-drip-irrigation-2839 [Accessed 22 March 2021].

Das, A., Ramkrushna, G.I., Choudhury, B.U., Munda, G.C., Patel, D.P., Ngachan, S.V., Ghosh, P.K., Tripathi, A.K., Das, S. and Kumar, M. (2012). Natural resource conservation through indigenous farming systems: Wisdom alive in North East India. *Indian Journal of Traditional Knowledge*, 11(3): 505-513. Available online: http://nopr.niscair.res.in/handle/123456789/14393 [Accessed on 27 May 2021].

Kassam, A. and Friedrich, T. (2012). An ecologically sustainable approach to agricultural production intensification: Global perspectives and developments. *Field Actions Science Reports (Facts Reports): The Journal of Field Actions,* Special Issue 6: 01-06. Available online: http://journals.openedition.org/factsreports/1382. [Accessed 22 March 2021].

Lyngdoh, E.A.S. and Sanjay-Swami (2018). Phytoremediation effect on heavy metal polluted soils of Jaintia Hills in North Eastern Hill Region. *International Journal of Current Microbiology and Applied Sciences,* 7(11): 1734-1743. DOI: https://doi.org/10.20546/ijcmas.2018.711.199.

Ray, S.K., Chatterjee, D., Rajkhowa, D.J., Baishya, S.K., Hazarika, S. and Paul, S. (2020). Effects of integrated farming system and rainwater harvesting on livelihood improvement in North-Eastern region of India compared to traditional shifting cultivation: Evidence from an action research. *Agroforestry Systems*, 94: 451-464. DOI: https://doi.org/10.1007/s10457-019-00406-3.

Saha, R., Mishra, V.K. and Khan, S.K. (2011). Soil erodibility characteristics under modified land-use systems as against shifting cultivation in hilly ecosystems of Meghalaya, India. *Journal of Sustainable Forestry*, 30(4): 301-312. DOI: https://doi.org/10.1080/10549811.2011.531992.

Sanjay-Swami (2017). Organic farming: A way towards maintaining soil health, improving crop productivity and livelihood security of tribals in NE India. In: *Enhancing Socio-economic Status and Livelihood Security of Tribal Farmers of Meghalaya*, (Eds.) Ram Singh, N.S. Azad Thakur, K. Noren Singh, Rajkumar Josmee Singh, L. Devarani and Kennedy N., CPGS, CAU, Barapani, pp. 33-40.

Sanjay-Swami (2017). Organic farming: An eco-friendly approach for sustainable agriculture. *CAU Farm Magazine*, 7(2): 30-37.

Sanjay-Swami (2018). Shifting cultivation: A tribal way of life in North East India and alternative approaches for increasing productivity. *The Pharma Innovation Journal,* 7(3): 380-385. Available online:

https://www.thepharmajournal.com/archives/2018/vol7issue3/PartF/7-3-34-826.pdf [Accessed on 25 May 2021].

Sanjay-Swami (2019a). Managing fragile hill ecosystems of North Eastern Region. *Soil and Water Conservation Today*, 14(1): 02.

Sanjay-Swami (2019b). Ecosystem approach to make agriculture more efficient, more sustainable in Meghalaya. *Souvenir, CAU Regional Agri-Fair 2019-20*, November 11-13, 2019: 52-57.

Sanjay-Swami(2021). Bamboo drip irrigation: Traditional way of irrigating crops in Meghalaya. *Just Agriculture: e-Magazine*, 01 (8): 18-21.

Sanjay-Swami, Singh, S., Patgiri, P., Raj, V.A. and Singh, T.D. (2021). Ecological sustainability in agricultural production intensification: NER perspective. In: *Sustainable Agriculture: Recent Advances,* (eds.) Sanjay-Swami and Singh, S. New Delhi, India: Biotech Books, pp. 1-20.

Sanjay-Swami, Yadav, O.S. and Gurjar, G.N. (2018). Use of biochar for increasing carbon sequestration in soil. In: *Souvenir*, 27th National Conference of SCSI on "Sustainable Management of Soil and Water Resources for Doubling Farmers' Income" (eds.) Bipul Deka *et al*., October 25-27, 2018, Assam Chapter of SCSI, AAU, Jorhat, Assam, pp. 75-77.

SCBD (2004). *The Ecosystem Approach (CBD Guidelines)*. Secretariat of the Convention on Biological Diversity, Montreal, pp. 50.

Shabong, C.S. (2015). Meghalaya mission organic: Moving towards safer food. Available on: http://megagriculture.blogspot.com/2015/01/meghalaya-mission-organic-moving.html#:~:text=The%20Department%20of%20Agriculture%2C%20Meghalaya,Green%2C%20Oolong%20and%20Black%20Tea. [Accessed on 22 April 2021].

Sowmya, K.S. (2014). Organic farming: Scope in India, *Global Journal of Advanced Research*, 1(2): 101-102. Available online: https://www.researchgate.net/publication/340826171_Organic_farming_A_way_towards_maintaining_soil_health_improving_crop_productivity_and_livelihood_security_of_tribals_in_NE_India [Accessed on 25 May 2021].

Yadav, O.S. and Sanjay-Swami (2018). Utilizing bio-char potential for acid soil management. *Soil and Water Conservation Today*, 13 (4): 05-06. Available online: https://www.researchgate.net/publication/332545002_Utilizing_Bio-char_Potential_for_Acid_Soil_Management [Accessed on 25 May 2021].

Yadav, O.S. and Sanjay-Swami (2019). Performance of tomato (*Solanum lycopersicum* L.) in acid soil under integrated nutrient management with biochar as a component. *International Journal of Current Microbiology and Applied Sciences*,8(05): 793-803. DOI: https://doi.org/10.20546/ijcmas.2019.805.094.

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The nation that
destroys its soil
destroys itself.
Franklin D. Roosevelt

Chapter 9

Integrated River Basin Management: Lessons Learned from the Nepal Himalaya

By Prakash Singh Thapa, Sunita Ranabhat, Kishor Aryal, Bindu Ghimire and Kabi Raj Khatiwada

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Integrated River Basin Management: Lessons Learned from the Nepal Himalaya

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Abstract

Water and watershed resources have been degraded due to population growth combined with unplanned urbanization, industrial growth, and inappropriate farming systems worldwide. An effective, efficient, and holistic management system is crucial for reversing the degradation. In the Himalayan landscape, integrated river basin management (IRBM) could play an important role, especially due to the topographical challenges and governmental structures, and inconsistencies between hydro-physical boundaries and administrative boundaries. In Nepal, since early 2005 several studies have been carried out on basin-level management. However, the Government of Nepal adopted a basin-level management approach for implementing IRBM only after 2017, a few years after federal restructuring. This paper aims to review the progress made in the political, legislative, and institutional arenas for the implementation of IRBM in Nepal. The study is based on policy analysis and a literature review. It highlights that Nepal is in the preparatory phase of establishing a legal-institutional framework for IRBM and lacks proper institutional mechanisms for translating the principles of IRBM to actions on the ground. The chapter identifies the strengths and gaps in existing institutional arrangements and sheds light on the practical aspects of IRBM implementation, which would be useful learning for the countries aiming to implement IRBM in similar landscapes globally. Based on the study, it is concluded that an integrated approach based on collaboration among the different tiers and sectors of government is essential for implementing IRBM and ensuring the sustainability of water resources.

Keywords

Institutions; IRBM; Policy; Resources; Watershed Management

Citation

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1. Introduction

Management approaches related to water and watersheds have undergone substantial changes in the last few decades (Gleick, 2000). The focus has shifted from political-administrative boundaries to transboundary hydrological boundaries (Giakoumis and Voulvoulis, 2018). Water resource management approaches that focus on administrative boundaries rather than hydro-physical boundaries are ineffective and non-inclusive (Easter, Dixon and Hufschmidt, 1991). The common approaches to water resource management include integrated water resource management (IWRM), integrated river basin management (IRBM) or integrated catchment management (ICM), and integrated watershed management (IWM) (Bach *et al.*, 2011; Mitchell and Hollick, 1993).

Among the various approaches to water resource management, IRBM is gaining widespread popularity in recent decades (Jewitt, 2002). IRBM seeks to focus on implementing water resource management on the basis of better coordination amongst operating and water management entities within a river basin (Karki, Shrestha and Winiger, 2011). IRBM secures an integrated, participatory, and coordinated approach to planning and managing the natural resources of the river basin with due consideration of multiple environmental, social, and economic nexuses in a catchment/watershed setting (Hooper, 2005). IRBM considers the management of naturally functioning river ecosystems with the integration of policies, and wider cross-cutting interests agreed upon by all major stakeholders' active participation and strategic decision-making through well informed, coordinated, and transparent process (Evers, 2016; WWF, 2002).

Globally, discussions on the need for integrated water resource management gained momentum after the Dublin Statement on Water and Development at the 1992 International Conference on Water and Environment (ICWE, 1992; Pangare *et al.*, 2006). The need for the river basin approach emphasizing IRBM became clear as water became a finite and vulnerable resource in the context of climate change and changing institutional arrangements (Eastham *et al.*, 2008; Song *et al.*, 2010).This approach focuses on using an integrated approach considering not just the water within the system (Dinar, 1999), but also the entire range of users and drivers and also adapts the principles of IWRM to a river system, thus considering the river (or lake) basin as an integrated whole (Pegram, Li and Quesne, 2013).

The application of the IRBM approach is being identified and practiced via enabling environment, institutional arrangements, and management instruments (Kattelus, 2009). The Global Water Partnership (GWP) promotes IRBM through the coordinated development and management of water, land, and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems (Abdel-Magid and Ahmed, 2002). Presently, the Water Resources Policy has been drafted by different international communities and countries (Meinzen-Dick, 2007) with the objective of obtaining the maximum social, environmental, and economic benefits from the available water resources at the basin level by adopting the principle of IWRM (Gooch and Stålnacke, 2010).

Water resource management in the Himalayan landscape is being increasingly challenging (Mukherji *et al.*, 2015) than in other parts of the world due to the unique geographical features, coupled with climate change, land-use change, and demographic diversity (Lepcha, Pandey and Ranjan, 2021; Tyler and Fajber, 2009). The activities and processes in the upstream areas have marked consequences in downstream areas (Tiwari and Joshi, 2012) and there is a need for particular attention to the linkages (Nepal, Flügel and Shrestha, 2014). IRBM is being more significant due to the integration of processes and impacts driven by topography in the process, and for supporting all the Sustainable Development Goals across the 2030 Agenda aligned with water sustainability (Silva *et al.*, 2020; Shivakoti, 2021).

National water policies, strategies, and legislation adopted by many Asian nations have been aligned to promote water resources management at the river basin scale (Molle and Hoanh, 2011). Along with other Himalayan and Asian countries, Nepal has also shown growing interest in watershed management over the last few decades (Fleming, 1983). The formation of river basin organizations (RBOs) at multiple tiers such as local, national, as well as transboundary can be considered as an important attempt to set up an institutional structure to execute policies, acts, regulations, and laws related to water resources management in an integrated way (Shivakoti, 2021). Nepal, being a Himalayan mountainous landscape has also started to implement IRBM by setting up different plans policies, and legislative bodies. The IRBM approach has been applied with a legal and institutional instrument with different names such as basin commissions, catchment councils, river basin management centers (RBMCs), public RBOs, and corporate RBOs, among others (Clausen, 2011; Hooper, 2005; ÖlundWingqvist and Nilsson, 2015; Selek and Selek, 2020).

In Nepal, the concept of IRBM has gained increased attention recently (Pradhan *et al.*, 2014) after federal restructuring in the year 2015. In Nepal, various laws and bylaws are being revised to align them with the spirit and provisions of the new Constitution promulgated in 2015 (Upadhyaya, 2019). Also, a high-level committee chaired by the forest minister was formed in 2017 to coordinate river basin management approaches, and four river basin management committees (RBMCs) were established (Paudel, Pal and Dhami, 2019). Political support, legal instruments, and sufficient financial and human resources (Gourbesville, 2008) with good water governance (Tortajada, 2010) are important for managing water resources in a holistic, equitable, efficient, and sustainable manner (Global Water Partnership, 2000). Establishing proper institutional mechanisms can help ensure integration, participation, coordination, and collaboration in river basin management (European Commission, 2002; Franzén, Hammer and Balfors, 2015). Several legal provisions required for initiating basin management have been introduced and related institutions have been formed to address issues of water-resource management-related conflicts (Suhardiman *et al.*, 2018) and develop interrelationships among water, soil, and land use in Nepal (MoFE, 2021). Nepal has performed with a slower working speed than its neighboring countries (Pradhanang and Tamanna, 2020). However, still, a number of acts and regulations are expected to be formulated sooner at the local and provincial levels to implement and execute IRBM to its full potential.

In this context, this chapter aims to review the progress made in the legislative and institutional arenas for the implementation of IRBM in Nepal. It further briefly identifies the concerned institutions in water resource management and tries to shed light on the practical aspects of IRBM evolution in Nepal. These experiences, steps, and lessons learned can be useful resources to policymakers who are attempting to implement IRBM in their country.

2. Key Features of IRBM

The IRBM approach is aimed at promoting the sustainable use of water in a river basin (Barrow, 1998). The river basin is a well-defined hydro geographical zone delineated by the topographical system, comprising surface and subsurface water, drained into a common outlet (Teodosiu, Barjoveanu and Teleman, 2003; Wester and Warner, 2002). IRBM has been defined and used in diverse ways over the last century (Watson, 2004). In the words of the World Wildlife Fund for Nature (2002), IRBM is defined as 'the process of coordinating conservation, management, and development of water, land, and related resources across sectors within a given river basin, to maximize the economic and social benefits derived from water resources equitably while preserving and, where necessary, restoring freshwater ecosystems. IRBM has occasionally been applied as a method for strengthening ecosystem amenities with greater representation of wider stakeholders and maximizing the return benefits basin network (Cai, Marston and Yingchun, 2015).

The IRBM approach requires institutional provisions that ensure participation, coordination, and collaboration at the river basin level (Andersson, Petersson and Jarsjö, 2012; Franzen *et al.*, 2015). The approach seeks to build synergy between policies, programs, and practices (Burns *et al.*, 2001) related to water and river basins in order to protect the environment (Karki, Shrestha and Winiger, 2011). The key principles of IRBM should form the basis of relevant legal and institutional structures and guide every stage of operation – from planning to evaluation – of IRBM programs (Andersson, Petersson and Jarsjö, 2012; European Commission, 2000). Although IRBM programs may vary according to the context of each country/region, there is a wide agreement on the fundamental principles of IRBM. The IRBM safeguards the continuity of natural resources and ecological services. Discussions on IWRM normally propose the river basin as a logical unit for conducting water management interventions (Newson, 1997); as a subset of IWRM, IRBM focuses on integration at all levels (Chenoweth, Malano and Bird, 2001).

Top-down institutions that operate from a distant center are inappropriate for river basin management. Besides, a solo entity cannot address conflicts over water resources within a community and the pressure faced by water sources in river basins (Molle *et al.*, 2007). It is important to harmonize efforts to conserve, manage, and develop water, land, and associated resources in a particular river basin. Such integration is necessary for ensuring the equitable distribution of financial and social rewards for the sustainable use and management of water resources and for preserving essential freshwater ecosystems (Global Water Partnership, 2000).

Other key features of IRBM include the harmonization of different activities related to water resource management and the decentralization of decision-making power across central, provincial, and local levels (Molle and Hoanh, 2009). Participation of local communities and stakeholders enhances resource management in the river basin, resulting in better planning and implementation (Carr, 2015). Therefore, public consent, acceptance, and full participation of concerned stakeholders must be emphasized (Dungumaro and Madulu, 2003). Likewise, sensitization and awareness-raising, institutional capacity enhancement, and the use of suitable techniques should be incorporated to support public participation (Ahmed, Mokhtar and Alam, 2020; Elfithri, Mokhtar and Zakaria, 2019; Poppe, Weigelhofer and Winkler, 2018).

IRBM normally requires collaboration among multiple stakeholders across several spatial and temporal scales in a river basin (Lim *et al.*, 2022; Surridge and Harris, 2007). Such collaboration is necessary for the effective provisioning of resources, social mobilization, and technical services (Hooper, 2005; Panten *et al.*, 2018). Along with the physical and operational aspects of water and land management, IRBM considers water diplomacy and transboundary cooperation, governance and institutional stakeholders, gender, and other socio-economic drivers of change (Nepal *et al.*, 2019).

Although there is no rulebook for successful IRBM, the aforementioned elements are crucial, together with good governance, justice, accountability, and information sharing for regulating the approach (Kerr, 2007; Korkmaz, Alkan and Altunbaş, 2009). The concept of IRBM can address existing challenges such as the degradation of land and water resources, ever-increasing conflicts over the use of resources, and lack of coordination among relevant actors. It is an important tool for managing supply and demand or the allocation of resources to different sectors, and for establishing strong upstream-downstream linkages across the river basin.

3. Global Approaches to IRBM Implementation:

Realizing the importance of IWRM, many governments in the world have adopted the IRBM approach as a promising management approach. When a river passes from the headwaters (upstream) to the floodplains (downstream), it connects different bio-physical elements of a river basin, thereby creating physical and socio-cultural interlinkages. Globally speaking, discussions on the need for integrated water gained momentum after the Dublin Statement on Water and Development at the 1992 International Conference on Water and Environment. They focused on reforming institutional arrangements for enhanced coordination between the sub-sectors at a national level over a geographical scale and setting up institutional arrangements for managing water and related resources.

Similarly, UN-Water (2008) prepared a status report on the integrated water resource management, and water efficiency plans for the Commission on Sustainable Development 16 (CSD16). The report highlights that in the developed nations, 6 out of 27 (22%) countries have fully implemented national IWRM plans whereas 10 (37%) have plans in place and have partially implemented them. In the case of developing countries, 17 (22%) out of 77 countries, partially executed IWRM plans, and an additional 2 countries (3%) have fully implemented these plans.

Since, IWRM can be applied to a particular location, whereas IRBM looks at the whole basin including full ranges of scales from location to basin level, IRBM is gaining attention and is in the phase of implementation in different parts of the globe at different scales has shown promising results (Boekhorst *et al.*, 2010; Mokhtar *et al.*, 2011; Song *et al.*, 2010). Such as the implementation of this IRBM framework led to substantial improvements in the Liao River Basin (Leendertse, Mitchell and Harlin, 2008). Pollution loads have been reduced by 60% and the quality of river water has improved considerably. Similarly, in Colombia, after the IWRM approach was implemented for the conservation of La Cocha Lagoon at a local level, threats to the lagoon and surrounding wetlands were reduced (Lynch *et al.*, 2016). Likewise, there have been success stories of IWRM from Sri Lanka, the USA, China, and other parts of the world (Fulazzaky, 2014; Jianping and Haizhou, 2015; Moore, 2021).

4. Methodology

In this paper, we reviewed available literature on IRBM and investigated current policy frameworks to understand IRBM practices and possible pathways in Nepal. In order to accomplish this, three broad steps were taken. As a starting point, all institutions with a shared goal of water resource management under the government of Nepal were identified through informal discussions with other key stakeholders. In the second step, all relevant policies, legislation, plans, and program documents were gathered and reviewed (Table 1). The documents were gathered by visiting the institutions and meeting with the heads of departments and ministries. Several documents were accessed from the official websites of government institutions. As a third step, we collected and reviewed the various journals, newsletters, and infographics produced by different government departments and non-government organizations and referred in this article. There was an effort to ensure that all documents related to water, water resource, watershed, catchment, and river basin are prioritized and not overlooked.

Table 1: List of documents reviewed (within Nepal)

S. No.	Reviewed documents	Number
1.	Constitutions of Nepal	1
2.	Strategies	2
3.	Policies	6
4.	Plans	15
5.	Acts	8
6.	Rules and regulations	11

Additionally, expert consultation (n=10) was done with the professionals working in the sector of water, forest, and land resource management at different provincial governments and local governments to gain a better understanding of the issues and challenges. Since water resource management is concerned with multidisciplinary areas of conservation and development, we selected 5 experts from the government sector (federal government = 1, provincial government = 2, local government = 2), 2 from INGOs, 2 from civil society actors and 1 from media having an experience of more than 3 years in this sector. The questions were open-ended conversations inclined to understand the personal observations with the existing plans, policies, and water resources management policies in Nepal. It helped to understand mechanisms, lesson learned and the way forward. Also, during the literature review process, the activities launched by the different boards and conservation partners, and their coordination with the Government of Nepal was closely observed. The full titles of the documents (Strategies, policies, plans, acts, rules, and regulations) reviewed are presented in tabular form (Tables 2, 3, 4 and 5).

5. IRBM Approach in Nepal

Indigenous communities across Nepal have been managing water and watersheds in their habitats for generations. The traditional approach of watershed management involved managing land, water, biota, and other resources in a defined area for harnessing ecological, social, and economic benefits (Bogati, 1997). Although water management practices may vary across communities, their goal has always been conservation and effective management of the river basin. Examples of such practices include – protecting and maintaining the cleanliness of the wetland '*chisapan*' area; construction and continuation of the recharge '*aahal*' area; planting of the pipal (*Figus religiosa*) near a spring; and the community-based water allocation and diversion system '*paalo baadney*' (Sharma, Bajracharya and Sitaula, 2009). Although not documented in scientific papers, these practices were widespread and passed down orally over generations. Integrated watershed management (IWM) approaches practiced at watershed level has increased land cover, supplied benefits to nearest communities and reduced number of disasters (Thapa, Chaudhary and Dasgupta, 2022). Policy and programme level interventions in water management were implemented after the third Five-Year Plan (1965-1970). Watershed management activities started formally in Nepal with the formation of the Department of Soil Conservation and Watershed Management (DSCWM) under the Ministry of Forests and Environment (MoFE) in 1974. Several policies, acts, regulations, and institutions have been established for managing water and watersheds in Nepal as described in following sections.

5.1 Existing Plans/Policies/Strategies that support IRBM

Since the formation of the Water and Energy Commission Secretariat (WECS) in 1975, Nepal has launched various efforts to manage its river basins. Based on the recommendation from the WECS and other studies about water resource management, the government realizes the importance of IWRM, and internalized its program in subsequent periodic five-year development plans of the country (Khanna *et al*., 2016). Table 2 shows the different sectoral policies related to basin management. Forest policy is the master policy for forest, soil and water conservation, biodiversity, and watersheds. Forest policy envisions the management of soil and water through a participatory and integrated approach that promotes coordination and linkages between upstream and downstream communities (MoFE, 2019). National Water Resources Policy 2020 seeks to bring economic prosperity and social transformation by using water resources according to the river basin plans. Similarly, Hydropower Development Policy 2001 focuses on hydropower generation. Both policies consider the whole river basin as the unit for the management and use of water resources, an essential concept in IRBM; these policies are implemented by the Ministry of Energy, Water Resources, and Irrigation (MoEWRI). Other policy interventions from the government include the irrigation policy 2013, climate change policy 2019, and wetland policy 2012 which have embraced the importance of integrated water resource management for sustainable development.

National Water Plan 2005 is one of the important documents developed by WECS, adopts IWRM as a principal component, and envisions the establishment of powerful river basin institutions. Similarly, Water Resources Strategy 2002 recognizes the need to manage water resources in an integrated and sustainable way through a participatory approach. National Water Supply and Sanitation Sector Policy 2014 aims to address water supply and sanitation issues – an essential part of IRBM – in both rural and urban areas. Irrigation Policy 2013 envisions that irrigation projects shall be guided by the principle of IRBM. In 2015, Nepal promulgated a new Constitution providing for a multitier government structure namely federal, provincial, and local government (Adhikari, 2021). The government seeks to promote holistic management of land and water resources as well as provide multiple benefits of water to communities. The government also aims to address climate and water-induced disasters through an integrated watershed management approach. Meanwhile, IRBM has been adopted as a conceptual framework for water resources planning and management worldwide (UNEP, 2012; UN-Water, 2008; Van der Zaag, 2005).

Table 2: Policies, plans, and strategies related to the water sector in Nepal

Policies/Plan/Strategy	*Key provision on water management*	*Ministry/Department*
Hydropower Development	Hydropower generation	MoEWRI

Policy 2001		
Water Resources Strategy 2002	Access to sufficient water and sanitation	WECS
National Water Plan 2005	Management of water resources on a basin-scale rather than on a project scale	WECS
National Wetland Policy 2012	Wetlands management	MoFE/DNPWC
Irrigation Policy 2013	Sustainable irrigation	MoEWRI/ Department of Water Resources and Irrigation (DWRI)
National Biodiversity Strategy and Action Plan 2014-2024	Payment for Ecosystem Services (PES) in selected sub-watersheds	MoFE/Department of National Parks and Wildlife Conservation (DNPWC)
National Water Supply and Sanitation Sector Policy 2014	Drinking water supply and sanitation for rural and urban areas	MoEWRI
Forest Policy 2019	Forest, watershed, biodiversity	MoFE
National Climate Change Policy 2019	Climate change adaptation through integrated watershed management	MoFE
National Water Resources Policy, 2020	Achieve economic prosperity and social transformation by using water resources according to river basin plans	MoEWRI
The Constitution of Nepal	Provisioned as fundamental rights	Government of Nepal (GoN)

5.2 Evolution of Watershed/Basin Management in National Plans

In Nepal, periodic plans for national development are prepared and implemented along with other sectoral plans. Since the 1956, several periodic development plans have been formulated and implemented in the country. The National Planning Commission (NPC) is mandated by the GoN to formulate national periodic plans (Table 3) for the nation's development.

During the Fourth Five-Year Plan (1970-1975) period, the Department of Soil and Water Conservation (DoSWC) under the Ministry of Forest was established in 1974. Likewise, the Fifth Plan (1975-1980) envisioned a massive erosion control program to implement soil and watershed conservation and education programmes nationwide. During the Sixth Five-Year Plan period (1980-1985), Soil Conservation and Watershed Management Act 1982 and Regulations 1985 came into existence. After this, the Seventh Plan (1985-1990) made the mandatory provision of environmental assessment for development projects and during that period the environment division was established in the DoSWC. During the Ninth Plan (1997-2002) period, an integrated watershed management approach was envisioned. Then consecutively, the Tenth (2002-2007), Eleventh (2007-2010), Twelfth (2010-2013), and Thirteenth plans (2013-2016) highlighted that soil and watershed management programmes would be designed using a basin approach across the country. The Fourteenth Plan (2014-2019) has envisioned inter-watershed water diversion using surface, subsurface, and groundwater for irrigation, hydropower generation, dry land management, and climate change management through a basin approach. The development process became more complex in the last 20 years as the development paradigm shifted from a focus on economic growth to human, societal, and environmental development. Similarly, an approach paper for the Fifteenth Plan (2019-2024) states that the policy and plans shall be prepared for four major river basins, and an integrated watershed management approach shall be used for disaster risk minimization and water management.

Table 3: Nepal's periodic plans and evolution of watershed /basin management approach

Periodic Plan Year	*Provisions related to the watershed, water, and environment in policies/plans*
1965-1970 (Third Plan)	Importance of soil and water conservation recognized;
1970-1975 (Fourth Plan)	DoSWC established, in 1974.
1975-1980 (Fifth Plan)	Regional development concept in SCWM introduced; Fourteen WM projects implemented; Concept of integrated WM formally introduced; River training work continued.
1980-1985 (Sixth Plan)	River control work transferred to the Ministry of Water Resources; Soil Conservation Act 1982 and Regulations 1985 passed; Environment Impact Study Project 1980 implemented under DSCWM.
1985-1990 (Seventh Plan)	Twenty-Five-Year Master Plan for the Forestry Sector endorsed with SCWM as a priority programme.
1992-1997 (Eighth Plan)	Expansion of the number of SCWM offices in the country (District offices established).
1997-2002 (Ninth Plan)	Nepal Environment Protection Action Plan 1998 endorsed SCWM as a priority; 45 permanent and 10 temporary district soil conservation offices established.
2002-2007 (Tenth Plan)	Emphasized Churia/Siwaliks, people's participation, and integrated watershed management. SCWM programmes through a basin approach nationwide.
2007-2010 (Eleventh Plan)	Execution of watershed improvement activities mentioned in the National Water Resources Strategy and the National Water Plan. Upscaling of SCWM initiatives countrywide.
2010-2013 (Twelfth Plan)	River basin management approach for integrated conservation and management of watersheds. Integrated Chure watershed conservation plan preparation, upstream-downstream linkage for watershed management at a landscape level.
2013-2016 (Thirteenth Plan)	Basin approach for watershed management in large rivers, water disaster control.
2016-2019 (Fourteenth Plan)	Inter-watershed water diversion using surface, subsurface, and groundwater. Dryland management and climate change adaptation through watershed management, basin approach continued.

2019-2024 (Fifteenth Plan)	Integrated watershed management plans for river basins namely Koshi, Gandaki, Karnali, and Mahakali to be prepared and implemented.

5.3. Provisions for Water and Watershed Management in Existing Acts

Nepal has no separate Act regarding IRBM, but the IRBM concept is reflected in many legislative documents in the country. Nepal has been amending and revising the legal framework to better manage water and the environment. Existing laws in Nepal can be categorized into following five main categories.

1. Constitution
2. Statutes/Act
3. Rules and regulations
4. Policies
5. International treaties/conventions
6. Formation orders
7. Others(guidelines/circulars)

Primary legislation such as Acts, and Regulations are formed in the parliament and executed by the GoN. There are several Acts concerning the management of water, land, forest, environment, and other natural resources (Table 4).

Table 4: Major Acts related to water and water resources

Acts	*Key provision on water management*	*Ministry/Department*
Soil and Watershed Conservation Act 1982	Watershed management, Disaster risk reduction	MoFE/DoFSC
Electricity Act 1993	Water as a main source of hydropower	MoEWRI, DoED
Water resource Act 1993	Management and utilization of water resources	MoEWRI/DoWRI
Local Self Governance Act 1999	Water source, environment and sanitation, irrigation, and river training	Ministry of Federal Affairs and General Administration (MoFAGA)
Solid Waste Management Act 2011	Environment and waste management	MoFAGA
Disaster Risk Reduction and Management Act 2017	Relief from water-induced disasters	(Ministry of Home Affairs) MoHA
Local Government Operation Act 2017	Drinking water supply, watershed conservation	MoFAGA
Environment Protection Act 2019	Assessment of development activities and water pollution	MoFE/Department of Environment (DoE)
Forest Act 2019	Watershed, water cycles and watershed services	MoFE/DoFSC

Currently, there are nine Acts (Table 3) with some provisions for watershed management. These Acts include the Electricity Act 1993, which considers water as a main source of hydropower and states that negative impacts on water sources should be minimized. The MoEWRI is responsible for implementing this Act. Forest Act 2019 regards watershed services as part of ecosystem services, and development activities are prohibited in erosion-prone areas. Soil and Watershed Conservation Act was endorsed in 1982 and it envisions integrated watershed management as the main approach for water and soil conservation, but this Act has been dormant for the last 25 years. Water Resource Act was enacted in 1993 to protect, manage and utilize surface and subsurface water sources. The Act prohibited activities that would have adverse effects on water and the environment and may trigger soil erosion, flood, and landslides. Environment Protection Act was formulated in 1993 for the protection of the environment with proper use and management of natural resources. Under this Act, projects that may have adverse effects on the environment must carry out an Initial Environment Examination (IEE) and an Environment Impact Assessment (EIA) prior to commencement.

5.4. Provisions on Water and Watershed Management in Existing Regulations

Table 5 presents the rules and regulations related to the water and water resource management sector. These rules and regulations elaborate on the provisions of related Acts. They cover the protection of aquatic animals, rainwater harvesting, pollution control, drinking water, irrigation system, water flow and use, and soil conservation and management. Similarly, Shivpuri Nagarjun National Park Rules 2019 also highlighted that water sources from the national park are affected by excessive extraction and need to be conserved. In this regard, payment for use of water resources has been envisioned in the Rules, and the Park administration is to monitor the implementation of the provision.

Table 5: Rules and regulations related to the water sector in Nepal

Rules/Regulations	*Key provision on water management*	*Ministry/Department*
Aquatics (Contract) Rules1962	Water or Aquatics Contract, Protection of Aquatic animal	Ministry of Agriculture and Livestock Development (MoALD)/Department of Agriculture (DoA)
Water Resources Regulation 1993	Water resource management	Ministry of Water Supply (MoWS)
Environment Protection Regulation 1997	Sets standards for pollution control	MoFE/Department of Environment (DoE)
Drinking-Water Rules 1998	Drinking-Water supply, Maintain quality of water	MoWS/ Department of Water Supply and Sewerage Management (DWSSM)
Local Self Governance Regulation 1999	Water-related plan and project implementation	Ministry of Federal Affairs and General Administration (MoFAGA)
Irrigation Rules 2000	Irrigation system, Surface water/ Groundwater	MoEWRI, Department of Irrigation (DoI)

Mountaineering Expedition Rules 2002	Environment protection, pollution control	Ministry of Culture, Tourism and Civil Aviation (MoCTCA)/ Department of Transport (DoT)
Mines and Mineral Matter(1st Amendment) Regulation 2003	Mines and minerals extraction, water flow and use, surface, groundwater	Ministry of Industry, Commerce, and Supplies (MICS) / Department of Mines and Geology (DMG)
Rafting Rules 2013	Water entertainment/travel	MoCTCA
Soil and Watershed Conservation Regulation, Amendment 2013	Soil and water conservation (SWC)	MoFE/DoFSC
Shivpuri Nagarjun National Park Rules 2019	Payment for the use of water resources from national parks and buffer zone	MoFE/DNPWC

5.5. Consortium, Participatory Approach for Conservation

The active involvement of people is a key component of water resource management in Nepal. Participation of locals, primary stakeholders, and government/non-government organizations plays a huge role in the implementation of the IRBM concept in Nepal (Sharma *et al.*, 1997). The government has also introduced policies to support the role of the public/private sector in hydropower development. The Community-Based Water Resource Development and Management (CBWRDM) programme is being carried out in different locations; however, it is implemented at the local level scale such as in the Durlung watershed (Khanna *et al.*, 2016).

Likewise, the non-government sector has made some effort to promote the concept such as FAO, WWF, IUCN, ICIMOD, WaterAid, and other organizations are actively promoting the concept of IRBM. Past donor-funded projects on improving watershed management include the CARE International funded Begnas Tal-Rupa Tal (BTRT) Watershed Management Project, Swiss/German funded Tinau watershed project, European Union funded Bagmati watershed project, the ADB-funded Building Climate Resilience of Watersheds in Mountain Eco-Regions (BCRWME) projects in West Seti and Budhi Ganga watersheds, JICA supported Participatory Watershed Management and Local Governance Project (PWMLGP) (Achet and Fleming, 2006; Kayastha, Bjracharya and Shrestha, 1997; Fleming, 1983; Suelzer and Sharma, 1986). However, these projects were short-lived. Effective and long-term implementation of the IWRM/IRBM approach requires a more robust approach (Suhardiman, Clement and Bharati, 2015).

Several projects have adopted IRBM approaches in Nepal. Koshi River Basin Management Project (KRBM) piloted the IRBM approach in 2009 to operationalize the National Water Plan 2005. Initiated by WECS in association with WWF Nepal, this project aims to make optimum use of water and related resources from the Koshi basin for socio-economic development while maintaining ecological balance. Bagmati River Basin Improvement Project (2014-2021) was initiated by the GoN for improving the river environment and managing floods. ICIMOD in collaboration with the Department of Forests and Soil Conservation (DoFSC) has promoted integrated river basin management through the Koshi Basin Initiative (2018-2021).

5.6. Shift in the Water Resource Management Approach to IRBM

Earlier, water resources/watershed management programmes used a top-down approach that focused on managing a small portion of the river basin. Figure 1 shows how the approach to resource conservation has shifted over time, and how the strategy and policy for water resource management have been changing according to the needs of present times and the changing global context. Water resource management encompasses different aspects of IRBM. To promote the concept of the IRBM, Nepal is shifting from a site-specific micro-watershed management approach towards a broader scale river basin management approach that involves multitier governments and stakeholders related to the river basin within the country and sometimes transboundary institutions as well.

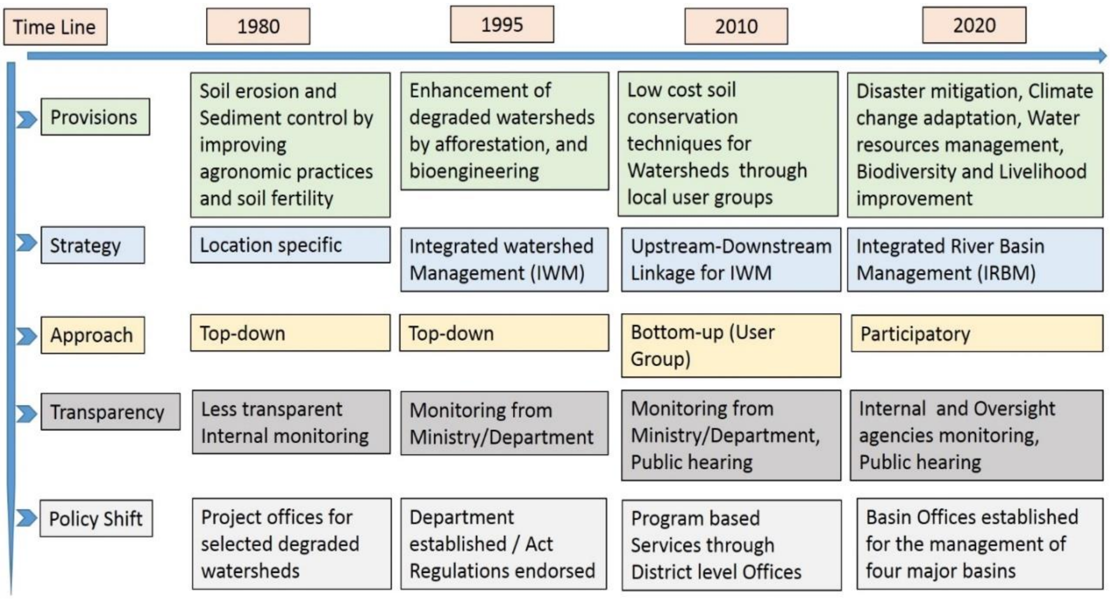

Figure 1: A paradigm shift in water resources/watershed management in Nepal

5.7. Current Organizational Structure and Arrangement for IRBM

The Constitution of Nepal 2015 is the overarching legislation guiding the conservation, management, and use of environmental resources including water in the country. The constitution mentioned the need to reduce poverty and promote shared prosperity through the holistic management of natural resources of the river basin (*Clause 51 of the Constitution*). The Constitution has ensured the separation of powers among the three tiers of government (federal, provincial, and local) for the formulation of policy and the use, safeguarding, and management of available water resources (Gautam and Kumar, 2019).

In general, we have identified several central, provincial, and local level institutions working on the common theme of water resource management is presented in figure 2 in a hierarchical position. This study has not presented their detailed role and responsibilities but only presented the way they are linked and share information with the central government. Ministries, departments, provincial government, local government, commissions/boards, and conservation partners exchange the information produced or collected in vertical and horizontal ways among each other and with the central government (Shown by the two-way arrow in figure 2). The sectoral entities submit the data to the higher authorities and the respective higher authorities are responsible to compile the data to make the meaningful information (Shown by one way arrow in figure 2). In this context to coordinate several organizations the National Development Action Committee (NDAC) chaired by the Prime Minister, at its 39th meeting in 2017, decided to form an authorized High-level committee chaired by the Minister of Forest and Environment to look after river basin management approaches. The high-level committee further formed a technical committee consisting of the Joint Secretary of the NPC (as the chairperson) and representatives from various ministries and departments to prepare an approach paper on IRBM (GoN/NPC, 2017). NDAC and the High-level committee were chaired by political personnel. The technical committee was formed to include the experts and specialists in the field of water resource management to study IRBM and recommend the High-level committee for decision-making about IRBM policy and programs.

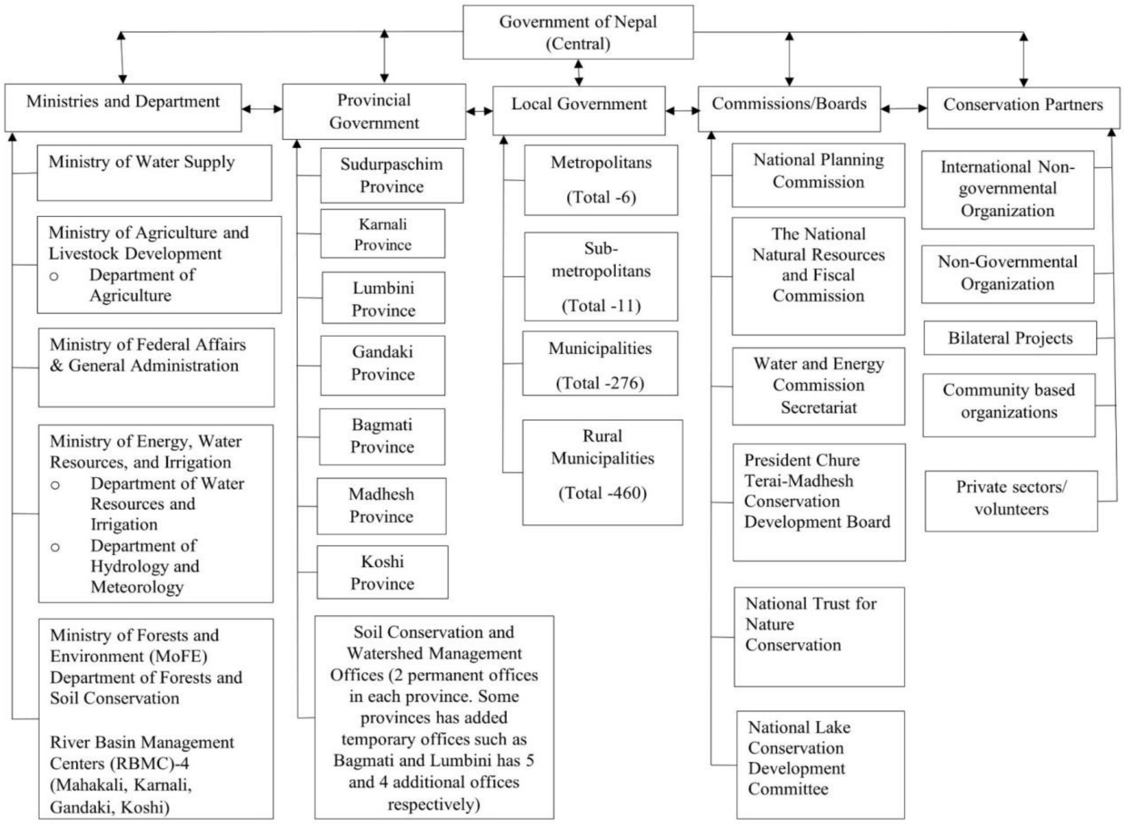

Figure 2: Various institutions related to water resource management and data/information sharing direction to their higher authorities

More specifically, in this context, by the Federal government, under the MoFE, four river basin management centers (RBMC) have been established to carry out targeted interventions in the large river systems of Nepal, namely Koshi, Gandaki, Karnali, and Mahakali (Table 6, Figure 3) (GoN/OPMCM, 2018).

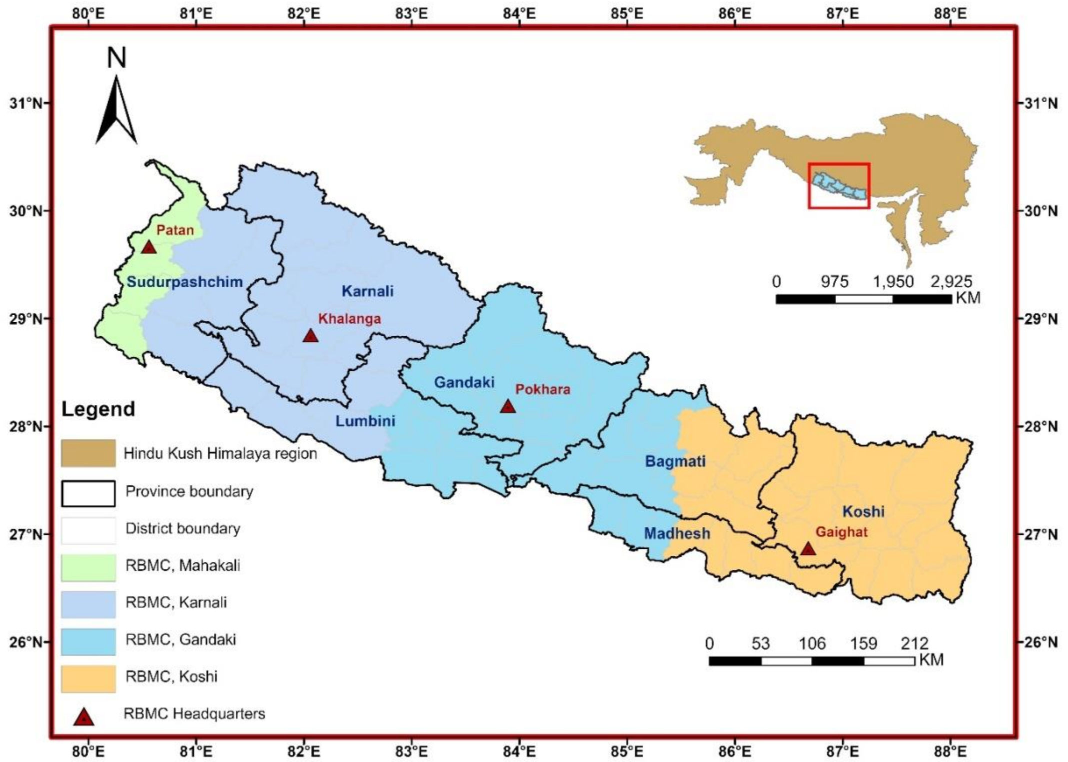

Figure 3: River Basin Management Centre (RBMC) working area and provinces boundary in Nepal

These Basin Management Centers (BMCs) are mandated to carry out watershed management interventions using a river basin approach. For this, they have to coordinate and collaborate with the line agencies. The BMCs are supposed to generate data related to watershed management, provide technical assistance to state ministries, and facilitate basin management issues in interprovincial affairs. They are currently organizing awareness programs, holding workshops and seminars, and preparing plans for the river basins in collaboration with the central government and conservation partners working in the respective basins. The unit for carrying out their interventions is the sub-watershed. However, these institutions lack sufficient human and financial resources for addressing complex problems as they have a large working area starting from 68.69 sq. km in the Mahakali basin to 55,328.61 sq. km in the Karnali basin.

Table 6: River Basin Management Centre's working area and districts covered

Working area	*Headquarters' location*	*No. of districts covered*
Basin Management Centre, Koshi (42,090.90 sq. km)	Udayapur, Gaighat	24 districts
Basin Management Centre, Gandaki (43,399.86 sq. km)	Kaski, Pokhara	28 districts
Basin Management Centre, Karnali (55,328.61 sq. km)	Jajarkot, Khalanga	21 districts
Basin Management Centre, Mahakali (6969.46 sq. km)	Baitadi, Patan	4 districts

Note: The area of the Basin Management Centre is calculated based on information provided by the local level portal of MoFAGA and includes fringe areas of independent sub-basins

6. Issues, Challenges, and Lessons Learned

Nepal is starting to adopt the IRBM approach for water resource management, but various challenges remain. Government programs in the water sector are fragmented and implemented by different institutions, departments, and offices. There is a lack of a holistic approach for carrying out IRBM activities, and different ministries have different policies on river basin management. During the federal restructuring, the hydro-physical boundary was neglected to define local units' and provincial units' boundaries. These boundaries are serving as a territorial and administrative demarcation that was based on political decisions to capture certain resources and include certain actors. But the river basins are intersecting these administrative boundaries and extend beyond political boundaries requiring institutions not only at the provincial level but also at the national level and transboundary level. This further necessitates coordination among various institutions and stakeholders for their active participation in the planning and implementation of water resource management interventions to achieve IRBM objectives as mentioned by Clement, Suhardiman and Bharati, 2017. Likewise, there are many departments/ministries working on the same water and related natural resources; so, it seems necessary to establish a powerful authority to coordinate multi-provincial water resource management issues in a holistic way. The focus should now shift from the formulation of plans and policies to carrying out institutional reforms from the central to local level for effective water resource management. A proper feedback loop mechanism from the local level to the central level has not been set up yet. The River Basin Management Centers have recently been established and their functions have been defined but they lack sufficient human as well as financial resources to function and operate at the river basin level.

7. Conclusion and A Way Forward

The IRBM is a broad framework for the management of water and watershed resources. This paper shows how Nepal is moving towards the IRBM approach as the country has shifted from the unilateral system to the federal system. It highlights three major points. First, practices of water resource management are changing with time and demand an integrated approach that can ensure the participation of various stakeholders in all phases, from planning to implementation, as well as coordination and collaboration. Site-specific interventions and fragmented development activities only deteriorate the quality of the river basins rather than ensuring the sustainability of water resources. The IRBM approach is a promising approach, and it needs to be carefully implemented to improve the management of watersheds and thus enhance the livelihood, achieve prosperity, and create resilient communities. Second, the implementation of IRBM demands a great degree of political will along with well-resourced institutions. The Basin Management Centers, if empowered with strong policies and adequate resources, could be the best option for implementing the IRBM approach in Nepal. Third, after federal restructuring, local and provincial governments have gained the right to make their own policies and legislation. And there could be some conflict of interest in water resource management as the administrative boundaries do not follow the hydrological boundaries. Diverse legislative authorities govern the management of water resources and basins through different ministries and departments. So, a powerful authority is needed to bridge the relations among local, provincial, and federal governments for sustainable management of water resources. Resource management efforts in Nepal have yet to realize the full potential of the IRBM approach. However, with adequate political will, resources, and collaboration at all levels, IRBM could help ensure the sustainability of the river basins as well as improve the livelihood of communities. The lessons learned from Nepal will be helpful for other countries that are aiming to implement IRBM in their countries.

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9. References

Abdel-Magid, I. and Ahmed, S. (2002). Integrated Water Resources Management and Global Water Partnership. Paper presented at the Global and National Water Partnership Workshop, 13 August 2002, Khartoum. DOI: https://doi.org/10.13140/RG.2.1.4444.4647.

Achet, S.H. and Fleming, B. (2006). A watershed management framework for mountain areas: Lessons from 25 years of watershed conservation in Nepal. *Journal of Environmental Planning and Management*, 49(5): 675–694. DOI: https://doi:10.1080/09640560600849962.

Adhikari, D.B. (2021). Planning Guideline for Three Tires Government of Nepal. *Theoretical Economics Letters*, 11(3): 558–571. DOI: https://doi.org/10.4236/tel.2021.113037.

Ahmed, M.F., Mokhtar, M.B. and Alam, L. (2020). Factors influencing people's willingness to participate in sustainable water resources management in Malaysia. *Journal of Hydrology: Regional Studies*, 31, 100737. DOI: https://doi.org/10.1016/j.ejrh.2020.100737.

Andersson, I., Petersson, M. and Jarsjö, J. (2012). Impact of the European Water Framework Directive on local-level water management: Case study Oxunda Catchment, Sweden. *Land Use Policy*, 29: 73–82. DOI: https://doi.org/10.1016/j.landusepol.2011.05.006.

Bach, H., Clausen, T.J., Trang, D.T., Emerton, L., Facon, T., Hofer, T., Lazarus, K., Muziol, C., Noble, A.D., Schill, P., Sisouvanh, A., Wensley, C. and Whiting, L. (2011). From local watershed management to integrated river basin management at national and transboundary levels [Report]. Mekong River Commission. Available online at: https://cgspace.cgiar.org/handle/10568/4752 [accessed 8 March 2022].

Barrow, C.J. (1998). River basin development planning and management: A critical review. *World Development*, 26(1): 171–186. DOI: https://doi:10.1016/s0305-750x(97)10017-1.

Boekhorst, D., Smits, T., Yu, X., Li, L., Lei, G. and Zhang, C. (2010). Implementing Integrated River Basin Management in China. *Ecology and Society*, 15. DOI: https://doi.org/10.5751/ES-03369-150223.

Bogati, R. (1997). A case study of people's participation in Begnastal and Rupatal (BTRT) watershed management in Nepal. In Case studies of people's participation in watershed management in Asia (GCP/RAS/161/NET). FAO (UN), Nepal. Available online at: https://www.fao.org/3/X5669E/x5669e04.htm [accessed 6 March 2022].

Burns, B., Bandaragoda, D.J. and Samad, M. (2001). Integrated Water-Resources Management in a River-Basin Context: Institutional Strategies for Improving the Productivity of Agricultural Water Management. In: Proceedings of the Regional Workshop, Malang, Indonesia. International Water Management Institute. Available online at: https://www.ircwash.org/sites/default/files/Bruns-2002-Integrated.pdf [accessed 1 February 2022].

Cai, X., Marston, L. and Yingchun, G. (2014). Decision support for integrated river basin management—Scientific research challenges. *Science China Earth Science*, 58: 1–9. DOI: https://doi.org/10.1007/s11430-014-5005-2.

Carr, G. (2015). Stakeholder and public participation in river basin management—An introduction. *WIREs Water*, 2(4): 393–405. DOI: https://doi.org/10.1002/wat2.1086.

Chenoweth, J.L., Malano, H.M. and Bird, J.F. (2001). Integrated River Basin Management in the Multi-jurisdictional River Basins: The Case of the Mekong River Basin. *International Journal of Water Resources Development*, 17(3): 365–377. DOI: https://doi.org/10.1080/07900620120065147.

Clausen, T.J. (2011). Scoping and planning of Integrated Water Resources Management (IWRM) and River Basin Management (RBM) component in Lao PDR and Thailand for the Mekong Water Dialogues, August 2011. Gland, Switzerland: IUCN, p.32. Available online at: https://portals.iucn.org/library/node/12820 [accessed 10 February 2022].

Clement, F., Suhardiman, D. and Bharati, L. (2017). IWRM discourses, institutional Holy Grail and water justice in Nepal. *Water Alternatives*, 10(3): 870–887. Available online at: https://www.water-alternatives.org/index.php/alldoc/articles/vol10/v10issue3/386-a10-3-12/file [accessed 18 February 2022].

Dinar, A. (1999). Review of Integrated Approaches to River Basin Planning, Development, and Management (SSRN Scholarly Paper No. 620675). Social Science Research Network. Available online at: https://papers.ssrn.com/abstract=620675 [accessed 3 May 2022].

Dungumaro, E.W. and Madulu, N.F. (2003). Public participation in integrated water resources management: The case of Tanzania. *Physics and Chemistry of the Earth, Parts A/B/C*, 28(20): 1009–1014. DOI: https://doi.org/10.1016/j.pce.2003.08.042.

Easter, K.W., Dixon, J.A. and Hufschmidt, M.M. (1991). Watershed Resources Management: Studies from Asia and the Pacific. Singapore: ISEAS Publishing. DOI: https://doi.org/10.1355/9789814345880.

Eastham, J., Mpelasoka, F., Mainuddin, M., Ticehurst, C., Dyce, P., Hodgson, G., Ali, R. and Kirby, M. (2008). Mekong River Basin Water Resources Assessment: Impacts of Climate Change. Water for a Healthy Country National Research Flagship Report Series, The Commonwealth Scientific and Industrial Research Organization (CSIRO), Canberra, Australia, p.131 . Available online at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.457.9113&rep=rep1&type=pdf [accessed 14 February 2022].

Elfithri, R., Mokhtar, M.B. and Zakaria, S. (2019). The need for awareness raising, advocacy, and capacity building in Integrated Water Resources Management toward sustainable development: A case study in Malaysia. *World Water Policy*, 5(1): 43–54. DOI: https://doi.org/10.1002/wwp2.12002.

European Commission (2000). Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000, establishing a framework for Community action in the field of water policy. *Official Journal of the European Communities L*, 327: 1–72. Available online at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32000L0060&from=EN [accessed 22 April 2022].

European Commission (2003). Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Guidance Document no. 8. Public Participation in Relation to the Water Framework Directive. Working group 2.9—Public Participation. Luxembourg.

Evers, M. (2016). Integrative river basin management: Challenges and methodologies within the German planning system. *Environmental Earth Sciences*, 75(14): 1085. DOI: https://doi.org/10.1007/s12665-016-5871-3.

Fleming, W.M. (1983). Management plan for the Phewa Tal catchment. Phewa Tal catchment management program: benefits and costs of forestry and soil conservation in Nepal. In: L. W. Hamilton (Ed.) Forest and Watershed Development and Conservation in Asia and the Pacific, pp. 217 – 288 (Boulder, CO: Westview Press).

Franzén, F., Hammer, M. and Balfors, B. (2015). Institutional development for stakeholder participation in local water management—An analysis of two Swedish catchments. *Land Use Policy*, 43: 217–227. DOI: https://doi.org/10.1016/j.landusepol.2014.11.013.

Fulazzaky, M.A. (2014). Challenges of Integrated Water Resources Management in Indonesia. *Water*, 6 (7): 2000–2020. DOI: https://doi.org/10.3390/w6072000.

Gautam, S. and Kumar, P. (2019). Moving towards sustainable Nepal - India water relations in the present context of federalism in Nepal. In: KEC Conference 2019, Kantipur Engineering College, Dhapakhel Lalitpur. [online] pp. 125-131. Available online at: http://kec.edu.np/wp-content/uploads/2020/01/Paper_22.pdf [accessed on 5 May 2022].

Giakoumis, T. and Voulvoulis, N. (2018). The Transition of EU Water Policy Towards the Water Framework Directive's Integrated River Basin Management Paradigm. *Environmental Management*, 62(5): 819–831. DOI: https://doi.org/10.1007/s00267-018-1080-z.

Gleick, P.H. (2000). A Look at Twenty-first Century Water Resources Development. *Water International*, 25(1): 127–138. DOI: https://doi.org/10.1080/02508060008686804.

Global Water Partnership (2000). Integrated Water Resources Management. TAC Background Papers No. 4, p. 22 (Stockholm: GWP Secretariat). Available online at: https://www.gwp.org/globalassets/global/toolbox/publications/background-papers/04-integrated-water-resources-management-2000-english.pdf [accessed on 25 May 2022].

GoN/MoFE (2014). National Biodiversity Strategy and Action Plan 2014-2020.Government of Nepal, Ministry of Forests and Environment, Singha Durbar, Kathmandu, Nepal, pp.18-200. Available online at: https://www.cbd.int/kb/Results?q=nepal [accessed on 9 April 2022].

GoN/NPC (2017). 39th NDAC Report. Government of Nepal, National Planning Commission, Singha Durbar, Kathmandu, Nepal. Available online at: https://www.npc.gov.np/images/category/39ndac_report.pdf [accessed 20 February 2022].

GoN/OPMCM (2018). Cabinet-Decisions. Government of Nepal, Office of the Prime Minister and Council of Ministers, Singhadurbar, Kathmandu, Nepal. [online-Nepali language] Available online at: https://www.opmcm.gov.np/cabinet-decision/ [accessed 2 April 2022].

Gooch, G.D. and Stålnacke, P. (2010). Science, policy, and stakeholders in water management-An integrated approach to river basin management. London, pp.1-60. DOI: https://doi.org/10.4324/9781849775151.

Gourbesville, P. (2008). Challenges for integrated water resources management. *Physics and Chemistry of the Earth, Parts A/B/C*, 33(5): 284–289. DOI: https://doi.org/10.1016/j.pce.2008.02.002.

Hooper, B. (2005). Integrated River Basin Governance: Learning from International Experience. United Kingdom: WA Publishing, pp.1-268. DOI: https://doi.org/10.2166/9781780402970.

ICWE (1992). The Dublin Statement on Water and Sustainable Development. (International Conference on Water and the Environment). Available online at: https://www.gdrc.org/uem/water/dublin-statement.html [accessed 2 April 2022].

Jewitt, G. (2002). Can Integrated Water Resources Management sustain the provision of ecosystem goods and services? *Physics and Chemistry of the Earth, Parts A/B/C*, 27(11): 887–895. DOI: https://doi.org/10.1016/S1474-7065(02)00091-8.

Jianping, W. and Haizhou, M. (2015). The effectiveness of small-to-medium river basin organizations in China: A case study of the Erhai Lake Basin Management Commission. *International Journal of Water Resources Development*, 31(4): 589–603. DOI: https://doi.org/10.1080/07900627.2014.935979.

Karki, M.B., Shrestha, A.B. and Winiger, M. (2011). Enhancing Knowledge Management and Adaptation Capacity for Integrated Management of Water Resources in the Indus River Basin. *Mountain Research and Development*, 31(3): 242–251. DOI: https://doi.org/10.1659/MRD-JOURNAL-D-11-00017.1.

Kattelus, M. (2009). Integrated Water Resources Management in Practice: Better Water Management for Development – Edited by Roberto Lenton and Mike Muller. *Natural Resources Forum*, 33(4): 339–340. DOI: https://doi.org/10.1111/j.1477-8947.2009.01248.x.

Kayastha, B.N., Bjracharya, K.M. and Shrestha, A. (1997). Begnas Tal Rupa Tal (BTRT) Watershed Management Project. Final Evaluation Report (Kathmandu: CARE International Nepal Office).

Kerr, J. (2007). Watershed Management: Lessons from Common Property Theory. *International Journal of the Commons*, 1. DOI: https://doi.org/10.18352/ijc.8.

Khanna, S.A., Shrestha, K.L., Maskey, R.K., Lamsal, A., Pyakurel, K., Poudyal, M., Ranjit, M., Karki, D., Aryal, R. and Shrestha, A. (2016). Integrated Water Resource Management (IWRM): A Case Study of Durlung Watershed, Bagmati Zone, Nepal. *Hydro Nepal: Journal of Water, Energy and Environment*, 18: 47–54. DOI: https://doi.org/10.3126/hn.v18i0.14645.

Korkmaz, M., Alkan, H. and Altunbaş, S. (2009). Water Resources Management: Socio Economic Assessments (The Example of Egirdir (Lake Management Plan in Turkey). International Davraz Congress, Isparta, pp. 1666–1675.

Leendertse, K., Mitchell, S. and Harlin, J. (2008). IWRM and the environment: A view on their interaction and examples where IWRM led to better environmental management in developing countries. *Water SA*, 34(6): 691–698. DOI: https://doi.org/10.4314/wsa.v34i6.

Lepcha, P.T., Pandey, P.K. and Ranjan, P. (2021). Hydrological significance of Himalayan surface water and its management considering anthropogenic and climate change aspects. *IOP Conference Series: Materials Science and Engineering*, 1020(1): 012013. DOI: https://doi.org/10.1088/1757-899X/1020/1/012013.

Lim, C.H., Wong, H.L., Elfithri, R. and Teo, F.Y. (2022). A Review of Stakeholder Engagement in Integrated River Basin Management. *Water*, 14 (19): 2973. DOI: https://doi.org/10.3390/w14192973.

Lynch, A.J.J., Kalumanga, E., Ospina, G.A., Lynch, A.J.J., Kalumanga, E. and Ospina, G.A. (2016). Socio-ecological aspects of sustaining Ramsar wetlands in three biodiverse developing countries. *Marine and Freshwater Research*, 67(6): 850–868. DOI: https://doi.org/10.1071/MF15419.

Meinzen-Dick, R. (2007). Beyond panaceas in water institutions. Proceedings of the National Academy of Sciences, 104(39): 15200–15205. DOI: https://doi.org/10.1073/pnas.0702296104.

Mitchell, B. and Hollick, M. (1993). Integrated catchment management in Western Australia: Transition from concept to implementation. *Environmental Management*, 17 (6): 735–743. DOI: https://doi.org/10.1007/BF02393894.

MoFE. (2019). राष्ट्रिय वन नीति [National Forests Policy-2075]. Ministry of Forests and Environment, Government of Nepal. Available online at: https://mofe.gov.np/downloadfile/Ban%20Niti_1554873640.pdf [accessed on 23 April 2022].

MoFE (2021). Vulnerability and Risk Assessment and Identifying Adaptation Options in the Forest, Biodiversity and Watershed Management in Nepal. Ministry of Forests and Environment, Government of Nepal. Kathmandu, Nepal. Worldwide Print Solution, pp.17-149. Available online at: http://www.mofe.gov.np/downloadsdetail/3/2018/98853603 [accessed 21 March 2022].

Mokhtar, M., Toriman, M., Hossain, M. and Weng, T. (2011). Institutional challenges for integrated river basin management in Langat River Basin, Malaysia. *Water and Environment Journal*, 25: 495–503. DOI: https://doi.org/10.1111/j.1747-6593.2010.00245.x.

Molle, F. and Hoanh, C.T. (2009). Implementing integrated river basin management: Lessons from the Red River Basin, Vietnam. Colombo, Sri Lanka: International Water Management Institute, (IWMI Research Report 131), pp.9-22. Available online at: https://www.iwmi.cgiar.org/publications/iwmi-research-reports/iwmi-research-report-131 [accessed 22 March 2022].

Molle, F. and Hoanh, C.T. (2011). Implementing integrated river basin management in the Red River Basin, Vietnam: A solution looking for a problem? *Water Policy*, 13(4): 518–534. DOI: https://doi.org/10.2166/wp.2011.012.

Molle, F., Wester, P., Hirsch, P., Jensen, J.R., Murray-Rust, H., Paranjpye, S. and van der Zaag, P. (2007). River basin development and management. In Water for food Water for life: A comprehensive Assessment of Water Management in Agriculture, pp. 585–625. DOI: https://doi.org/10.1002/9781118786352.wbieg0907.

Moore, S. (2021). Toward effective river basin management (RBM): The politics of cooperation, sustainability, and collaboration in the Delaware River basin. *Journal of Environmental Management*, 298, 113421. DOI: https://doi.org/10.1016/j.jenvman.2021.113421.

Mukherji, A., Molden, D., Nepal, S., Rasul, G. and Wagnon, P. (2015). Himalayan waters at the crossroads: Issues and challenges. *International Journal of Water Resources Development*, 31(2): 151–160. DOI: https://doi.org/10.1080/07900627.2015.1040871.

Nepal, S., Flügel, W.A. and Shrestha, A.B. (2014). Upstream-downstream linkages of hydrological processes in the Himalayan region. *Ecological Processes*, 3(1): 19. DOI: https://doi.org/10.1186/s13717-014-0019-4.

Nepal, S., Shrestha, A.B., Goodrich, C.G., Mishra, A., Prakash, A., Bhuchar, S., Vasily, L.A., Khadgi, V. and Pradhan, N.S. (2019). Multiscale Integrated River Basin Management from a Hindu Kush Himalayan Perspective, Resource Book, ICIMOD, Kathmandu. Available online at: https://lib.icimod.org/record/34656 [accessed 17 April 2022].

Newson, M. (1997). Land, Water and Development: Sustainable management of river basin systems. 2nd edition. London: Routledge. DOI: https://doi.org/10.4324/9780203443521.

ÖlundWingqvist, G. and Nilsson, Å. (2015). Effectiveness of River Basin Organisations – an institutional review of three African RBOs. DOI: https://doi.org/10.13140/RG.2.1.1046.0006.

Pangare, V., Pangare, G., Shah, V., Rao, P.S. and Neupane, B.R. (2006). Global Perspectives on Integrated Water Resources Management. Academic Foundation. Available online at: https://www.abebooks.com/9788171885619/Global-Perspectives-Integrated-Water-Resources-8171885616/plp [accessed 25 April 2022].

Panten, K., van Heel, B.F., Fliervoet, J.M. and van den Born, R.J.G. (2018). Cross-Border Collaboration in River Management: Views on Participation in a Dutch-German Case Study. *Water Resources Management*, 32(12): 4063–4078. DOI: https://doi.org/10.1007/s11269-018-2039-9.

Paudel, S., Pal, P. and Dhami, H.S. (2019). Restructuring Integrated Watershed Management Models for the Federal Democratic Regime of Nepal. *Journal of Forest and Natural Resource Management*, 1(1): 69–76. DOI: https://doi.org/10.3126/jfnrm.v1i1.22654.

Pegram, G., Li, Y. and Quesne, T.L. (2013). River Basin Planning: Principles, Procedures and Approaches for Strategic Basin Planning. Asian Development Bank. Available online at: https://www.adb.org/publications/river-basin-planning-principles [accessed 11 February 2022].

Poppe, M., Weigelhofer, G. and Winkler, G. (2018). Public Participation and Environmental Education. In S. Schmutz & J. Sendzimir (Eds.), Riverine Ecosystem Management: Science for Governing Towards a Sustainable Future, pp. 435–458. Springer International Publishing. DOI: https://doi.org/10.1007/978-3-319-73250-3_22.

Pradhan, N.S., Sijapati, S., Parajuli, U. and Dongol, B.S. (2014). From policy to practice: Institutional arrangements for integrated river basin management in Nepal. In: Squires, V., Daniell, K., and Milner, H. (ed.). River Basin Management in the 21st Century, Understanding People and Place: CRC Press, pp.397-415. DOI: https://doi.org/10.1201/b17168-22.

Pradhanang, S.M. and Tamanna, M. (2020). Water management: south asia. In: Wang, Y. (Ed.). Fresh Water and Watersheds (2nd ed.). CRC Press. DOI: https://doi.org/10.1201/9780429441042.

Selek, B. and Selek, Z. (2020). River Basin Management. In N. B. Harmancioglu and D. Altinbilek (Eds.), Water Resources of Turkey, pp. 445–465. Springer International Publishing. DOI: https://doi.org/10.1007/978-3-030-11729-0_13.

Sharma, P.N., Mishra, B., Gurung, J., Dent, F.J., Achet, S.H., Escano, J., Gamage H. and Gunawardena, E.R.N. (1997). Participatory processes for integrated watershed management. In: P. N. Sharma, (ed.) Participatory processes for integrated watershed management, pp.20-27. PWMTA-FARM Field Document No.7. Netherlands

Government/UNDP/FAO. Available online at: https://www.fao.org/3/X5269E/X5269e00.htm [accessed 5 May 2022].

Sharma, S.; Bajracharya, R. and Sitaula, B. (2009). Indigenous technology knowledge in Nepal: A Review. *Indian Journal of Traditional Knowledge*, 8(4): 569-576. Available online at: http://nopr.niscair.res.in/handle/123456789/6260 [accessed 27 April 2022].

Shivakoti, B.R. (2021). A River Basin Approach for the Coordinated Implementation of Water Related Targets in Sustainable Development Goals (SDGs). In Water, Climate Change, and Sustainability, pp. 21–31. John Wiley & Sons, Ltd. DOI: https://doi.org/10.1002/9781119564522.ch2.

Silva, J. da, Fernandes, V., Limont, M., Dziedzic, M., Andreoli, C.V. and Rauen, W.B. (2020). Water sustainability assessment from the perspective of sustainable development capitals: Conceptual model and index based on literature review. *Journal of Environmental Management*, 254, 109750. DOI: https://doi.org/10.1016/j.jenvman.2019.109750.

Song, X., Ravesteijn, W., Frostell, B. and Wennersten, R. (2010). Managing water resources for sustainable development: The case of integrated river basin management in China. *Water Science and Technology*, 61(2): 499–506. DOI: https://doi.org/10.2166/wst.2010.848.

Song, X., Ravesteijn, W., Frostell, B. and Wennersten, R. (2010). Managing water resources for sustainable development: The case of integrated river basin management in China. *Water Science and Technology*, 61(2): 499–506. DOI: https://doi.org/10.2166/wst.2010.848.

Suelzer, R. and Sharma, K. (1986). Working with people: some experience with people-centered approach (PDPP) In: Tinau Watershed Project, Tansen Palpa: TWP current index 1986/87 – 09.

Suhardiman, D., Bastakoti, R.C., Karki, E. and Bharati, L. (2018). The politics of river basin planning and state transformation processes in Nepal. *Geoforum*, 96: 70–76. DOI: https://doi.org/10.1016/j.geoforum.2018.07.019.

Suhardiman, D., Clement, F. and Bharati, L. (2015). Integrated water resources management in Nepal: key stakeholders' perceptions and lessons learned. *International Journal of Water Resources Development*, 31 (2): 284–300. DOI: https://doi.org/10.1080/07900627.2015.1020999.

Surridge, B. and Harris, B. (2007). Science-driven integrated river basin management: A mirage? *Interdisciplinary Science Reviews*, 32(3): 298–312. DOI: https://doi.org/10.1179/030801807X211711.

Teodosiu, C., Barjoveanu, G. and Teleman, D. (2003). Sustainable water resources management :River basin management and the EC Water Framework Directive. *Environment Engineering and Management Journal*, 2:377–394. DOI: https://doi.org/10.30638/eemj.2003.033.

Thapa, P.S., Chaudhary, S. and Dasgupta, P. (2022). Contribution of integrated watershed management (IWM) to disaster risk reduction and community development: Lessons from Nepal. *International Journal of Disaster Risk Reduction*, 76, 103029. DOI: https://doi.org/10.1016/j.ijdrr.2022.103029.

Tiwari, P.C. and Joshi, B. (2012). Environmental Changes and Sustainable Development of Water Resources in the Himalayan Headwaters of India. *Water Resources Management*, 26(4): 883–907. DOI: https://doi.org/10.1007/s11269-011-9825-y.

Tortajada, C. (2010). Water Governance: Some Critical Issues. *International Journal of Water Resources Development*, 26 (2): 297–307. DOI: https://doi.org/10.1080/07900621003683298.

Tyler, S. and Fajber, L. (2009). Land and Water Resource Management in Asia: Challenges for climate adaptation. p.13. Available online at: https://www.iisd.org/publications/report/land-and-water-resource-management-asia-challenges-climate-adaptation [accessed 1 May 2022].

UNEP (2012). The UN-Water status report on the application of integrated approaches to water resources management. Nairobi, Kenya: UN Environment Programme. Available online at: https://www.unwater.org/publications/un-water-status-report-application-integrated-approaches-water-resources-management-rio20/ [accessed 5 May 2022].

UN-Water (2008). Status Report on Integrated Water Resources Management and Water Efficiency Plans. New York: The Commission on Sustainable Development. Available online at: https://www.unwater.org/publications/status-report-integrated-water-resource-management-water-efficiency-plans-csd-16/ [accessed 7 April 2022].

Upadhyay, S.N. and Gaudel, P. (2018). Water Resources Development in Nepal: Myths and Realities. *Hydro Nepal: Journal of Water, Energy and Environment*, 23, 22. DOI: https://doi.org/10.3126/hn.v23i0.20822.

Upadhyaya, R. (2019). Problem of Statelessness in Nepal. NUTA Journal, 64-69. Available online at: https://www.nepjol.info/index.php/nutaj/article/view/23230 [accessed 10 February 2022].

Upreti, T. (2006). International watercourses law and its application in South Asia. Kathmandu: Pairavi Prakashan. Available online at: https://lawcat.berkeley.edu/record/264965 [Accessed 15 February 2022].

Van der Zaag, P. (2005). Integrated Water Resources Management: Relevant concept or irrelevant buzzword? A capacity building and research agenda for Southern Africa. *Physics and Chemistry of the Earth, Parts A/B/C*, 30(11): 867–871. DOI: https://doi.org/10.1016/j.pce.2005.08.032.

Watson, N. (2004). Integrated river basin management: A case for collaboration. *International Journal of River Basin Management*, 2(4): 243–257. DOI: https://doi.org/10.1080/15715124.2004.9635235.

Wester, P. and Warner, J. (2002). River basin management reconsidered. In: Turton, A. and Henwood, R. (Eds), Hydropolitics in the developing world: A southern African perspective. Pretoria: African Water Issues Research Unit. Cedilla print. pp.60-71.

WWF (2002). Managing Water Wisely: Promoting Sustainable Development Through Integrated River Basin Management-UK. Available online at: https://wwfeu.awsassets.panda.org/downloads/managingwaterwiselyeng2.pdf [accessed 26 March 2022].

Zevenbergen, C., Rijke, J., van Herk, S., Ludy, J. and Ashley, R. (2008). Room for the River: International relevance. Water Governance 02/2013. Available online at: https://edepot.wur.nl/431674 [accessed 30 April 2022].

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Prakash Singh Thapa is currently pursuing a Ph.D. in Ecosystem-based Solutions for Disaster Risk Reduction (Eco-DRR) at Ishikawa Prefectural University, Japan. He holds a master's degree in forestry from Tribhuvan University, Nepal and was honored with a Gold Medal from the Rt. Honorable President of Nepal for his outstanding academic performance. Concurrently, he serves as an Under-secretary in the Department of Forests and Soil Conservation under the Ministry of Forests and Environment, Government of Nepal. He has earned nearly 15 years of experience as a Government Officer in various facets of expertise, including Forest Management, Reducing Emissions from Deforestation and Forest Degradation (REDD+), Soil Conservation & Watershed Management, and Springshed Management. He recently achieved noteworthy milestones as a project coordinator for two watershed initiatives: "Landslide Prevention and Stabilization of Slopes in the Most Earthquake Affected District of Nepal," carried out in collaboration with the Government of Nepal and FAO TCP/NEP/3601; and "Building Resilience to Landslides through Support for Community-Based Rehabilitation and Mitigation Actions and the Establishment of Early Warning Systems in Nepal," executed in partnership with the Government of Nepal, FAO, and USAID OSRO/NEP/602. These endeavors were undertaken in response to a significant earthquake in Nepal. Mr. Thapa's contributions extend to scholarly pursuits, reflected in his publication record encompassing articles in national and international journals concerning forestry and watershed management.

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Bindu Ghimire is pursuing her Ph.D. specializing in investigating the cause and effect of the Bagmati River's (independent sub-basin) as well as its tributaries' slumping condition in central Nepal. Her research addresses the impacts of the deterioration in water quality of Bagmati river on both livestock and human populations. Her academic pursuits are based at Nepal's Tribhuvan University where she is serving as associate professor since 2017. She has dedicated herself to imparting knowledge to and guiding graduate students through this capacity. She is conversant on wide range of topics, including climate change, livelihood and health. A solid grounding in environmental microbiology combines alongside with this wide-ranging expertise. She has played a significant part in contributing to numerous published articles and book chapters.

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Chapter 10

Agrobiodiversity Indicators and Measurement using R

By Bal Krishna Joshi

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Agrobiodiversity Indicators and Measurement using R

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Abstract
Agrobiodiversity is the most important part of biodiversity. It can be described, quantified, compared, and related by using different statistical tools called agrobiodiversity statistics (agro-statistics). Six components and 25 groups of agrobiodiversity should be used for agrobiodiversity analysis. Six types and levels of agrobiodiversity can be quantified. Both quantitative and qualitative data are used for estimating scores and indices. The measurement objects for describing agrobiodiversity are community, household, site, crop group, species, landrace, etc. These objects are called operational agricultural units (OAU). Agromorphological, molecular, and perception data are used in agrobiodiversity studies. Among the many software, RStudio is very good. It is an integrated part of R and includes a console, syntax-highlighting editor, tools for plotting, history, debugging, and workspace management. Vegan and BiodiversityR packages are commonly used for estimating diversity indices and multivariate analysis. Richness, Shannon index and Simpson index are very common means of quantifying agrobiodiversity. Spatial and temporal analysis of agrobiodiversity helps monitor the status and plan the programs and activities.

Keywords
Agrobiodiversity index; Agrobiodiversity statistics; Measurement; Indicators; R package

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1. Introduction

Agrobiodiversity (also called agricultural genetic resources, AGRs) is a part of biodiversity and includes all genetic resources that are economically beneficial. In majority of the countries, native agrobiodiversity is neglected and underutilized due to their high priority to monomorphic and high yielding varieties. Many different factors are contributing to losing the AGRs. Among them the major factor is the rapid expansion of single improved homogenous varieties and breeds in the world. Such single improved variety is generally developed through studying a single species or variety or set of genotypes, and there are limited studies on the whole agrobiodiversity at a particular site. The general trend is that, rather than evaluating, describing and improving the native agrobiodiversity, improved variety or breed is easily adopted and expanded due to which many indicators are being affected. Indicators are any values, scores or status which explain about the agrobiodiversity of a particular location. Agrobiodiversity indicators have not been standardized across the world; and even the methodologies to estimate and measure the indicators are not available. Indicators are very important to manage the agrobiodiversity better, to plan programs and activities, and to monitor the trends (PAR, 2018; Sthapit *et al.*, 2017).

For the conservation of forest biodiversity (non-agrobiodiversity), different indicators and approaches have been used, for example red listing of the species. Many types of species have been defined and given due attention. Different types of species include Alien, Charismatic, Dominant, Emblematic, Endangered, Endemic, Exotic, Flagship, Focal, Foundation, Indicator, Indigenous, Invasive, Keystone, Landscape, Priority, Rare, Specialty, Substitute, Surrogate, Target, Threatened, Tourism, Umbrella and Vulnerable species. Similar approaches can be applied at species and landrace level to support AGRs. Quantification of AGRs is another aspect that identifies such species or landraces.

Different types of scores and indices along with coefficients can be estimated and used as indicators (Grum and Atieno, 2007; Jarvis *et al.*, 2000; Joshi *et al.*, 2005). Several statistical tools can be applied using computer software to quantify agrobiodiversity. Quantifications (measurements) of agrobiodiversity are generally done at different levels e.g., at the agroecosystem, species, varieties, and administrative units. Agrobiodiversity in any area should be estimated properly that leads to choosing the conservation approaches effectively. This paper, therefore, describes different operational agricultural units (OAU) for estimating diversity indices using R packages. Among the various components under agrobiodiversity statistics, this paper focuses on the measurement of agrobiodiversity. With the approaches described in this paper, one can rank any household, community, district, or the country and can locate a center of the diversity. A hotspot of agrobiodiversity and red zone for agrobiodiversity can be identified, in addition to identifying the indicator species and landraces.

2. Agrobiodiversity Components and Groups

Agrobiodiversity covers all genetic resources that have value for food, nutrition, health, and other economic uses to human beings. It has six components, and they are crops, forages, livestock, insects, microorganisms, and aquatic genetic resources (Joshi *et al.*, 2020c). Insects and microorganisms include only economic and beneficial species. Under aquatic genetic resources, only economically important species are included e.g., fish. Each of these components can further be divided into four sub-components. They are cultivated/ domesticated, semi-domesticated, wild relatives, and wild edible species (Joshi and Shrestha, 2017; Joshi and Shrestha, 2019).

Based on the economic uses, agricultural genetic resources can be grouped into 25 groups. They are 1. cereals, 2. pseudocereals, 3. millets, 4. sugar and starch crops, 5. grain legumes, 6. oilseed crops, 7. summer vegetables, 8. winter vegetables, 9. roots and tubers, 10. winter fruits, 11. summer fruits, 12. spices, 13. beverages and narcotics, 14. fibers, 15. forage trees, 16. forage grasses, 17. ornamental plants, 18. medicinal plants, 19. supportive plants, 20. economic and beneficial (EB) insects, 21. EB microorganisms, 22. fish/aquatic animals, 23. aquatic plants, 24. poultry, and 25. livestock (Joshi and Shrestha, 2019, Joshi and Shrestha 2017). Supportive plants include green manuring crops, cover crops, pesticide plants, and other economically important plants that are not included in the above groups.

These components, sub-components, and economic groups (Joshi *et al.*, 2020c; Joshi and Shrestha, 2019) are very useful to estimate different types of diversity indexes, indicators, and scores of a particular site, community, or household over a certain period. The AGRs may be of exotic and native types and both types can be considered for agrobiodiversity measurement, but measurement based on only native AGRs would be more valuable and important. There are many other grouping systems of AGRs (Joshi and Shrestha, 2019), and these groups can also be considered to quantify agrobiodiversity.

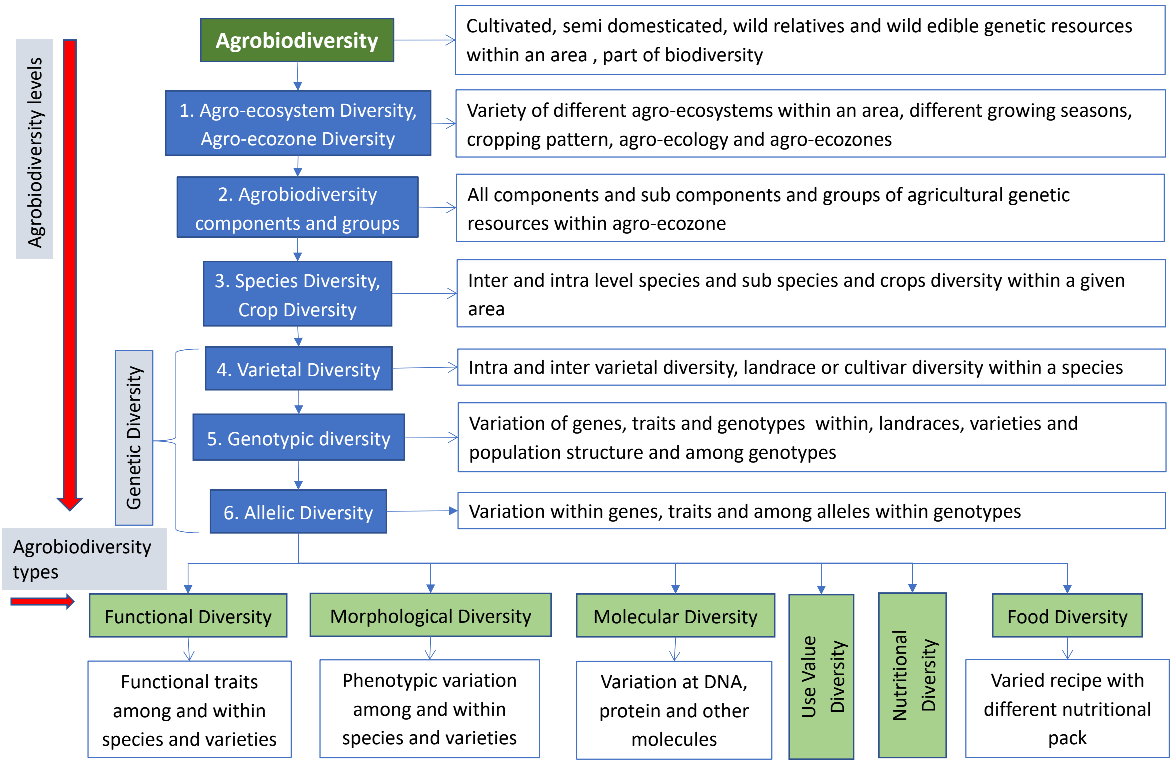

Figure 1: Types of agrobiodiversity based on levels, traits, and use-values.
Source: Joshi *et al.* (2020b)

3. Agrobiodiversity Levels and Types

Agrobiodiversity can be measured and studied at different levels or hierarchies by using different traits. Based on levels (coverage of objects), there are six types of agrobiodiversity

(Figure 1) (Bajracharya *et al*., 2012; Joshi *et al*., 2020b). Genetic diversity includes three levels of diversity i.e., varietal diversity, genotypic diversity, and allelic diversity. Agrobiodiversity can also be described under six types of diversity based on traits and use-values. These include functional diversity, morphological diversity, molecular diversity, use-value diversity, nutritional diversity, and food diversity. All these 12 types of diversity should be measured and studied at a particular site in a given period. Based on the data types, objectives, and objects, different measures are used to estimate and compare these different types of agrobiodiversity. Diversity can also be assessed based on cropping patterns, growing season, land type and habitat. at species and varietal levels. Morpho type is very simple indicator to measure the diversity.

4. Agrobiodiversity Statistics (Agro-statistics)

Agro-statistics is a science of studying agrobiodiversity using different statistical tools, methods, and principles. Many common statistical tools are useful for measurement (quantification), characterization (description), classification (grouping), evaluation (comparison) and association (relationship) of agrobiodiversity (Figure 2) (Bajracharya *et al*., 2012; Grum and Atieno, 2007; Jarvis *et al*., 2000; Joshi *et al*., 2005). With the development of different molecular markers and computing software, genetic parameters are also commonly estimated. Description of these tools has been described by Joshi *et al*. (2005). Both parametric and non-parametric tests are also commonly used to compare agrobiodiversity. Appropriate test statistics are given in figure 3 based on data types and the number of objects (factors) used. Both temporal and spatial analysis (called trend analysis) can be carried out to see the status and changes in agrobiodiversity.

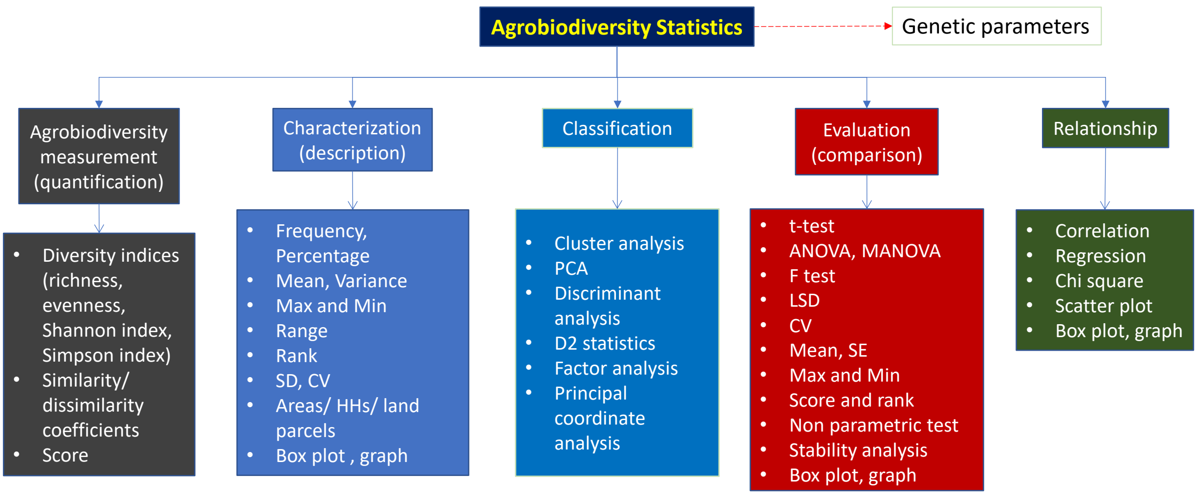

Figure 2: Different statistical tools for agrobiodiversity study.

5. Agrobiodiversity Measurement (Quantification)

Agrobiodiversity measurement includes the quantification of AGRs at different levels. Based on the quantification, AGRs can be grouped at the level of different strata e.g., red list, endangered, rare, common, etc. (Joshi and Shrestha, 2019). The main measures of agrobiodiversity are richness, evenness, diversity indices (Shannon, Simpson indices), similarity coefficients, dissimilarity coefficients, scores (Grum and Atieno, 2007; Jarvis *et al*., 2000; Joshi *et al.*, 2005; Joshi *et al.*, 2018; Kindt and Coe, 2005). Another measure is species density, which takes into account the number of species in an area. Similarly, landrace density can also be estimated. These measures should be measured at six different levels and types of agrobiodiversity (Figure 1) e.g., household, community, ward, municipality, district, province, and country. Such estimates are generally calculated based on native agrobiodiversity and are, therefore, useful for identifying the hotspot areas for agrobiodiversity. Quantification helps locate the center of diversity, identify the hotspot and red zone areas for agrobiodiversity. Hotspot areas are those areas that have the higher diversity score and indices, high diversity on wild relatives, endemic species, many rare and unique landraces, and species, and different types of land and cropping patterns.

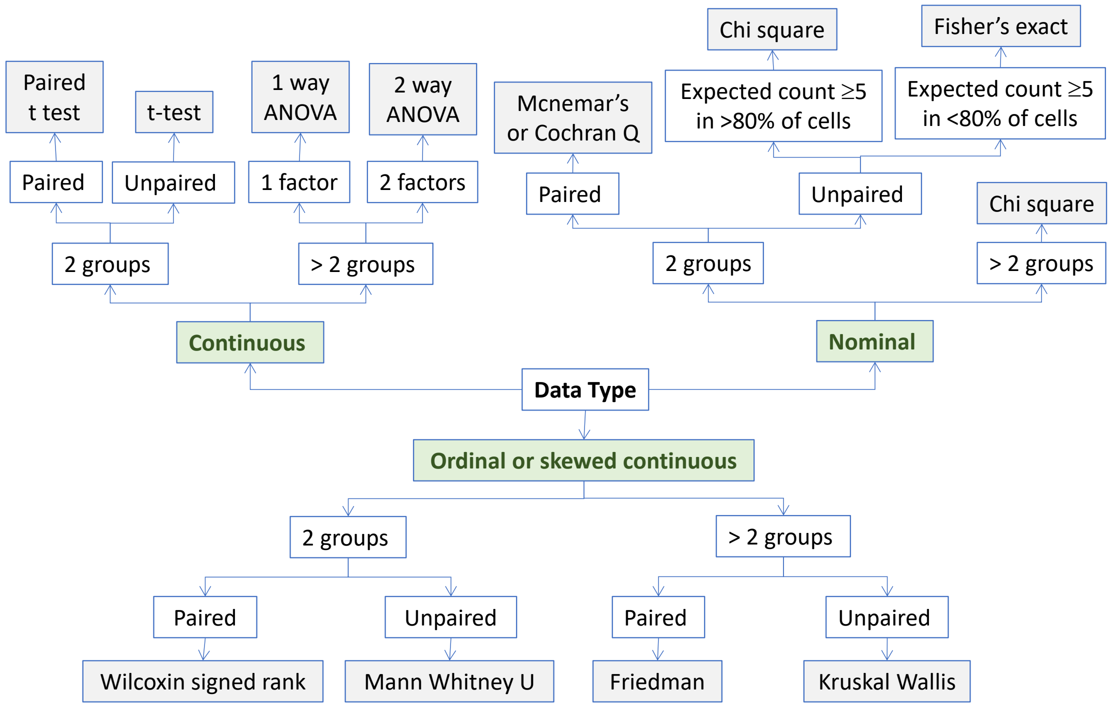

Figure 3: Statistical testing tools (parametric and non-parametric) for comparing agrobiodiversity based on data types

Measurement (quantification) may be based on phenotypic, genotypic, perception, and survey data. Such data can be collected and measured through community biodiversity register and community seed bank, diversity block, diversity collection, diversity fair, field/transect walk, focus group discussions, food fair, household survey, key informant interviews, online survey, lab experiment, literature review, local market, on-farm, and on-station trials. Diversity changes over time and space are also estimated using different diversity measures, which are important for monitoring and applying appropriate methods for conservation and utilization.

For the index calculation at different levels, one can count the number of species within-group, or several landraces within species as well as group (Borcard, Gillet and Legendre, 2011; Grum and Atieno, 2007; Joshi and Baniya, 2006; PAR, 2018; Pudasaini *et al.*, 2016). Taking the natural logarithms of species richness or landrace richness, an index can be calculated. The proportion of each group, species, or landraces can be calculated by dividing the number of that groups, species, or landraces by the total number of all groups, species, or landraces in a given area. The formula for calculating the Shannon diversity index, Simpson index, evenness, and other indices can be applied on these data. Agrobiodiversity index (ABDI) can be of household (HH), village or community, district, province, agroecozone, and country. A weighted index using either agrobiodiversity components or groups can be estimated as described in the literature[1]. In some cases, microorganisms, insects, ornamental plants, and the medicinal plant may be excluded from the calculation due to data unavailability.

The percentage of species or landraces in each group or species can be calculated considering the total number of species or landraces in the country or studied areas (Joshi *et al.,* 2007; Joshi *et al.,* 2018; Pudasaini *et al.,* 2016). Based on the data obtained, each household or area or district can be ranked. For example, ABDI (based on landraces) for each household is equal to the number of landraces in each species or group divided by the total number of landraces in a community or district.

6. Agrobiodiversity Indicators (Score and Index)

Agrobiodiversity indicators are any scores, indices, signs, symptoms, values, drivers, or marks that speak about the status of total diversity, trends on diversity, the status of intra- and inter-level diversity of species, and landraces in a particular area. It indicates that the agrobiodiversity is increasing, remaining constant, or decreasing. There is a wide range of methods of measuring various dimensions of agrobiodiversity, which is often referred to as the agrobiodiversity indicators, scores, and indices (Boversity International, 2017; Joshi *et al.,* 2020b; Kindt and Coe, 2005; PAR, 2018; Sthapit *et al.*, 2017). Diversity indicators, indices, and scores can be used to compare within and between different populations at species, landraces, and genetic levels over locations and years.

Agrobiodiversity indicators can be assessed at three different systems, namely, in consumption and market system, in production system, and in genetic resource management system (Sthapit *et al.,* 2017). Some indicators include the red zone, red list, landraces coverage (based on five cell analysis), cropping pattern, mixture, monocrop vs. multicrops, land type, food items, native products in the market, the richness of species and landraces, population size, etc. A red list is the list of names of genetic resources (at genotype, landrace, variety, strain, and breed levels) under different groups based on the analysis of distribution and population size (also called five cell analysis), and trait distribution. Among these indicators, scores and indices are more commonly estimated and used.

Diversity indices and scores are calculated using both qualitative and quantitative data. In case of quantitative data, it needs to be converted into qualitative groups. The proportion of entries in i^{th} class can be calculated using morphological data considering the different phenotypic classes of traits. Similarly, frequency data on genebank collection can be used to estimate different indices. Many ways can be used to estimate several types of household scores and indices. Household-level diversity can be of household diversity score and index as given below.

6.1 A1. Household Agrobiodiversity Score (HHABDS)

1. Number of species (species richness, n) in each of 6 agrobiodiversity components (crops, forages, livestock, economical insects, economically important microorganisms, aquatic agricultural species) over a year.

[1] https://news.mongabay.com/2016/05/top-10-biodiverse-countries/

2. Number of landraces (landrace richness, n) per species for each of 6 components in a year.
3. Land type, n (marshy/ wetland, pond/aquatic, slopy upland, terrace upland, slopy low land, terrace low land, riverside, agroforestry land, grassland).
4. Functional diversity (number of special functions using special landraces) in a year
5. Unique diversity value (the number of specialty/ unique landraces divided by the total number of landraces).
6. Agrobiodiversity group score (or agrobiodiversity group richness) (based on 25 agrobiodiversity groups i.e., cereals, pseudocereals, millets, sugar and starch crops, grain legumes, oilseed crops, summer vegetables, winter vegetables, roots and tubers, winter fruits, summer fruits, spices, beverages and narcotics, fibers, forage trees, forage grasses, ornamental plants, medicinal plants, supportive plants, economical and beneficial (EB) insects, EB microorganisms, fish and aquatic animals, aquatic plants, poultry, and livestock), at 0 or 1 scale over a year with maximum 25 score.
7. Dietary diversity score (based on 15 groups: cereals, pseudocereals, millets, roots and tubers, vegetables, fruits, nuts, meat and poultry, eggs, fish and aquatic animals, pulses and legumes, milk and milk products, oil/fat and ghee[2], sugar and honey, and miscellaneous) at 0 or 1 scale on half-year basis with maximum 15 score.
8. Social agrobiodiversity score (number of religious or culturally associated landraces, considering all 6 agrobiodiversity components).
9. Food diversity score (number of food items/recipes eaten per meal, average of morning, day, and evening foods).
10. Food component score (number of species in food per meal, average of morning, day, and evening foods).
11. The average area per species (crops and forages) in square meter.
12. HH agrobiodiversity score: sum from above 1 to 10 scores.

6.2 A2. Household Agrobiodiversity Index (HHABDI)

A. Based on species within agrobiodiversity group
- HH agrobiodiversity group richness, n
    1. HH Shannon diversity index (based on number of species within a group)
    2. HH Simpson index (based on number of species within a group)
    3. HH species evenness (specie within a group)

B. Based on landraces within the agrobiodiversity group
- HH agrobiodiversity group richness, n
    4. HH Shannon diversity index (based on number of landraces within a group)
    5. HH Simpson index (based on number of landraces within a group)
    6. HH landraces evenness (specie within a group)

C. Based on landraces within species
- HH agrobiodiversity species richness, n
    7. HH Shannon diversity index (based on number of landraces within a species)
    8. HH Simpson index (based on number of landraces within a species)
    9. HH species evenness (specie within a group)

[2] It is made by melting butter.

10. HH agrobiodiversity index (HHABDI): sum of above 1 to 9 index values.

In the similar way of household scores and indices, one can estimate village or community agrobiodiversity scores and indices as follows.

6.3 B.1. Village Agrobiodiversity Score (VABDS)

1. Number of species (species richness, n) in each of 6 agrobiodiversity components (crops, forages, livestock, economical insects, economical microorganisms, aquatic agricultural species) over a year.
2. Number of landraces (landrace richness, n) per species for each of 6 agrobiodiversity components over a year.
3. Land type, n (marshy/ wetland, pond/aquatic, sloppy upland, terrace upland, sloppy low land, terrace low land, riverside, agroforestry land, grassland).
4. Functional diversity (number of special functions using special landraces) in a year.
5. Unique diversity value (number of specialty/ unique landraces, functional trait-specific genotypes divided by total number of species).
6. Village agrobiodiversity score (based on 25 agrobiodiversity groups, i.e. cereals, pseudocereals, millets, sugar and starch crops, grain legumes, oilseed crops, summer vegetables, winter vegetables, roots and tubers, winter fruits, summer fruits, spices, beverages and narcotics, fibers, forage trees, forage grasses, ornamental plants, medicinal plants, supportive plants, economical and beneficial (EB) insects, EB microorganisms, fish and aquatic animals, aquatic plants, poultry, and livestock) at 0 or 1 scale over a year with maximum 25 score.
7. Village dietary diversity score (based on 15 groups: cereals, pseudocereals, millets, roots and tubers, vegetables, fruits, nuts., meat and poultry, eggs, fish and aquatic animals, pulses and legumes, milk and milk products, oil/ fat and ghee, sugar and honey, and miscellaneous) at 0 or 1 scale on half-year basis with maximum 15 score.
8. Social agrobiodiversity score (number of religious or culturally associated landraces, considering all 6 agrobiodiversity components).
9. Food diversity score (number of food items/recipes eaten per meal, average of morning, day, and evening foods).
10. Food component score (number of species in food per meal, average of morning, day, and evening foods).
11. Village agrobiodiversity score: sum of above 1 to 10 values.
12. The average area per species (crops and forages) in square meter.
13. Average agrobiodiversity HH score.
14. Average social agrobiodiversity HH score.
15. The average number of species per HH.
16. The average number of landraces per HH.
17. Average areas per HH.

6.4 B.2. Village Agrobiodiversity Index (VABDI)

A. Based on species within agrobiodiversity group

- Agrobiodiversity group richness, n
    1. Village Shannon diversity index (based on number of species within a group)
    2. Village species evenness (specie within a group)

3. Village Simpson's index

B. Based on landraces within the agrobiodiversity group

- Agrobiodiversity group richness, n

4. Village Shannon diversity index (based on number of landraces within a group)
5. Village landraces evenness (specie within a group)
6. Village Simpson's index

C. Based on landraces within species

- Agrobiodiversity species richness, n

7. Village Shannon diversity index (based on number of landraces within a species)
8. Village species evenness (specie within a group)
9. Village Simpson's index
10. Village agrobiodiversity index (VABDI): Sum of above 1 to 9 values

Similarly, we can estimate agrobiodiversity indices and scores at district, province/ state levels or any defined specific areas. OAUs can be further ranked based on these scores and indices. The followings are additional measures of agrobiodiversity.

- Agrobiodiversity index at HH, community, district, province, ward levels using the number of species or landraces divided by the total number of species or landraces in a country
- Analog site index of a particular landrace or species, calculated from climate analog tool based on reference site of a particular landrace or species
- Driver index can be estimated for each of different drivers (factors) in a particular area over the particular time frame, using the formula, lost landraces divided by the total number of landraces available before the effect of this driver.

7. Data Types and Collections

Different types of data are generated and collected for the measurement and other studies of agrobiodiversity. Different data types for agrobiodiversity study are given in figure 4. Data could be agro-morphological, molecular, and perception, which can be generally collected from on-station research, on-farm trial, surveys, and lab research. Several methods and techniques can be used to collect data and information (see Joshi *et al.*, 2005 for detail).

Apps and software are available for collecting data and information electronically both online as well offline. FieldLab is an application for Android tablets that are used for data collection in the field. It is developed by IRRI[3] and is available freely. Field Book is a simple app for taking phenotypic notes. It is an open-source application for field data collection on Android[4] and is available from Google Play[5]. The Fieldbook2020 software developed by CIMMYT[6] provides offline capabilities for managing pedigrees, phenotypic data, seed stocks, and field books for a breeding program. It provides integrated

[3] http://bbi.irri.org/products/fieldlab
[4] http://dx.doi.org/10.2135/cropsci2013.08.0579
[5] https://play.google.com/store/apps/details?id=com.fieldbook.tracker&hl=en&gl=US
[6] https://www.cimmyt.org/

management of global information on genetic resources, crop improvement, and evaluation for individual crops. R Package[7] included in this software is useful for statistical analyses. Biologer[8] is simple and free software designed for collecting data on biological diversity.

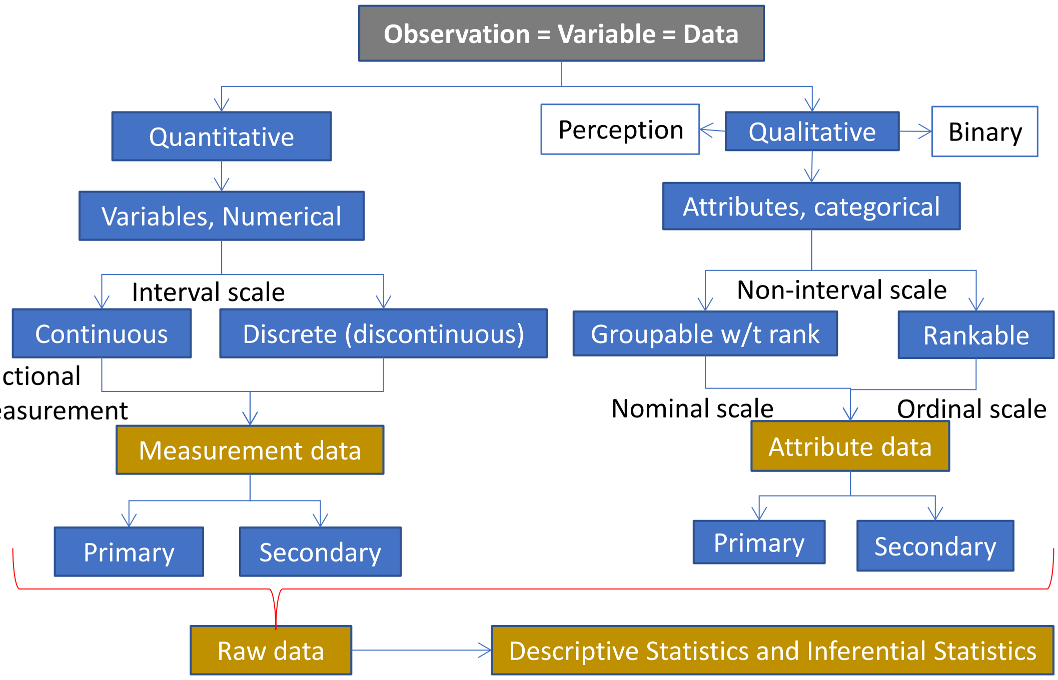

Figure 4: Data types for measuring on-farm agrobiodiversity at ecosystem, species, and cultivar levels

Perception data is generally collected from a survey. Along with the advancement of information technology, many data collections survey tools are available. These online tools are very useful to minimize errors and speed up data processing. Some electronic media-based survey tools are given below.

- Surveymonkey[9]: A cloud-based survey tool that helps users create, share, collect and analyze surveys.
- Google forms[10]: It is used to create online forms and surveys.
- SoGoSurvey[11]: A cloud-based platform that enables creation, distribution, and multilingual analysis of surveys, forms, polls, quizzes, and assessments.
- mWater Portal[12]: Free platform for data collection, data visualizations, and data-driven management of infrastructure in emerging economies.
- ODK[13]: It is an Open Data Kit, open-source software for collecting, managing, and using data in resource-constrained environments.

[7] https://data.cimmyt.org/dataset.xhtml?persistentId=hdl:11529/10548370
[8] https://biologer.org/
[9] https://www.surveymonkey.com/
[10] https://www.google.com/forms/about/
[11] https://experience.sogosurvey.com/
[12] https://portal.mwater.co/#/
[13] https://opendatakit.org/

8. Measurement Objects

The information for measuring agrobiodiversity comes from different levels. These levels are alleles, genes, genotypes, cultivars (varieties and landraces), crops, species, components and groups, agroecosystems or agroecozones, parcels or plots, households (farmers), villages, communities, ethnicities, wards, municipalities, landscapes, regions, districts, provinces/ states, countries, and continents. These levels are measurement objects, called OAU (operational agricultural unit).

In addition, there are several crop groups that are OAU based on different criteria e.g., use-value base, economic importance base, national list base, habitat base, red list base, growing season base, national priority base, etc. Examples are cereals, vegetable fruits, released variety, registered variety, major, minor, primary, secondary, staple, commodity, high value, commercial, industrial, food crops, feed crops, manuring crops, pesticidal plants, cash crops, cover crops, trap crops, catch crop, cultivated, semi-domesticated, wild edible, field crops, garden crops, aquatic plants, common, rare, endangered, extinct, localized, vulnerable, winter crops, summer crops, and off-season (Joshi and Shrestha, 2019).

Object or OAU refers to the things being analyzed, interpreted, evaluated, or described. Variable or character refers to the properties used to describe the objects under study. Variables may be both qualitative and quantitative, and include agromorphological, genotypic, and perception data. These are measured or observed from an individual, representative samples, or population. In some cases, agromorphological markers, traits, and molecular markers can be treated as OAU.

9. Software for Agrobiodiversity Statistics

Many software are available for agrobiodiversity statistics. The general and molecular software are given below.

I. General Statistical Software

- AGROBASE[14]: For data management, experiment management, and statistical analysis.
- CropStat[15]: For data management and basic statistical analysis of experimental data.
- DIPVEIW: For genebank data management and analysis.
- DIVA-GIS[16]: For mapping and geographic data analysis (a geographic information system (GIS).
- Genstat[17]: For data analysis, particularly in the field of agriculture.
- GGEbiplot[18]: For biplot analysis, conventional statistical analysis, and decision making based on univariate and multivariate data.
- Instat+[19]: A general statistical package.
- Minitab[20]: Simple and general statistical package.

[14] https://www.agronomix.com/AGROBASE.aspx
[15] http://bbi.irri.org/products
[16] https://www.diva-gis.org/
[17] https://www.vsni.co.uk/software/genstat
[18] http://ggebiplot.com/
[19] https://instat.software.informer.com/3.3/
[20] https://www.minitab.com/en-us/

- MS Excel[21]: Spreadsheet software program, a powerful data visualization, and analysis tool.
- MSTAT-C[22]: For the design, management, and analysis of agronomic research experiments.
- NTSYSpc[23]: Commonly used package for numerical taxonomy and multivariate analysis system.
- Past[24]: For scientific data analysis, with functions for data manipulation, plotting, univariate, multivariate statistics, ecological analysis, time series, and spatial analysis.
- R[25] and RStudio[26]: For statistical computing and graphics.
- SAS[27]: For data management, advanced analytics, and multivariate analysis.
- SPSS[28]: A software platform that offers advanced statistical analysis, a vast library of machine learning algorithms, and text analysis.
- STAR[29]: Statistical tool for agricultural research.
- Statistica[30]: A data analysis and visualization program.
- Statistix[31]: Statistical analysis program.
- PDA[32]: For biodiversity analysis and conservation prioritization problems.
- BioDiversity Pro[33]: A free statistical package program enabling many measures of diversity to be calculated for a dataset of taxa by samples.

II. Molecular Data Analysis Software

- Arlequin[34]: Powerful genetic analysis packages performing a wide variety of tests, including hierarchical analysis of variance.
- GDA[35]: For the analysis of discrete genetic data.
- GenAlEx[36]: Excel Add-In for the analysis of genetic data, particularly useful for dominant data such as RAPD and AFLP data.
- MEGA[37]: For reconstructing phylogenies using distance matrices and maximum parsimony methods, and includes neighbor-joining, branch-and-bound parsimony methods and bootstrapping.
- PHYLIP[38]: Extensive package of programs for inferring phylogenies.
- POPGENE[39]: For the analysis of genetic variation among and within populations using co-dominant and dominant markers, and quantitative data.

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[21] https://www.microsoft.com/en-ww/microsoft-365/excel
[22] https://www.canr.msu.edu/afre/projects/microcomputer_statistical_package_mstat._1983_1985
[23] http://www.appliedbiostat.com/ntsyspc/ntsyspc.html
[24] https://www.nhm.uio.no/english/research/infrastructure/past/index.html
[25] https://www.r-project.org/
[26] https://www.rstudio.com/
[27] https://www.sas.com/en_us/home.html
[28] https://www.ibm.com/analytics/spss-statistics-software
[29] http://bbi.irri.org/products
[30] https://www.statistica.com/en/
[31] https://www.statistix.com/
[32] http://www.cibiv.at/software/pda/
[33] https://www.sams.ac.uk/science/outputs/
[34] http://cmpg.unibe.ch/software/arlequin35/
[35] https://phylogeny.uconn.edu/software/
[36] https://biology-assets.anu.edu.au/GenAlEx/Welcome.html
[37] https://www.megasoftware.net/
[38] https://evolution.genetics.washington.edu/phylip.html
[39] https://sites.ualberta.ca/~fyeh/popgene.html

- PowerMarker[40]: A comprehensive set of statistical methods for genetic marker data analysis, designed especially for SSR/SNP data analysis.
- STRUCTURE[41]: Uses a clustering method to identify population structure and assigns individuals to those populations.

10. R Packages for Agrobiodiversity Measurement and Study

Most of the software and R packages used in biodiversity analysis can be used for agrobiodiversity analysis. Past is simple and free software that can be used for agrobiodiversity data. It is good for generating a graph, doing multivariate analysis, estimating different diversity indices, and analyzing time-series data. Some of the R packages useful for analysis of agrobiodiversity data are:

- adiv[42]: Analysis of Diversity, with functions, data sets, and examples for the calculation of various indices of biodiversity including species, functional and phylogenetic diversity.
- agricolae[43]: Statistical Procedures for Agricultural Research, offers extensive functionality on experimental design especially for agricultural and plant breeding experiments and other statistical analysis.
- analogues[44]: To calculate the climatic similarity between a reference site and a prescribed area, helps identifying locations with similar climates.
- BAT[45]: Biodiversity assessment tools, assess alpha and beta diversity in all their dimensions (taxonomic, phylogenetic and functional).
- BiodiversityR[46]: For statistical analysis of biodiversity and ecological communities.
- BioFTF[47]: To study biodiversity with the functional data analysis.
- BIO-R[48]: Biodiversity analysis using molecular data.
- GGEBiplotGUI[49]: A graphical user interface for the construction of, interaction with, and manipulation of GGE biplots.
- hclust[50]: Hierarchical cluster analysis on a set of dissimilarities and methods for analyzing it.
- prcomp[51]: Performs a principal components analysis on the given data matrix and returns the results as an object of class prcomp.
- pscyh[52]: Procedures for psychological, psychometric, and personality research.
- rich[53]: For the analysis of species richness.
- vegan[54]: For community ecologists with multivariate and diversity analysis and other functions.

40 https://brcwebportal.cos.ncsu.edu/powermarker/
41 https://web.stanford.edu/group/pritchardlab/structure.html
42 https://cran.r-project.org/web/packages/adiv/index.html
43 https://cran.r-project.org/web/packages/agricolae/index.html
44 https://github.com/CIAT-DAPA/analogues
45 https://biodiversityresearch.org/software/
46 https://www.worldagroforestry.org/output/tree-diversity-analysis
47 https://cran.r-project.org/web/packages/BioFTF/index.html
48 https://data.cimmyt.org/dataset.xhtml?persistentId=hdl:11529/10820
49 https://cran.r-project.org/web/packages/GGEBiplotGUI/index.html
50 https://www.rdocumentation.org/packages/stats/versions/3.6.2/topics/hclust
51 https://www.rdocumentation.org/packages/stats/versions/3.6.2/topics/prcomp
52 https://cran.r-project.org/web/packages/psych/index.html
53 https://cran.r-project.org/web/packages/rich/index.html
54 https://cran.r-project.org/web/packages/vegan/index.html

11. Data Preparation, Import and Analysis in R

A very common data frame in agrobiodiversity study is a data matrix that contains information about the properties, traits, characters, variables of several OAU (individuals, samples, specimens and population). For example, data is a household data matrix (household by several landraces within a species) and it is a count data set. The first column is household name or number, and it may be a community, site, household, species, agrobiodiversity component, agrobiodiversity group, or any other OAU. Other columns are the number of landraces under different crop species, and it may be species, cultivars, or any other variables. Data is generally prepared in MS Excel, and it is good to cross-check and verify the data before importing it into the R environment. The useful commands in Excel for data check are freezing or splitting panes, filter, sort, text to a column, data validation, exploratory data analysis, scatter plot, etc.

RStudio is more user-friendly, and the following analysis and process are based on RStudio. RStudio has four windows, script/editor window, data import/workspace window, console/ command window, and file/plot/package window. Among many R packages, vegan and BiodiversityR are more useful for estimating agrobiodiversity indices (Kindt and Coe, 2005), and, therefore, methods including R script are described below. To import data, the import dataset menu under environment is used. Here example data file is hhdata. The followings are the R scripts to import, view data, and converting imported data into a data frame.

```
library(readxl)#loading readxl package
hhdata <- read_excel
training/ram/hhdata.xlsx")#importing data from given drive and saving this
data into hhdata
View(hhdata)#to see the data
hhdata<- as.data.frame (hhdata)#converting imported excel data into R data
frame
rownames(hhdata) <- hhdata[,1] #assigning row names from 1st column
hhdata[,1] <- NULL #removing the first column
hhdata #to display data contents
```

Followings are the R script for installation and estimating diversity indices using R package, vegan

```
#install vegan package from a menu, Package then install in RStudio
S=apply(hhdata>0,1,sum)# estimate species richness (S) without loading vegan
S # to display a richness
library(vegan) #loading vegan package
H=diversity(hhdata)#estimate Shannon diversity index
help(diversity)# look for description of function diversity
simp=diversity (hhdata, index="simpson") #estimate simpson index
J = diversity (hhdata, index ="simpson")/log(S) #estimate Pielou's evenness (J)
diversity(hhdata[-1], index="shannon")#exclude first column in case of data file
with first column as row name
barplot(simp) #plot simpson index
pairs(cbind(H, simp), pch="+", col="blue") #plot all
## Species richness (S) and Pielou's evenness (J):
```

S <- specnumber(hhdata) #estimate richness
cor(H,simp) #correlation coefficient between the Shannon and Simpson indices

A useful picture of diversity across several units is the function anosim() in the package, vegan. This analysis ranks all the dissimilarities among accessions and produces a boxplot of the ranks of dissimilarities within a given unit e.g., household. As an example, iris data set within this package is given below.

data(iris) #loading data in R memory
distiris<-dist(iris[,1:4]) #distance matrix computed by using the specified distance measure to compute the distances between the rows of a data matrix
anoiris<-anosim(distiris,iris$Species) #analysis of similarities (anosim) provides a way to test statistically whether there is a significant difference between two or more groups of sampling units.
plot(anoiris) #produces a boxplot of the ranks of dissimilarities within a given unit.

Another useful R package is BiodiversityR, which is a graphical user interface for statistical analysis of biodiversity and ecological communities, including species accumulation curves, diversity indices, Renyi profiles, GLMs for analysis of species abundance and presence-absence, distance matrices, Mantel tests, and cluster, constrained and unconstrained ordination analysis. It is menu-driven built within Rcmdr package. BiodiversityR analyzes two datasets simultaneously as does the vegan community ecology package. These data sets are the community datasets (rows correspond to sample units and columns correspond to species) and the environmental datasets.

It is suggested to install the package in R following the guidelines[55] as described in the installation guide. The manual[56] can also be accessed.

Followings are the commands and steps for analysis in BiodiversityR. An analysis can be carried out either through menu driven or using commands:

library (BiodiversityR) #load BiodiversityR package
library (Rcmdr) #load Rcmdr package
BiodiversityRGUI() #open graphical interface
help("BiodiversityRGUI", help_type="html") #to see details.

These are the steps for doing analyses with the menu options of BiodiversitR. To select the species and environmental matrices, follow these menu-driven steps:

BiodiversityR > Environmental Matrix > Select environmental matrix
Select the dune.env dataset as an example
Biodiversity > Community Matrix > Select community matrix
Select the dune dataset as an example.

To calculate diversity indices for each site, follow these steps:

BiodiversityR > Analysis of diversity > Diversity indices …
Diversity index: Shannon
Calculation method: separate per site.

To calculate diversity indices for each site using the command options of BiodiversityR, use the following scripts:

Diversity.1 <- diversityresult(dune, index="Shannon",method="each site")
Diversity.1
Diversity.2 <- diversityresult(dune, index="Simpson",method="each site")

[55] https://www.worldagroforestry.org/sites/default/files/users/admin/Installation%20of%20BiodiversityR%202018.pdf
[56] http://apps.worldagroforestry.org/downloads/Publications/PDFS/b13695.pdf

11.1 Interpretation

Richness (S) is a number of species, landraces, and particular traits in household, community, sites, or landrace. It quantifies types of the dataset. Shannon index (Shannon diversity index or Shannon Weaver index, H') includes both species number and evenness, where a greater number of species increase diversity, as does a more equitable distribution of individuals among species. High H' is representative of a diverse and equally distributed community. H' is strongly influenced by species richness and by rare species. Simpson index (D) is a measure of diversity, which takes into account both richness and evenness. The value of D ranges from 0 to 1, the greater the value the greater the diversity. The Simpson index gives more weight to evenness and common species. Evenness (Pielou's evenness, E) is a measure of the relative abundance of the different species making up the richness of an area. A community dominated by one or two species is considered to be less diverse than one in which several different species have a similar abundance. Its value ranges from 0 to 1 and 1 is complete equitability.

12. Conclusion

Native agrobiodiversity is generally neglected for conservation, quantification, evaluation, and monitoring. Different statistical tools can be used under agrobiodiversity statistics. Many software and R package are now available for agrobiodiversity study including measurement. Six types and levels of agrobiodiversity need to quantify and study for better management of agrobiodiversity. An operational agricultural unit is like a factor in which variables are generated and analyzed. Multivariate analysis and diversity indices are the major statistical components used in agrobiodiversity measurement. Estimates help generate the agrobiodiversity indicators that ultimately drive the program plans and activities. Many different types of scores and indices can be measured for household, community, any other administrative unit, and other OAUs. Among the many software and R packages, vegan and BiodiversityR are very useful packages for estimating diversity indices and multivariate analysis along with many statistical features. Such estimates should be measured over a certain geo-region and period to monitor the status, plan the program, and rank the geo-regions.

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14. References

Bajracharya, J., Rana, R., Joshi, B.K., Subedi, A. and Sthapit, B. (2012). Measuring on-farm crop diversity. In: B.R. Sthapit, P. Shrestha and M.P. Upadhyay (eds.), *On-farm management of agrobiodiversity in Nepal: Good practices.* Kathmandu: NARC, LIBIRD and Bioversity International, pp. 9-12.

Bioversity International (2017). *Agrobiodiversity Index. Program Oversight.* A paper presented in 49th Board Meeting of Bioversity International, Rome, Italy, 10 – 12 May 2017.

Borcard, D., Gillet, F. and Legendre, P. (2011). *Numerical ecology with R.* LLC: Springer Science+Business Media.

Grum, M. and Atieno, F. (2007). St*atistical analysis for plant genetic resources: clustering and indices in R made simple*. Handbooks for Genebanks, No. 9. Rome: Bioversity International.

Gurung, R., Sthapit, S.R, Gauchan, D., Joshi, B.K. and Sthapit, B.R. (2016). *Baseline Survey Report: II. Ghanpokhara, Lamjung.* Integrating Traditional Crop Genetic Diversity into Technology: Using a Biodiversity Portfolio Approach to Buffer against Unpredictable Environmental Change in the Nepal Himalayas. Pokhara: LI-BIRD, NARC and Bioversity International. Available online at https://cgspace.cgiar.org/handle/10568/81039 [Accessed on 11 August 2021].

Jarvis, D.I., Myer, L., Klemick, H., Guarino, L., Smale, M., Brown, A.H.D., Sadiki, M., Sthapit, B. and Hodgkin, T. (2000). *A Training Guide for In Situ Conservation On-farm.* Version 1. Rome: International Plant Genetic Resources Institute.

Joshi, B.K. and Baniya, B.K. (2006). A diversity in qualitative traits of Nepalese cultivated buckwheat species. *Fagopyrum*, 23:23-27.

Joshi, B.K. and Shrestha, B.B. (2017). Notes on plant and crop classification. In: B.K. Joshi, H.B. KC and A.K. Acharya (eds.), *Conservation and Utilization of Agricultural Plant Genetic Resources in Nepal.* Proceedings of 2nd National Workshop, 22-23 May 2017, Dhulikhel: NAGRC, FDD, DoA and MoAD, pp. 17-20.

Joshi, B.K. and Shrestha, R. (eds.) (2019). Working Groups of Agricultural Plant Genetic Resources (APGRs) in Nepal. *Proceedings of National Workshop*, 21-22 June 2018, Kathmandu: NAGRC, NARC.

Joshi, B.K., Ghimire, K.H., Gurung, R., Pudasaini, N., Pant, S., Paneru, P., Gauchan, D., Mishra, K.K. and Jarvis, D. (2020b). On-farm Agrobiodiversity Measurement and Conservation. In: B.K. Joshi, D. Gauchan, B. Bhandari and D. Jarvis (eds.), *Good Practices for Agrobiodiversity Management*. Kathmandu: NAGRC, LI-BIRD and Alliance of Bioversity International and CIAT, pp. 15-24.

Joshi, B.K., Gorkhali, N.A., Pradhan, N., Ghimire, K.H., Gotame, T.P., KC, P., Mainali, R.P., Karkee., A. and Paneru, R.B. (2020c). Agrobiodiversity and its Conservation in Nepal. *Journal of Nepal Agricultural Research Council* 6: 14-33. DOI: https://doi.org/10.3126/jnarc.v6i0.28111.

Joshi, B.K., Gurung, S.B., Mahat, P.M., Bhandari, B. and Gauchan, D. (2018). Intra-Varietal Diversity in Landrace and Modern Variety of Rice and Buckwheat. *The Journal of Agriculture and Development*, 19: 1-8. Available online at https://cgspace.cgiar.org/handle/10568/97576 [Accessed on 30 August 2021].

Joshi, B.K., Shrestha, P., Upadhyay, M.P., Chaudhary, B., Mudwari, A., Baniya, B.K., and KC, H.B., (2007). On-farm variation and household diversity of pigeon pea landraces in Kachorwa, Nepal. *Nepal Agric. Res. J.*, 8:28-34. Available online at https://www.nepjol.info/index.php/NARJ/article/view/11567 [Accessed on 30 August 2021].

Joshi, B.K., Upadhyay, M.P., Bimb, H.P., Gauchan, D. and Baniya, B.K. (2005). Data analysis methods adopted under in-situ global project in Nepal. *Nepal Agric. Res. J.*, 6: 99-109. Available online at https://www.nepjol.info/index.php/NARJ/article/view/3371 [Accessed on 30 August 2021].

Kindt, R. and Coe, R. (2005). *Tree diversity analysis. A manual and software for common statistical methods for ecological and biodiversity studies*. Nairobi: World Agroforestry Centre (ICRAF).

PAR (Platform for Agrobiodiversity Research) (2018). *Assessing Agrobiodiversity: A Compendium of Methods*. Platform for Agrobiodiversity Research, Rome.

Pudasaini, N., Sthapit, S.R., Gauchan, D., Bhandari, D., Joshi, B.K. and Sthapit, B.R. (2016). *Baseline Survey Report: I. Jungu, Dola*kha. Integrating Traditional Crop Genetic Diversity into Technology: Using a Biodiversity Portfolio Approach to Buffer against Unpredictable Environmental Change in the Nepal Himalayas. Pokhara: LI-BIRD, NARC and Bioversity International.

Sthapit, B.R., Gauchan, D., Joshi, B.K. and Chaudhary, P. (2017). Agrobiodiversity index to measure agricultural biodiversity for effectively managing it. In: B.K. Joshi, H.B. KC and A.K. Acharya (eds.), *Conservation and Utilization of Agriculture Plant Genetic Resources in Nepal*. Proceed. 2nd National Workshop, May 22-23, 2017, Dhulikhel: NAGRC/FDD/MoAD.

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Chapter 11

Agrobiodiversity and Natural Resource Management in Traditional Agricultural Systems of Northeast India

By Wishfully Mylliemngap

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Agrobiodiversity and Natural Resource Management in Traditional Agricultural Systems of Northeast India

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Abstract

North-East India, which falls under the Indian Eastern Himalayan region and forms part of two global biodiversity hotspots, is well-known for its rich diversity of flora, fauna, cultures, and traditional knowledge systems. Agriculture is the main occupation of the communities living in this mountainous region supplemented by the utilization of wild useful species from the nearby forests. Traditional agriculture in North-East India follows a mixed cropping pattern through multi-cropping, crop rotation, and use of multipurpose nitrogen (N)-fixing trees, along with protection of semi-domesticated and wild biodiversity, including medicinal plants, wild edible fruits and vegetables, fodder plants and other useful species. Presently, there has been a gradual shift from subsistence cultivation to commercial agriculture driven by market forces and modernization, leading to a transition from traditional to intensive agriculture and monoculture of cash crops. This has resulted in reduced cultivation of local crop varieties and the disappearance of the associated traditional ecological knowledge (TEK). Therefore, the present study attempts to review the contribution of traditional agricultural practices to agrobiodiversity conservation and sustainable natural resource management. Traditional practices such as shifting (*Jhum*) cultivation systems, bamboo-drip irrigation, paddy-cum-fish cultivation, traditional agroforestry systems of different Indigenous communities residing in different states of North-East India were mentioned in this review. It is undeniable that TEK was developed by communities through many centuries by trial-and-error methods to conform to the local climate, topography, ecology, and socio-cultural relevance to the concerned Indigenous communities. This knowledge, therefore, has a great scope for improvement by integration with scientific knowledge for transforming into sustainable agricultural systems in the face of climate change adaptation and mitigation of the vulnerable mountain communities of the Himalayan region.

Keywords

Indigenous communities; Agriculture; Traditional knowledge; Sustainable farming; Conservation

Citation

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1. Introduction

Agricultural biodiversity or agrobiodiversity has been defined by the Food and Agriculture Organization (FAO) as "*The variety and variability of animals, plants and micro-organisms that are used directly or indirectly for food and agriculture, including crops, livestock, forestry and fisheries. It comprises the diversity of genetic resources (varieties, breeds) and species used for food, fodder, fibre, fuel and pharmaceuticals. It also includes the diversity of non-harvested species that support production (soil micro-organisms, predators, pollinators), and those in the wider environment that support agroecosystems (agricultural, pastoral, forest and aquatic) as well as the diversity of the agroecosystems*" (FAO, 1999). In short, agrobiodiversity constitutes the biodiversity components that contribute to food and agriculture, which includes genetic resources of crops and livestock as well as of other plants, animals, and microorganisms sustaining the structure and functions of the agroecosystems. Agrobiodiversity has been reported to contribute to agricultural productivity and food security, stability of farming systems and reduce the pressure of agriculture on fragile areas, forests, and endangered species (Thrupp, 2000) and can enhance human food diversity and nutrition (Remans *et al.,* 2014). Recent works reported that food crops obtained from traditional cultivars and non-cultivated plants gathered from diverse ecosystems which compose many local diets globally, contain higher nutrient content (FAO, 2010). In addition to providing food and livelihood, agrobiodiversity is also a source of other material requirements such as clothing, shelter, medicines, new breeding varieties, and ecosystem services including maintenance of soil fertility and biota, soil and water conservation (CBD, 2018). For example, wild relatives of crops have been found to provide several desirable traits such as disease resistance, abiotic stress tolerance, quality improvements, and yield increases which have proved to be valuable in agriculture breeding programs (Tyack *et al.,* 2020). The use of cover crops in agroecosystems can provide regulating ecosystem services such as nutrient cycling, water storage, improvement of water quality, decreased erosion, weed and pest control and carbon sequestration (Dabney *et al.,* 2001; Frasier *et al.,* 2016; Pinto *et al.,* 2017; Schipanski *et al.,* 2014). Additionally, there may be a heritage and cultural value of traditional agroecosystems and the species contained in them in different parts of the world (Qiyi *et al.,* 2009), that even though they may not be directly useful to people now; yet the present generation would like to preserve them for posterity.

Cochrane (1975) defined traditional agriculture as "*the customary methods of earning a living from the land that have been handed down to posterity by word of mouth or by practice and have, therefore, withstood the test of time*". Traditional agricultural practices have been developed over many centuries by local communities taking cognizance of the local biodiversity, topography, climate and socio-cultural setup, and has been a source of livelihood for people in many regions of the world (Koohafkan and Altieri, 2010; Pulido and Bocco, 2003). The Indigenous knowledge evolved from these agricultural systems is usually very rich and detailed comprising of knowledge on plant use, soil types and land use classification, micro-climate and being developed by local communities not only through observation of nature but also through 'trial-and-error' experimentations in the field. Even with the advancement of modern agriculture, many of these traditional agricultural (TA) practices are still in existence today in many parts of the world. Traditional agricultural (TA) systems have been known to contribute to the conservation of biodiversity including agrobiodiversity (Altieri, 2004) and were also considered as being of paramount importance for preventing species loss (Eriksson, 2021). In TA systems, farmers employed numerous Indigenous practices for utilization, enhancement, and conservation of biodiversity (Altieri, 2004; Koohafkaan, 2012). Traditional varieties and landraces of many major and minor crops are cultivated by farmers, thus, enhancing more diversity in production systems, which is conducive to sustainable agricultural development. TA systems maintain high genetic diversity that occurs due to natural interspecific and inter-varietal breeding among crop plants (Elias *et al.,* 2001).

In present days, TA is facing different kinds of threats such as low economic viability, people's migration, climate change as well as replacement by modern extensive agriculture. Consequently, there is gradual abandonment of these practices leading to loss of valuable Indigenous crop varieties and the associated traditional ecological knowledge embedded within them. Responding to these global threats, the FAO in 2002 launched a programme known as GIAHS-Globally Important Agricultural Heritage Systems, aimed to conserve and help in adaptive management of TA systems having outstanding values (FAO, 2018). Nevertheless, TA is receiving significant attention nowadays as a sustainable alternative to industrial farming (Fraser *et al.,* 2015) especially for developing a climate-smart food production system (Singh and Singh, 2017). In comparison to modern extensive agriculture, which is mainly focused on maximizing production, TA has been considered a more sustainable practice since it involves the use of local knowledge and available resources, minimal use of external inorganic inputs, recycling of agricultural and other wastes through composting and adaptive measures to extreme climatic events (Altieri *et al.,* 1987; Anex *et al.,* 2007; Denevan, 19952015; Ellis and Wang, 1997; Naylor *et al.,* 2005; Schiere and Kater, 2001). The use of organic inputs enhances soil health through nutrient enrichment and diversity of soil microbiota (Koohafkan and Altieri, 2010). Crop residue management and reduced tillage characteristic of TA systems improve C sequestration in soils (Aguilera *et al.,* 2013) that can potentially contribute to mitigation of GHGs emission (Sanz-Cobena *et al.,* 2017). Moreover, mixed cropping practiced in TA diversifies the food systems and reduces risks due to crop failure, and insect and pest attacks (Patel *et al.,* 2019; Sauerborn *et al.,* 2000). Armitage (2003) identified that maintaining traditional agroecological systems along with the associated adaptive resource management strategies used by local groups is one of the opportunities to enhance conservation. Coeto *et al.* (2019) indicated that the ecological and cultural resilience of agroecosystems of Mexico was higher when there is sufficient transmission of the biocultural legacy from the ancestors and the attachment of peasant families to it. Similarly, in the Indian Himalayan Region (IHR), Chandra *et al.* (2010) suggested that agroecosystems with traditional crops are more ecologically and economically viable and important for food security, thus, contributing to the long-term sustainability of agroecosystems and conservation and management of the surrounding landscape. Anthropological and ecological research conducted on traditional agriculture showed that most Indigenous modes of production exhibit a strong ecological basis and contribute towards the regeneration and preservation of natural resources (Denevan, 2001).

The North-Eastern region of India lies between 22° to 29°5'N latitudes and 88°E to 97°30' E longitudes and covers an area of about 262,379 sq. km. It is composed of 8 states, viz., Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Tripura and Sikkim. The region shares international boundary with 4 countries, viz., Bangladesh, Myanmar, Bhutan and China (Figure 1). Physiographically, the region can be categorised as the Indian Eastern Himalayas covering about 52% of the entire Eastern Himalayas. The

Eastern Himalayan region has been recognized as a 'Centre of Plant Biodiversity' and 'Eastern Asiatic Regional Centre for Endemism' (Wikramanayake, 2002). The convergence of the Indo-Malayan and Palearctic biogeographical realms in the landscape has resulted in rich flora and fauna (CEPF, 2005; Hua, 2012). The North-Eastern region of India comprises both the Himalayan and Indo-Burma global biodiversity hotspots. About 50% of the total flowering plants found in India have been known to occur here, out of which 40% are endemic species. Moreover, it was reported that the region is a place of origin of wild relatives of 132 economically important species including important and notable species of citrus, banana, rice, sugarcane, and pulses (Mao *et al.,* 2009). Therefore, the region has been recognized by the ICAR-National Bureau of Plant Genetic Resources (NBPGR) as being rich in wild relatives of crops. The region has been identified by the Indian Council of Agricultural Research (ICAR) as a 'centre of rice germplasm'. The region harbours a wide range of rice diversity estimated at 9,650 varieties and their wild relatives adapted to different environments such as upland, lowland, and deep-water (Hore and Sharma, 1995). It was reported that a total 2,639 accessions of rice germplasms, including their wild relatives, have been collected from the region between 1985 and 2002 (Hore, 2005).

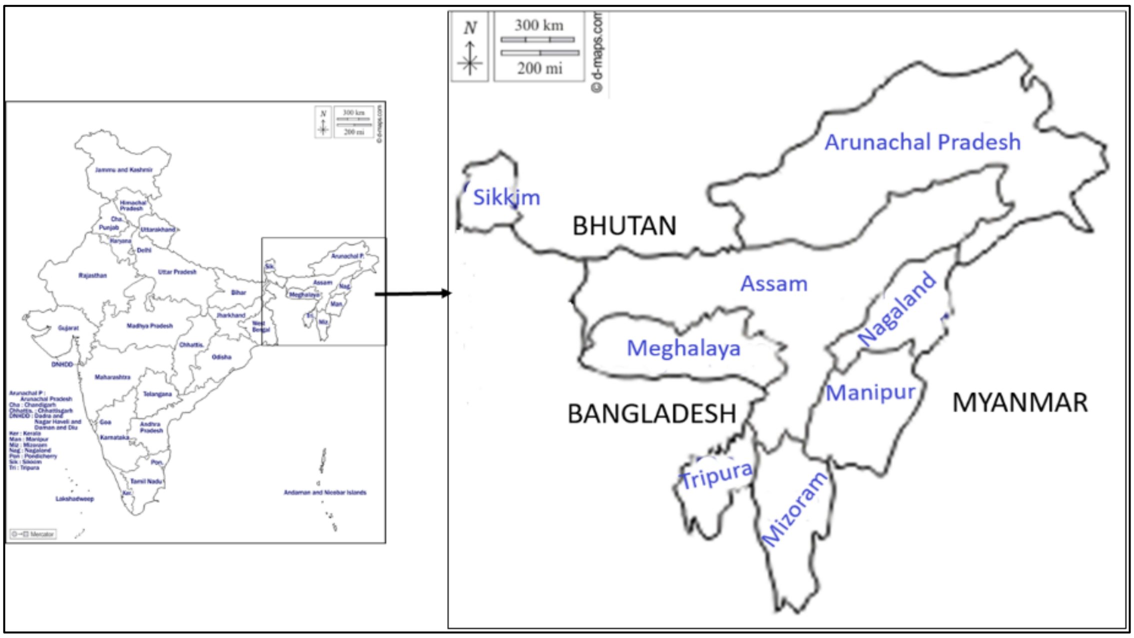

Figure 1: Map showing the location of the North-eastern region of India (modified from https://d-maps.com/)

In addition to its rich biodiversity, the region is also culturally diverse with over 46 million people (Census of India 2011) belonging to more than 200 culturally distinct ethnic communities. Rain-fed agriculture is the main livelihood source of these mountain communities supplemented by gathering of wild edible fruits and vegetables from nearby forests and farm fallows for self-consumption or additional income. The traditional ecological knowledge (TEK) associated with these practices is preserved in the form of stories, songs, folklore, proverbs, beliefs, rituals, customary laws, and other forms of oral traditions. The TA practices of this region vary from one community to another depending on the inherent TEK, socio-cultural setup and environmental and topographical conditions of the place. A number of TA practices such as paddy-cum-fish cultivation of *Apatani* tribe of Arunachal Pradesh, *Zabo* system and Alder-based agriculture in Nagaland, large cardamom agroforestry in Sikkim, Bamboo drip irrigation in Meghalaya are still prevalent till the present days indicating that they are sustainable, viable as well as cost-effective (De, 2021). However, with the advent of modernization and rush towards a cash economy, a large number of TA systems have been converted to intensive agriculture, monoculture cultivation and cash crop plantations. Moreover, traditional crops including local varieties of grains and vegetables are being slowly replaced by high-yielding varieties leading to gradual disappearance of many Indigenous crops.

From the above review of literature, it is clear that TA has the potential to contribute towards sustainability and resilience of mountain ecosystems as well as in conservation of biodiversity. Therefore, the present study attempts to emphasize the importance of traditional agricultural systems of Northeast India for the conservation of agrobiodiversity as well as the conservation and management of natural resources such as soil, water, and land. The traditional ecological knowledge involved in TAs has a great scope for improvement by integration with scientific knowledge to develop sustainable agriculture, especially for the climate change adaptation and mitigation of the vulnerable mountain communities of the Himalayan region.

2. Traditional Agricultural Systems

2.1 Shifting (Jhum) Cultivation Systems

Shifting cultivation, also known as slash-and-burn, swidden, or rotational bush fallow agriculture, is one of the most ancient farming systems believed to have originated in the Neolithic period 8,000 B.C. This practice is prevalent mostly in the mountainous and hilly regions of Central Africa, Latin America and Southeast Asia (van Vliet *et al.*, 2012). It is a type of mountain agriculture in which a patch of forest is cleared completely, the debris is left to dry and then burnt after which the land is used for cultivation for 1-2 years. At the end of the cropping period, the land is left fallow for a certain number of years ranging from 3-5 years to over 10-15 years or more, during which natural regeneration of vegetation takes place. After the fallow period is over when sufficient growth of forest is obtained the same land is again cleared for cultivation and the cycle is repeated. Shifting cultivation involves rotation of fields rather than rotation of crops. The important features of this agricultural practice include no tillage, use of primitive tools like dribbling sticks and hoes, dependence on manual labour, absence of manuring and irrigation and short-term use of land, followed by a long fallow period. It is a form of subsistence agriculture whereby a farmer grows different types of food crops mostly for household consumption while the surplus produce is either bartered for other goods or sold for a little cash income. The merits and demerits of *Jhum* cultivation have been a subject of debate among the scientific community worldwide for a few decades now (Fox, 2000; Mertz, 2002; Mertz *et al.*, 2009; Pedroso-Junior *et al.*, 2009). However, no clear consensus has emerged so far regarding its sustainability or ecological influences (Ribeiro Filho *et al.*, 2013).

In North-East India, shifting cultivation, popularly known as *Jhum* cultivation is prevalent in the states of Arunachal Pradesh, Nagaland, Manipur, Meghalaya, Tripura and hill districts of Assam (Figure 2). It is an inseparable part of the socio-cultural life of the local communities and most of their religious rites and rituals and community festivals revolve around this practice (Priyadarshni, 1995; Teegalapalli and Datta, 2016). It is practiced in community land on hilly forest tracts. The traditional head of the village along with village elders are responsible for allotment of *Jhum* plots to each household. Land clearing, sowing and harvesting are generally carried out with community participation, except in rare occasions where activities were done by the members of the family to which the particular plot is allotted. The cultivation pattern involves mixed cropping where different types of crops are grown on the same plot. The type of crops grown varies among tribes and locations. Commonly, staple food grains like paddy, maize, and millet are grown along with legumes, root and tuber crops and leafy vegetables. These crops have different harvesting seasons, thereby, providing a continuous source of food supply throughout the year. The abandoned fallow fields continue to provide different resources intermittently in the form of residual crops, wild and semi-domesticated edible fruits and vegetables, medicinal plants, etc. Therefore, *Jhum* cultivation has been a source of sustenance and livelihood for the people in the region especially those living in the remote areas where there are limited means of communication and market linkages.

2.1.1 Agrobiodiversity of shifting cultivation systems

Jhum cultivation systems follow multi-cropping pattern with minimum tillage. Paddy, maize and millets are the major crops grown along with pulses, Colocasia, pumpkin, cucumber, and other food crops (Dollo *et al.,* 2005). In Nagaland, the alder-based *Jhum* cultivation is well-known. In this system, the nitrogen-fixing alder (*Alnus nepalensis*) trees are maintained in the *Jhum* plots and pollarded at 1-2 m above the ground level. The lopped branches and leaves are burned on the field after which the soil is prepared for cultivation. The major crops/vegetables grown are millets, Job's tear, maize, potato, tomato, chilli, cabbage, cauliflower, squash, cucumber, ginger, French bean, soybean and pea. In the *Jhum* cultivation of the *Nocte* and *Wancho* tribes of Arunachal Pradesh, a total of 60 species of crop plants were reported belonging to 25 families, the maximum number of crops being from the families Cucurbitaceae, Poaceae, Solanaceae, Apiaceae and Dioscoreaceae (Bhuyan and Teyang, 2015). Teegalapalli and Datta (2016) estimated that around 7 varieties of rice, 2 types of millets and 30 different types of vegetables along with yam, sweet potato, corn and sugarcane were grown by the *Adi* tribe of Upper Siang district of Arunachal Pradesh. Bhuyan *et al.* (2012) reported 39 crop species from 14 families cultivated in *Jhum* fields of *Adi* tribe residing in East Siang district, Arunachal Pradesh. Similarly, *Nocte* tribe of Arunachal Pradesh were cultivating up to 20 species in their *Jhum* field (Tangjang, 2009). Additionally, one study in certain *Jhum* fields of North-East India reported rich diversity of as many as 12 species of Solanum, 9 species of chillies and 18 species of Cucurbitaceae (Asati and Yadav, 2004) while another recorded about 22 important crop species (Dikshit and Dikshit, 2004).

Besides crop diversity, *Jhum* fallows also serve as a habitat for wildlife as well as wild useful species such as medicinal plants, wild edible plants, fodder plants and alike. Studies in and around the Dampa Reserve Forest in Mizoram revealed that the diversity of bird species in *Jhum* sites were more similar to rainforest than were monocultures (Mandal and Raman, 2016). They also argued that rapid recovery of dense and diverse secondary bamboo forests during fallow periods makes the shifting agricultural landscape mosaic a better form of land use for bird conservation than monocultures.

2.1.2 Resource management in shifting cultivation systems

In Alder-based *Jhum* cultivation of Nagaland, the alder trees were not cut completely but managed in the *Jhum* field for several years. These actinorhizal N-fixing trees enrich the soil with nitrogen, thus maintaining fertility of the soil. Studies have found that these soils were rich in nutrients and harbour very high active microbial populations making the soil more productive (Giri *et al.,* 2018). Besides, the trees are also multipurpose, the pollarded branches being used for timber and fuel while the fallen leaves enrich the soil with organic matter and helps in recovery of soil during the fallow period.

Figure 2: A freshly cleared and burned shifting cultivation patch in Nagaland (Photo credit: Anup K. Das)

Another method of soil management in *Jhum* cultivation is an indigenous technique of soil erosion control by farmers in Wokha district of Nagaland by construction of a structure known as *Echo* in the local language (Figure 3). *Echo* consists of short bamboo barricades strategically placed horizontally across the slope in *Jhum* fields to reduce water runoff and check soil erosion. The structure generally lasts up to 3 years or sometimes up to 5 years. Scientific studies carried out on the efficiency of *Echo* for soil erosion control revealed that the structure could retain soil about 229.5 t/ha/yr in the first year, about 153.0 t/ha/yr in the second year and about 91.8 t/ha/yr in the third year (Singh *et al.,* 2016). Application of traditional knowledge and skills on *Echo* along with scientific improvisation of the technique can be a good option for sustainable management of land and soil resources in the vast *Jhum* area of the state as well as the whole region. The technique can also be adopted in other agricultural areas with steep topography.

Traditional practice of soil erosion control in shifting cultivation locally called *Paneng* or *Panpeng* is unique to *Adi* tribe of Arunachal Pradesh. *Adi* is one of the largest tribal communities of Arunachal Pradesh inhabiting the districts of East Siang, Upper Siang, West Siang and Western part of Lower Dibang Valley. They trace their origin from *Tanii,* 'the first human being' which they regarded as *Abo Tanii (Abo* meaning 'father' in their local dialect). They are comprised of more than 30 sub-tribes. Historians, anthropologists, and scholars believed that the tribe has migrated from Tibetan province. *Paneng* or *Panpeng* is a traditionally developed method of using logs of wood to reduce surface runoff during rainy season and check soil erosion. In this method, unburnt or half-burnt logs felled and burnt during the slashing of field were laid parallel to each other against the slope gradient to reduce the force of water flow and prevent the topsoil from being washed away. The structure is strengthened by wooden poles locally called *Sipit/Hipit* or wooden stumps called *Hiir*. Uprooted weeds from the field were also dumped alongside the logs which further enhance the efficacy of controlling soil erosion. In addition, the *Panpeng* also helps block any stone or gravel falling from upper slope that may damage the crops (Samal *et al.,* 2019).

Figure 3: *Echo*, a traditional method of soil erosion control in shifting cultivation fields in Wokha district of Nagaland (Photo credit: Anup K. Das)

2.2. Paddy-cum-fish Cultivation

2.2.1 Agrobiodiversity in paddy-cum-fish cultivation

Paddy-cum-fish cultivation is an Indigenous organised farming method of the *Apatani* tribe of Arunachal Pradesh locally known as *Aji-ngyii*: *Aji* meaning cultivation and *ngyii* meaning fish (Figure 4). The practice was considered to be one of the most productive and efficient agricultural systems of the region (Nimachow *et al.,* 2010). The practice involves integration of wet-rice cultivation with Indigenous millet (*Eleusine coracana*) and fish rearing on the same field. While paddy is grown on the field, millet is grown along the bunds surrounding the rice fields. *Houttuynia cordata*, an edible herb growing wild on the lower sides of bunds is not weeded out, but retained, to act as soil binder to further strengthen the bunds. About 16 local varieties of rice and 4 millet varieties, classified into early- and late-maturing varieties, have been reported to be grown in the wet-rice farming systems (Dollo *et al.,* 2009; Kala, 2008) (Table 1). Different types of fish were also reared on the standing water of the rice fields. Additionally, shallow trenches were dug inside the paddy terraces. During monsoon season when water supply is abundant, the water in the paddy field is maintained at about 5 to 10 cm and fishes can move all over the rice fields. During the drier period when water is scarce, water remains only in the trenches where fishes retreat and continue to grow. Manuring of paddy fields also act as nutrition source for the fishes, as such there is no requirement for additional fish feeds. In this system, both paddy and fishes are produced together by proper management of rainwater (Rai, 2004). Different species of Indigenous fishes such as *tali ngiyi* (*Channa* spp.), *papi ngiyi* (*Puntius* spp.), *ngilyang ngiyi* (*Schizothorax* spp.), *tabu ngiyi* (eels), *ribu* (*Nemaucheilus*), *ngiyi papi* (dorikona or weed fish) found naturally occurring in the stream draining the paddy fields are raised in the system. Other commercial species were introduced by the state government such as common carp (*Cyprinus caprio*), silver carp (*Hypophthalmichthyes molitrix*), grass carp (*Ctenopharyngodon idella*), *Labeo gonius* and *Barbonymus gonionotus*. However, the common carp remains the most reared species and the success rates is also found to be higher than the other varieties of fish (Nimachow *et al.*, 2010).

Figure 4: Paddy-cum-fish cultivation, Indigenous farming method of the *Apatani* tribe of Arunachal Pradesh (Photo credit: Tilling Rinya)

Table 1: Different landraces of paddy and millet cultivated by *Apatani* of Arunachal Pradesh (*Source:* Dollo *et al.*, 2009; Kala 2008)

Land races	*Early maturing variety*	*Late maturing variety*
Paddy (*Oryza sativa*)		
1. Eamo	*Ampu Ahare* (most commonly cultivated)	*Ampu Hatte* (rarely cultivated)
		Radhe Eamo (rarely cultivated)
		Eylang Eamo (most commonly cultivated)
		Ampu Puloo Hatte (extinct)
2. *Mipye*		
(i) Pyate Mipye	*Kogii Pyate* (commonly cultivated)	

Land races	*Early maturing variety*	*Late maturing variety*
	Zeehe Pyate (rarely cultivated)	
	Pyate Pyapu (rarely cultivated)	
(ii) Pyaping Mipye	*Tepe Pyaping* (most commonly cultivated)	
	Pyapu Pyaping (rarely cultivated)	
	Kogii Pyaping (rarely cultivated)	
	Zeehe Pyaping (rarely cultivated)	
	Pyare Mipye (cultivated near settlements)	
	Mishang Mipye (rarely cultivated)	
	Mithu Mipye (commonly cultivated)	
	Eylang Mipye (rarely cultivated)	
Millet (*Eleusine coracana*)		
Sarse	*Surpu Ahare* (commonly cultivated)	*Sartii* (rarely cultivated)
		Ahki sarse (rarely cultivated)
		Surpu Latha (most commonly cultivated)

2.2.2 Water resource management in paddy-cum-fish cultivation

The whole *Apatani* plateau is devoid of any big river or water body and depend on few small rivulets or streams for irrigating agricultural fields. As the community practices wet rice cultivation along with fish rearing, stagnant water is essential in their agricultural field for a period of 4-5 months. This has made the community search for an ingenious way to utilize the water of existing springs and streams efficiently and also to harvest and store the rainwater. With local skills and knowledge, the community has developed a well-designed system of channelizing the water from streams and rainwater to their agricultural field. The water from stream is blocked at an appropriate elevation with barriers (*Borang*) made of locally available wood and bamboo. The stored water is then channelized through canals locally called *Sugang* into each and every agricultural field. Maintenance and repair of the *Sugangs* were done by the beneficiaries of the community. The water thus brought to the fields is retained with the help of bunds called *Agber*. In each field, water is retained at a desired level, above which an outlet made of bamboo pipe is built to drain the excess water into the adjacent field situated at a lower level. The stepwise distribution of water to all the field is maintained, and the excess water drained out from each field block is further channelized towards a common final outlet.

Paddy-cum-fish cultivation is also practiced in other northeastern states, though the Apatani system is well-documented. In the system practiced in valley area of Manipur, trenches called "*Kom*" with a width of 4-5 metres (depending upon size of the paddy field) were dug on one side or along the whole boundary of paddy field. This *Kom* is filled with water where fish farming is carried out and the middle portion of the area is left for paddy. This practice has been carried out in almost every household since time immemorial and is very effective in terms of production and economic value.

2.3 Traditional Agroforestry System and Homestead Gardens

The Intergovernmental Panel on Climate Change (IPCC) has recognised agroforestry systems as one among the potential land uses important for food security and carbon sequestration contributing to climate change mitigation and adaptation (IPCC, 2019). In northeast India, agroforestry has been an integral part of traditional agriculture of the indigenous communities. Traditional agroforestry systems can be regarded as close-to-nature ecosystems providing ecosystem services similar to the forests such as the biodiversity, provision of food and fibre, water resources and its purification, climate regulation and carbon sequestration, nutrient cycling, primary production, production of oxygen, and soil formation, and recreation and the cultural services. The large cardamom-based agroforestry systems of Sikkim consist of a variety of shade tree species such as *Schima wallichii, Engelhardtia acerifolia, Eurya acuminata, Leucosceptrum canum, Maesa chisia, Symplocos theifolia, Ficus nemoralis, F. hookeri, Nyssa sessiliflora, Osbeckia paniculata, Viburnum cordifolium, Litsea polyantha, Macaranga pustulata,* and *Alnus nepalensis*, hence, supporting conservation of tree biodiversity (Sharma *et al.*, 1994). Sharma *et al.* (2007) studied the large cardamom-based agroforestry of Sikkim and observed that these systems accelerate the nutrient cycling, increase soil fertility and productivity, reduce soil erosion, conserve biodiversity, conserve water and soil, serve as carbon sink, improves the living standards of the communities by increasing the farm incomes and also provides aesthetic values for the mountain societies.

Traditional agroforestry of the Nyshi tribe of Arunachal Pradesh was found to harbour up to 80 species of useful plants of which 47 species were food plants, 21 species medicinal and 31 species used for other purposes (Deb *et al.*, 2009). These agroforestry systems were multi-storeyed, the top canopy comprising of *Livistona jenkinsiana, Grevillea robusta,* etc., the sub-canopy is dominated by *Artocarpus heterophyllus, Mangifera indica* while the middle storey was dominated by fruit trees such as papaya, guava and citrus species. The forest floor species mainly comprise of pineapple and vegetable crops, as well as wild food and medicinal herbs such as *Ageratum conyzoides, Spilanthes* sp. and other Asteraceae species..

In Meghalaya, important horticultural crops grown in the home gardens and agroforestry systems include orange (*Citrus reticulata)*, pineapple (*Ananas comosus*), lemon (*Citrus limon*), guava (*Psidium guajava*), jackfruit (*Artocarpus heterophyllus*) and bananas (*Musa* sp.). Intercropping of arecanut (*Areca catechu*), betel leaf (*Piper betle*) and black pepper (*Piper nigrum*) are the chief commercial crops commonly found in the agroforestry systems in the southern slopes of the state. Tynsong *et al.* (2018) reported rich plant diversity species in this agroforestry system comprising of 94 tree species, 17 species of shrubs and 48 herb species.

The pond-based agroforestry is a type of integrated farming system followed by the farmers in plains of Assam, Manipur, South Garo hills of Meghalaya and Tripura to meet the demands for food supply and their livelihood options. This is often a very common practice in each household of these places to have a farm pond where fruit crops like banana, arecanut, vegetable garden, etc., are maintained in the embankment or nearby uplands of the pond. The ponds are being used for pisciculture and during the lean season, the pond water is used for irrigation of crops and fruit trees. Rearing of animals such as cow, pig, buffalo or goat as well as farming local poultry is also practiced. Vegetable waste from the nearby garden and home are either made into compost or added to the pond as feed for the fishes like grass carps. Paddy is then cultivated in the lowland areas.

The homestead garden is a traditional practice found to be practiced in most of the states. The homestead gardens are generally located close to the house and used for growing vegetables, fruits and other food crops required for the family. A wide variety of crops are grown throughout the year in homestead gardens including potato, cabbage, chilli, tomato, beans, carrot, onion, garlic, etc.

2.4 Bamboo Drip Irrigation

The Bamboo drip irrigation system (Figure 5) is an ingenious method of irrigation by the Indigenous communities residing in the War Jaintia areas in Jaintia Hills district of Meghalaya. The people here practice agroforestry system of arecanut, black pepper and betel leaf (*Piper betel*). Irrigation is needed for the betel vines and black pepper crops during the winter season when water is scarce. This irrigation system is believed to be around 200 years old. The practice has evolved to compensate with the steep and undulating topography of the area which makes it difficult to construct ground irrigation channels. This method utilizes the water from the uphill streams and springs and directs it to the fields till it reached the base of the plant where water reduce to drops. Usually, water sources are distant from plantation sites and so the main bamboo channel runs several meters, sometimes even a couple of kilometres. The water is tapped from the upper slopes which are then diverted to various parts of the field located in the lower hill slopes through a system of secondary and tertiary bamboo channels. Channel sections are made of bamboos of varying diameters, to control the water flow in such a way that the water reaches the site in the lower reaches, where it is circulated without spillage. The channels are supported by forked branches. The system is considered so efficient that it was estimated that water entering the bamboo pipe at about 18-20 litres per minute gets transported over several hundred metres through the intricate network of channels till it finally gets reduced to about 20-80 drops per minute at the root of the plant. The advantages of using bamboo are two-fold: it prevents leakage, increasing crop yield with less water, and makes use of natural, local, and inexpensive material. As water is applied locally, leaching is reduced (fertilisers/nutrients loss is minimised), weed growth and soil erosion is highly controlled and soil infiltration capacity is increased (Ryngnga, 2016).

Figure 5: Bamboo drip irrigation in 'War' Jaintia area of Meghalaya (Photo credit: B.R. Suchiang)

3. Discussions

This review presented a few of the unique TA practices of Indigenous communities of North-eastern India that are still sustained till the present day. The probable explanation for their continued existence is that the knowledge and practices have been constantly evolved and modified by the concerned communities through their inherent TEK to adapt to the ever-changing environment, climate, demography, resource availability and various other natural and anthropogenic changes occurring around them.

Shifting cultivation though often regarded as unproductive and unsustainable, several researchers in NE India have revealed its positive role on the environment. Studies suggested that, in the shifting cultivation regime, there is optimal utilization of natural resources, which is conducive to the stability and sustainability of agriculture in the mountain ecosystems (Ramakrishnan, 1992). Bhuyan and Teyang (2015) opined that *Jhum* cultivation of *Nocte* and *Wancho* tribes of Arunachal Pradesh is well adapted to the local environment and ecological balance is maintained by mixed cropping of cereals and tree crops in the same field. In Nagaland, Chase and Singh (2014) reported a decline in soil fertility following conversion of natural forests to agricultural land use. However, soil fertility of Alder-based *Jhum* fallows were similar to natural forests which implied that agricultural land use with proper tree-crop management is ideal for maintaining productivity and soil health. Bhagawati *et al.* (2015) studied the climate change prospects of *Jhum* cultivation in NE India and observed that this agricultural system is being practised based on traditional ecological knowledge (TEK) gained through years of association with nature. This knowledge, instead of being threat to climate or environment, can provide deeper insight into the many different aspects of sustainable development and the interrelated role of local peoples and their cultures.

In spite of the positive reviews, many scholars have also pointed out the negative impacts of shifting cultivation mainly due to the shortened fallow period. In some parts of the region, reduction in fallow period from the traditional 15-20 years or 8-10 years to about 3-4 years in recent times has also posed a threat to the sustainability of shifting cultivation practices since the short fallow cannot allow sufficient recovery of soil and vegetation before resuming cultivation in the same plot. Bera and Namasudra (2016) reported negative impacts of shifting cultivation in Tripura such as destruction of forest, threat of biodiversity, degradation of soil quality, etc., which might have been aggravated due to shortened fallow periods. Therefore, it is imperative to document the good practices involved in this form of agriculture such as mixed cropping, high agrobiodiversity, traditional methods of soil erosion control such as the *Echo* practised by some communities in Nagaland and *Paneng/Panpeng* in Arunachal Pradesh. Technical and scientific innovation to transform the system and reduce its negative impact should be built around the existing traditional skills and knowledge so that the changes can be easily adopted by the farmers. In some instances, adoption of site-specific agro-based interventions has proved to be beneficial in augmenting productivity of major crops and livestock, thus ensuring more income, employment and food security (Kumar *et al.,* 2016). In spite of certain crises that this agricultural system faces, proper scientific research and appropriate policy supports can encourage this farming system to provide adequate food and economic security for the peoples and motivate them to conserve and enhance local crop diversity in the traditional environment (Bhuyan and Teyang, 2015).

The traditional paddy-cum-fish agriculture of the *Apatani* tribe of Arunachal Pradesh reflected the tribe's ingenuity in achieving optimum utilization and management of natural resource such as land, water and bioresources (Kala *et al.,* 2008). The system also has replication potential in other places with similar micro-ecological conditions (Dollo, 2009). The integration of rice with fish along with other crops such as millets enables low-cost practice needed for food security and nutritional security and good income from a limited area (Baruah *et al.,* 2019). In addition, cultivation of different Indigenous varieties of rice and millets leads to the conservation of this valuable genetic diversity. Rai (2005) reported that this agroecosystem is very advanced and has exceptionally high economic and energy efficiency. In present days, there is gradual modification of the traditional practices such use of iron and plastic pipes, and concrete instead of locally available materials like bamboo and wood to build irrigation canals and check dams, which may pose a threat to the health of the agroecosystem and disappearance of community TEK (Dollo, 2009). Observations mentioned in table 1 revealed that, out of the 16 Indigenous varieties of paddy reported from this agricultural system, only 5 varieties were commonly cultivated, while the rest were rarely or not cultivated at present. Similarly, out of the 4 varieties of millets only two were commonly cultivated while other 2 were rarely cultivated. These changing preferences in cultivation of certain crop varieties over others may gradually decrease the number of varieties cultivated in the TA system which may eventually lead to their extinction and loss of a valuable genetic diversity.

Agroforestry, a type of land use where trees are grown alongside non-woody crops in the same land (with or without livestock), has been adopted by the traditional communities of North-East India to fulfil their multifarious needs of food, fodder, fuel, medicinal plants as well as to generate income and ensure optimised use of land resources. Large cardamom-based agroforestry systems of Sikkim have been found to harbour a rich agrobiodiversity, increased farmers' income as well as provide different types of ecosystem services (Sharma *et al.,* 2007). On the other hand, the pond-based agroforestry of the plain areas of Assam, Manipur, South Garo hills of Meghalaya and Tripura revealed the local knowledge of integrated farming system combining agriculture, forestry, fishery and water management (Das *et al.,* 2012). The practice exhibited an efficient cycling of nutrients within the system through composting of crop residues and vegetable wastes that are added back to the soil; vegetable waste is also used as feed for fishes while the pond water is also used for irrigation during dry periods. Similarly, the Indigenous arecanut, betel leaf and black pepper-based agroforestry of Meghalaya have been found to be fairly sustainable with minimal impact on plant diversity (Tynsong *et al.,* 2018). In a study conducted in southern India, Hombegowda *et al.* (2015) concluded that depleted soil organic carbon (SOC) stocks brought about by the conversion of forest to agricultural land can be recovered by converting the same land to agroforestry.

Bamboo drip irrigation is another Indigenous knowledge by the farmers of War Jaintia in Meghalaya to solve the problem of irrigation in steep hill slopes with undulating topography and manage water resource efficiently. This system has been appreciated for its environment-friendliness since it requires no cutting down of trees or shrubs in the forest area to build the irrigation channels. The irrigation system also has potential for adoption in other mountain farming systems including shifting cultivation areas (Das *et al.,* 2012). Another positive attribute of this system is its low cost of construction and use of locally available material (bamboo), and minimal labour requirements. The system had lasted for decades which imply its sustainability and social acceptability. Ryngnga (2016) opined that there is still scope for improving the efficiency and durability of the system through use of modern scientific interventions, of course, without diluting the existing Indigenous knowledge and skills developed by the community through decades of experience.

In present day, TA still remains as a primary mean of food production system for the rural mountain community who substantially contributed to their food and nutritional security and livelihood. On the other hand, with the aim to increase productivity of agricultural systems to meet out the needs of the growing human population and market demands to enhance farmers' income and achieve self-sufficiency, different agricultural incentives have been offered by governments and relevant line departments at national, regional or local levels. These government schemes have motivated the people towards market-oriented agriculture such as use of high yielding crop varieties, exotic crops in horticulture and cash crop plantation and other non-farm activities. In response to the changing needs and aspirations of the people there has been a gradual transformation of TA practices to other unsustainable land uses. For instance, introduction of high yielding varieties and exotic crops has necessitated the use of inorganic fertilizers and pesticides that can pose a threat to the agroecosystem health in the long run. Similarly, increase in cash crop cultivation has given rise to monoculture plantations and slowly replacing food crop cultivation areas, thus leading to decline in agrobiodiversity and food security, increase in risk through crop failure, pest and insect attacks and loss of ecosystem services. Mylliemngap *et al.* (2016) observed that, in some villages of Upper Siang district of Arunachal Pradesh, there has been gradual transition towards wet-rice cultivation/terrace rice cultivation and cultivation of Kiwi fruit and large cardamom as cash crops. This transformation has posed a threat to the agrobiodiversity where the cultivation of local varieties of paddy and millets has reduced greatly and there is a fear that already the region is losing of some important genetic resources in the meantime. Nimasow *et al.* (2014) studied the sustainability of horticultural practices in West Kameng district of

Arunachal Pradesh and suggested working out land suitability analysis of various crops and generating awareness of climate change and its impact on the global environment among the local people. Pal and Dasgupta (2014) appraised the two farming systems of shifting cultivation and wet rice-cum-fish agriculture of the Indigenous communities of Arunachal Pradesh who also support biodiversity conservation through their practice. They suggested integration of traditional knowledge with scientific methods and innovations for better sustainability of these practices. In some instances, adoption of site-specific agro-based interventions has proved to be beneficial in augmenting productivity of major crops and livestock, thus ensuring more income, employment and food security.

4. Conclusion

The present review highlighted the underlying essence of different traditional agricultural practices of the Indigenous communities of NE India in terms of management and conservation of biodiversity and natural resources. Shifting cultivation and traditional agroforestry systems were found to maintain a high level of agrobiodiversity along with efficient management of soil fertility, soil erosion control and supply of variable ecosystem services. On the other hand, paddy-cum-fish cultivation exhibited an advanced integrated farming of paddy, millets and fish with optimum utilization of land and an almost perfected irrigation channel system by tapping the limited rain and stream water resources available in the *Apatani* plateau and storing it to ensure adequate water for irrigation. The bamboo-drip irrigation revealed the excellent skills and knowledge of the farmers to design and construct an intricate irrigation system from locally available bamboo resources in the rough hilly terrains of southern Meghalaya where construction of ground irrigation channels was not feasible. The gradual transitions from TA system to modern commercial based farming would result in the loss of associated traditional ecological knowledge, agrobiodiversity along with its valuable genetic diversity and ecosystem services. Considering that TA is closely associated with tribal livelihood prospective, specific approaches could be implemented to strengthen the existing cultivation practice instead of imposing modern intervention. Therefore, urgent concerted efforts are required to promote the sustainable use and management of traditional farming systems by integration of TEK with scientific knowledge through a multi-stakeholder approach in order to make conservation efforts successful.

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6. References

Aguilera, E., Lassaletta, L., Gattinger, A. and Gimeno, B.S. (2013). Managing soil carbon for climate change mitigation and adaptation in Mediterranean cropping systems: a meta-analysis. *Agriculture, Ecosystems and Environment*, 168: 25-36. DOI: https://doi.org/10.1016/j.agee.2013.02.003.

Altieri, M.A. (1987). *Agroecology the scientific basis of alternative agriculture*. Boulder: Westview Press.

Altieri, M.A. (2004). Linking ecologists and traditional farmers in the search for sustainable agriculture. *Frontiers in Ecology and Environment*, 2(1): 35-42. DOI: https://doi.org/10.1890/1540-9295(2004)002[0035:LEATFI]2.0.CO;2.

Altieri, M.A., Nicholls, C.I., Henao, A. and Lana, M.A. (2015). Agroecology and the design of climate change-resilient farming systems. *Agronomy for Sustainable Development*, 35(3): 869–890. DOI: https://doi.org/10.1007/s13593-015-0285-2.

Anex, R.P., Lynd, L.R., Laser, M.S., Heggenstaller, A.H. and Liebman, M. (2007). Potential for enhanced nutrient cycling through coupling of agricultural and bioenergy systems. *Crop Science*, 47: 1327–1335. DOI: https://doi.org/10.2135/cropsci2006.06.0406.

Armitage, D.E. (2003). Traditional agroecological knowledge, adaptive management and the socio-politics of conservation in Central Sulawesi, Indonesia. *Environmental Conservation*, 30(1): 79–90. DOI: http://dx.doi.org/10.1017/S0376892902000079.

Asati, B. and Yadav, D. (2014). Diversity of Horticultural crops in North-Eastern region. *ENVIS Bulletin Himalayan Ecology*, 12(1): 1-11. Available online: http://gbpihedenvis.nic.in/PDFs/Top%20Ten%20Bulletin%20Articles/Diversity_of_Horticulture_Crops.pdf [Accessed 21 August 2021].

Baruah, D., Posti, R., Kunal, K., Ganie, P.A., Tandel, R.S., Sarma, D., Garima, Kago Tamang and Gyati Rinyo. (2019). Integrated rice-fish farming in hilly terraces of the Apatani Plateau, Arunachal Pradesh. *Aquaculture*, 23(2): 24-34. Available online: https://enaca.org/enclosure.php?id=1047 [Accessed 27 August 2021].

Bera, A. and Namasudra. P. (2016). Impact of Shifting Cultivation on the Environmental Changes in Gumti river Basin, Tripura. *Int. J. Recent Sc. Res.*, 7(6): 11771-11774. Available online: http://www.recentscientific.com/sites/default/files/5519.pdf [Accessed 21 August 2021].

Bhagawati, K., Bhagawati, G., Das, R., Bhagawati, R. and Ngachan, S.V. (2015). The Structure of *Jhum* (Traditional Shifting Cultivation System): Prospect or Threat to Climate. *International Letters of Natural Sciences*, 46: 16-30. DOI: https://doi.org/10.18052/www.scipress.com/ILNS.46.16.

Bhuyan, S.I. and Teyang, T. (2015). Crop Diversity in Traditional *Jhum* Cultivated Land Practiced by Ethnic Nocte and Wancho of Eastern Himalaya. *International Journal of Advanced Research in Science, Engineering and Technology*, 2(1): 365-375. Available online: https://www.ijarset.com/upload/2015/january/7_IJARSET_bhuyan.pdf [Accessed 11 August 2021].

Bhuyan, S.I., Tripathi, O.P., Khan, M.., Yumnam, J. and Mondal, J. (2012). A survey of Traditional crop species diversity and its conservation in *Jhum* fields among —Adi tribe of Boleng area in East Siang of Arunachal Pradesh. In: Dutta, B.K., Choudhury P., and Nath A.J. (Eds.). *Biodiversity Researches in North-East India*. Assam: Assam University, Silchar, p.35-44.

CBD (2018). What is agricultural biodiversity? Available online: https://www.cbd.int/agro/whatis.shtml [Accessed 22 July 2021].

CEPF (2005). Ecosystem profile: Indo-Burma hotspot, Eastern Himalayan Region. Washington DC: Critical Ecosystem Partnership Fund, WWF US-Asian Program. Available online: https://www.cepf.net/sites/default/files/final.ehimalayas.ep_.pdf [Accessed 13 August 2021].

Chandra, A., Kandari, L.S., Payal, K.C., Maikhuri, R.K., Rao, K.S. and Saxena, K.G. (2010). Conservation and Sustainable Management of Traditional Ecosystems in Garhwal Himalaya, India. *New York Science Journal,* 3(2): 71-77. Available online: http://www.sciencepub.net/newyork/ny0302/11_1248_Conservation_ny0302.pdf [Accessed 01 August 2021].

Chase, P. and Singh, O.P. (2014). Soil Nutrients and Fertility in Three Traditional Land Use Systems of Khonoma, Nagaland, India. *Resources and Environment,* 4(4): 181-189. DOI: https://doi.org/10.5923/j.re.20140404.01.

Cochrane, R.H. (1975). The role of Traditional agriculture. *Ekistics*, 39(230): 48-50.

Coeto, A.C., Castillo, Y.B.V. and Sánchez, J.A.C. (2019). Resilience and sustainability of traditional agroecosystems of Mexico: Totonacapan. *Revista Mexicana de Ciencias Agricolas,* 10(1): 165-175. DOI: https://doi.org/10.29312/remexca.v10i1.1789.

Dabney, S.M., Delgado, J.A. and Reeves, D.W. (2001) Using winter cover crops to improve soil and water quality. *Communications in Soil Science and. Plant Analysis,* 32: 1221–1250. DOI: https://doi.org/10.1081/CSS-100104110.

Das, A., Ramkrushna, G.I., Choudhury, B.U., Munda, G.C., Patel, D.P., Ngachan, S.V., Ghosh, P.K., Das, S. and Kumar, M. (2012). Natural resource conservation through indigenous farming systems: Wisdom alive in Northeast India. *Indian Journal of Traditional Knowledge,* 11(3): 505-513. Available online: http://nopr.niscair.res.in/handle/123456789/14393 [Accessed 02 August 2021].

De, L.C. (2021). Traditional knowledge practices of North-East India for sustainable agriculture. *Journal of Pharmacognosy and Phytochemistry,* Sp 10(1): 549-556. Available online: https://www.phytojournal.com/archives/2021/vol10issue1S/PartI/S-10-1-101-107.pdf [Accessed 22 June 2021].

Deb, S., Arunachalam, A. and Das, A.K. (2009). Indigenous knowledge of Nyishi tribe on traditional agroforestry systems. *Indian Journal of Traditional Knowledge,* 8(1): 41-46. Available online: http://nopr.niscair.res.in/handle/123456789/2973 [Accessed 01 September 2021].

Denevan, W.M. (1995). Prehistoric agricultural methods as models for sustainability. *Advances in Plant Pathology*, 11(1995): 21–43. DOI: https://doi.org/10.1016/S0736-4539(06)80004-8.

Denevan, W.M. (2001). *Cultivated landscapes of Native Amazonia and the Andes*. New York: Oxford University Press.

Dikshit, K.R. and Dikshit, J.K. (2004). Shifting cultivation studies in India: a review. *Man and Environment*, 29(2): 37–69.

Dollo, M. (2009). Traditional Irrigation System: A Case of Apatani Tribe in Arunachal Himalaya, North East India. *Mountain Forum Bulletin* (January 2009), pp. 9-11. Available on: https://www.researchgate.net/publication/251570730_Mihin_Dollo_2009_Traditional_Irrigation_System_A_Case_of_Apatani_Tribe_in_Arunachal_Himalaya_North_East_India [Accessed 15 August 2021].

Dollo, M., Samal, P.K., Sundriyal, R.C. and Kumar, K. (2009). Environmentally Sustainable Traditional Natural Resource Management and Conservation in Ziro Valley, Arunachal Himalaya, India. *Journal of American Science,* 5(5):41-52. Available online; https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1041.8675&rep=rep1&type=pdf [Accessed 29 August 2021].

Dollo, M., Singh, K.I., Saha, D., Chaudhry, S. and Sundriyal, R.C. (2005). Livelihood and Natural Resource Utilization Pattern in an Ethnically Diverse Area in Arunachal Pradesh. In: Bhatt, B.P. and Bujarbaruah, K.M. (Eds.), *Agroforestry in North East India: Opportunities and Challenges*. Meghalaya, India: ICAR Research Complex for NEH region, pp. 55-70.

Elias, M., Penet, L., Vindry, P., McKey, D., Panaud, O. and Robert, T. (2001). Unmanaged sexual reproduction and the dynamics of genetic diversity of a vegetatively propagated crop plant, cassava (*Manihot esculenta* Crantz), in a traditional farming system. *Molecular Ecology*, 10: 1895–1907. DOI: https://doi.org/10.1046/j.0962-1083.2001.01331.x.

Ellis, E. and Wang, S.M. (1997). Sustainable traditional agriculture in the Tai Lake Region of China. *Agriculture, Ecosystems and Environment*, 61(2–3): 177–193. DOI: https://doi.org/10.1016/S0167-8809(96)01099-7.

Eriksson, O. (2021). The importance of traditional agricultural landscapes for preventing species extinctions. *Biodiversity and Conservation* 30: 1341–1357. DOI: https://doi.org/10.1007/s10531-021-02145-3.

FAO (1999). Agricultural Biodiversity, Multifunctional Character of Agriculture and Land Conference, Background Paper 1. Maastricht, Netherlands. September 1999.

FAO (2018). Globally Important Agricultural Heritage Systems: Combining agricultural biodiversity, resilient ecosystems, traditional farming practices and cultural identity. Available online: www.fao.org [Accessed 21 August 2021]

FAO. 2010. *Expert Consultations on Nutrition Indicators for Biodiversity*. Rome: FAO.

Fox, J. (2000). How blaming 'slash and burn' farmers is deforesting mainland Southeast Asia. *Asia Pacific Issues,* 47: 1-8. Available online: https://www.files.ethz.ch/isn/28630/api047.pdf [Accessed 25 August 2021].

Fraser, J.A., Frausin, V. and Jarvis, A. (2015). An intergenerational transmission of sustainability? Ancestral habitus and food production in a traditional agro-ecosystem of the Upper Guinea Forest, West Africa. *Global Environmental Change* 31: 226–238. DOI: http://dx.doi.org/10.1016/j.gloenvcha.2015.01.013.

Frasier, I., Quiroga, A. and Noellemeyer, E. (2016). Effect of different cover crops on C and N cycling in sorghum NT systems. *Science of the Total Environment*, 562: 628–639. DOI: http://dx.doi.org/10.1016/j.scitotenv.2016.04.058.

Giri, K., Mishra, G., Jayaraj, R.S.C. and Rajesh Kumar. (2018). Agrobio-cultural diversity of alder based shifting cultivation practiced by Angami tribes in Khonoma village, Kohima, Nagaland. *Current Science*, 115(4): 598-599. DOI: http://dx.doi.org/10.18520/cs/v115/i4/598-599.

Hombegowda, H.C., van Straaten, O., Köhler, M. and Hölscher, D. (2016). On the rebound: soil organic carbon stocks can bounce back to near forest levels when agroforests replace agriculture in southern India. *Soil,* 2: 13. DOI: https://doi.org/10.5194/soild-2-871-2015.

Hore, D.K. (2005). Rice Diversity Collection, Conservation and Management in Northeastern India. *Genet Resour Crop Evol,* 52: 1129–1140. DOI: https://doi.org/10.1007/s10722-004-6084-2.

Hore, D.K. and Sharma, B.D. (1995). Valuable plant genetic resources of northeastern region. *Journal of North-Eastern Council*, 15: 41–44.

Hua, Z. (2012). Biogeographical Divergence of the Flora of Yunnan, Southwestern China Initiated by the Uplift of Himalaya and Extrusion of Indochina Block. *PLoS ONE*, 7(9): e45601. DOI: https://doi.org/10.1371/journal.pone.0045601.

IPCC (2019). Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (Eds.)].

Kala, C., Dollo, M., Farooque, Purohit, A.N. and Choudhury, D.C. (2008). Land-use management and Wet-rice cultivation (Jebi Aji) by the Apatani people in Arunachal Pradesh, India. *Outlook on Agriculture*, 37: 125-129. DOI: https://doi.org/10.5367/000000008784648906.

Koohafkan, P. (2012). Dynamic conservation of globally important agricultural heritage systems: for a sustainable agriculture and rural development. In: Barbara Burlingame, B. and Dernini, S. (Eds.), *Sustainable diets and biodiversity directions and solutions for policy, research and action*. Rome, Italy: FAO, pp. 56-65.

Koohafkan, P. and Altieri, M.A. (2010). *Globally important agricultural heritage systems: a legacy for the future*. Rome: UN-FAO.

Kumar, R., Patra, M.K., Thirugnanavel, A., Chatterjee, D. and Deka, B.C. (2016). Towards the Natural Resource Management for Resilient Shifting Cultivation System in Eastern Himalayas. In: Bisht, J.K., Meena, V.S., Mishra, P.K. and Pattanayak, A. (Eds.), *Conservation Agriculture: An Approach to Combat Climate Change in Indian Himalaya*. Singapore: Springer Nature Pte Ltd., pp. 409-436.

Mandal, J. and Shankar Raman, T.R. (2016). Shifting agriculture supports more tropical forest birds than oil palm or teak plantations in Mizoram, northeast India. *The Condor: Ornithological Applications*, 118: 345–359. DOI: https://doi.org/10.1650/CONDOR-15-163.1.

Mao, A.A., Hynniewta, T.M. and Sanjappa, M. (2009). Plant wealth of Northeast India with reference to ethnobotany. *Indian Journal of Traditional Knowledge*, 8(1): 96-103. Available online: http://nopr.niscair.res.in/handle/123456789/2979 [Accessed 25 August 2021].

Mertz, O. (2002). The relationship between length of fallow and crop yields in shifting cultivation: a rethinking. *Agroforestry Systems*, 55(2): 149-159. DOI: https://doi.org/10.1023/A:1020507631848.

Mertz, O., Padoch, C., Fox, J., Cramb, R.A., Leisz, S.J., Lam, N.I. and Vien, T.D. (2009). Swidden change in Southeast Asia: understanding causes and consequences. *Human Ecology*, 37(3): 259-264. DOI: https://doi.org/10.1007/s10745-009-9245-2.

Mylliemngap, W., Samal, P.K., Kanwal, K.S. and Basar, K. (2016). A note on changing trends in traditional agricultural practices of Adi tribe of Arunachal Pradesh. *Hima-Paryavaran*, 29(1): 10-12.

Naylor, R., Steinfeld, H., Falcon, W., Galloway, W., Smil, V., Bradford, E., Alder, J. and Mooney, H. (2005). Losing the links between livestock and land. *Science*, 310: 1621–1622. DOI: http://dx.doi.org/10.1126/science.1117856.

Nimachow, G., Rawat, J.S., Dai, O. and Loder, T. (2010). A sustainable mountain paddy-fish farming of the Apatani tribes of Arunachal Pradesh, India. *Aquaculture Asia Magazine,* 15(2): 25-28. Available online: https://enaca.org/?id=392&title=aquaculture-asia-magazine-april-june-2010 [Accessed 21 August 2021].

Nimasow, G., Chozom, K., Nimasow, O.D. and Tsering, P. (2014). Sustainable development of Horticulture in West Kameng district of Arunachal Pradesh (India): A debate on food security and climate change. *Herald Journal of Geography and Regional Planning,* 3(4): 131–139. Available online: http://www.heraldjournals.org/hjgrp/archive.htm [Accessed 22 August 2021].

Pal, T.K. and Dasgupta, J. (2014). Indigenous hill farming systems supporting biodiversity conservation in northeast India. *Proc. Nat. Sem. Trad. Knowl. & Soc. Prac.*, pp. 63-72. Available online: http://faunaofindia.nic.in/PDFVolumes/spb/058/index.pdf [Accessed 01 July 2021].

Patel, S.K., Verma, P. and Singh, G.S. (2019). Agricultural growth and land use land cover change in peri-urban India. *Environmental Monitoring and Assessment*, 191(9): 600. DOI: https://doi.org/10.1007/s10661-019-7736-1.

Pedroso-Junior, N.N., Murrieta, R.S.S. and Adams, C. (2009). Slash-and-burn agriculture: a system in transformation. In: Begossi, A. and Lopes, P. (Eds.), *Current Trends in Human Ecology.* Cambridge: Cambridge Scholars Publishing, pp. 12-34.

Pinto, P., Long, M.E.F. and Pin˜eiro, G. (2017). Including cover crops during fallow periods for increasing ecosystem services: Is it possible in croplands of Southern South America? *Agriculture, Ecosystems and Environment*, 248: 48–57. DOI: https://doi.org/10.1016/j.agee.2017.07.028.

Priyadarshni. (1995). Shifting cultivation: cropping patterns, *Jhum* cycle and problems. Available online: http://www.yourarticlelibrary.com/cultivation/shifting-cultivation-croppingpatterns-*Jhum*-cycle-and-problems/44650 [Accessed 02 August 2021].

Pulido, J.S. and Bocco, G. (2003). The traditional farming system of a Mexican indigenous community: The case of Nuevo San Juan Parangaricutiro, Michoacan, Mexico. *Geoderma*, 111: 249–265. DOI: https://doi.org/10.1016/S0016-7061(02)00267-7.

Qiyi, L., Hongfeng, B., Wenhua, Z., & JiangJu, Z. (2009). Influence of diversity of prototypical ethnic culture in diversity of glutinous rice in Southeast of Guizhou. *Agricultural Science and Technology Hunan*, 10: 184-188.

Rai S.C. (2005). Apatani paddy-cum-fish cultivation: An indigenous hill farming system of North East India. *Indian Journal of Traditional Knowledge,* 4(1): 65-71. Available online: http://nopr.niscair.res.in/handle/123456789/8494 [Accessed 11 August 2021]

Ramakrishnan, P.S. (1992). *Shifting Agriculture and Sustainable Development: An Interdisciplinary Study from North-Eastern India.* UNESCO-MAB Series, Paris, Carnforth, Lancs., U.K.: Parthenon Publication (republished by Oxford University Press, New Delhi, 1993).

Remans, R., Wood, S.A., Saha, N., Anderman, T.L. and DeFries, R.S. (2014). Measuring nutritional diversity of national food supplies. *Global Food Security*, 3: 174–182. DOI: https://doi.org/10.1016/j.gfs.2014.07.001.

Ribeiro Filho, A.A., Adams, C. and Murrieta, R.S.S. (2013). The impacts of shifting cultivation on tropical forest soil: a review. *Boletim do Museu Paraense Emílio Goeldi. Ciências Humanas*, 8(3): 693-727. DOI: https://doi.org/10.1590/S1981-81222013000300013.

Ryngnga, P. (2016). Traditional Irrigation System: Bamboo Dripping System in Meghalaya. *International Journal of Science and Research (IJSR)*, 7(10): 1532-1534. DOI: https://doi.org/10.21275/ART20192275.

Samal, P.K., Milli, R. and Dollo, M. (2019). Local knowledge in managing upland agriculture by the Adis in Arunachal Pradesh, Northeast India. In: Behera, M.C. (Ed.), *Shifting Perspectives in Tribal Studies: From an Anthropological approach to Interdisciplinarity and Consilience*. Singapore: Springer, pp. 329-349. DOI: https://doi.org/10.1007/978-981-13-8090-7_17.

Sanz-Cobena, A., Lassaletta, L., Aguilera, E., Del Prado, A., Garnier, J., Billen, G., Iglesias, A., Sanchez, B., Guardia, G., Abalos, D., and Plaza-Bonilla, D. (2017). Strategies for greenhouse gas emissions mitigation in Mediterranean agriculture: A review. *Agriculture, Ecosystems & Environment*, 238: 5-24. DOI: https://doi.org/10.1016/j.agee.2016.09.038.

Sauerborn, J., Sprich, H. and Mercer-Quarshie, H. (2000). Crop rotation to improve agricultural production in Sub-Saharan Africa. *Journal of Agronomy and Crop Science*, 184: 67–72. DOI: https://doi.org/10.1046/j.1439-037x.2000.00368.x.

Schiere, H. and Kater, L. (2001). Mixed crop–livestock farming: a review of traditional technologies based on literature and field experiences. Rome: FAO.

Schipanski, M.E., Barbercheck, M., Douglas, M.R., Finney, D.M., Haider, K., Kaye, J.P. and White, C. (2014). A framework for evaluating ecosystem services provided by cover crops in agroecosystems. *Agricultural Systems*, 125:12–22. DOI: https://doi.org/10.1016/j.agsy.2013.11.004.

Sharma, R., Sharma, E. and Purohit, A.N. (1994). Dry matter production and nutrient cycling in agroforestry systems of cardamom grown under the Alnus and natural forest. *Agroforestry Systems*, 27: 293-306. DOI: https://doi.org/10.1007/BF00705063.

Sharma, R., Xu, J. and Sharma, G. (2007). Traditional agroforestry in the eastern Himalayan region: Land management system supporting ecosystem services. *Tropical Ecology*, 48(2): 1-12. Available online: http://www.tropecol.com/pdf/open/PDF_48_2/06%20R%20Sharma.pdf [Accessed 10 June 2021].

Singh, L.K., Roma Devi, S. and Jiten, H. (2016). Modified *Echo* as an option for low-cost soil conservation measures for settled agriculture in Wokha, Nagaland - a case study. *The Bioscan*, 11(4): 2487-2491. Available online: http://www.thebioscan.com/supplementpaper/Modified-echo-as-an-option-for-low-cost-soil-conservation-measures-for-settle-agriculture-in-Wokha,-Nagaland---A-case-studyels [Accessed 10 August 2021].

Singh, R. and Singh, G.S. (2017). Traditional agriculture: a climate-smart approach for sustainable food production. *Energy, Ecology and Environment* 2(5): 296–316. DOI: https://doi.org/10.1007/s40974-017-0074-7.

Tangjang, S. (2009). Traditional slash and burn Agriculture as a historic land use practice. A case study from the ethnic Nocte in Arunachal Pradesh, India. *World Journal of Agriculture Sciences*, 5(1): 70-73. Available online: https://www.researchgate.net/publication/242367654_Traditional_Slash_and_Burn_Agriculture_as_a_Historic_Land_Use_Practice_A_Case_Study_from_the_Ethnic_Noctes_in_Arunachal_Pradesh_India [Accessed 04 August 2021].

Teegalapalli, K. and Datta, A. (2016). Field to a forest: Patterns of forest recovery following shifting cultivation in the Eastern Himalaya. *Forest Ecology and Management,* 364: 173–182. DOI: http://dx.doi.org/10.1016/j.foreco.2016.01.006.

Thrupp, L.A. (2000). Linking Agricultural Biodiversity and Food Security: The Valuable Role of Sustainable Agriculture. *International Affairs,* 76(2): 265-281. DOI: https://doi.org/10.1111/1468-2346.00133.

Tyack, N., Dempewolf, H. and Khoury, C.K. (2020). The Potential of Payment for Ecosystem Services for Crop Wild Relative Conservation. *Plants,* 9: 1305. DOI: https://doi.org/10.3390/plants9101305.

Tynsong, H., Tiwari, B.K. and Dkhar, M. (2018). Plant diversity of Betel Leaf Agroforestry of South Meghalaya, Northeast India. Asian Journal of Forestry, 2: 1-11. DOI: https://doi.org/10.13057/asianjfor/r020101.

van Vliet, N., Mertz, O., Heinimann, A., Langanke, T., Pascual, U., Schmook, B., Adams, C., Schmidt-Vogt, D., Messerli, P., Leisz, S., Castella, J.C., Jørgensen, L., Birch-Thomsen, T., Hett, C., Bech-Bruun, T., Ickowitz, A., Vu, K.C., Yasuyuki, K., Fox, J., Padoch, C., Dressler, W., and Ziegler, A.D. (2012). Trends, drivers and impacts of changes in swidden cultivation in tropical forest-agriculture frontiers: A global assessment. *Global Environmental Change*, 22: 418–429. DOI: https://doi.org/10.1016/j.gloenvcha.2011.10.009.

Wikramanayake, E., Dinerstein, E., Loucks, C.J., Olson, D.M., Morrison, J., Lamoreaux, J. and Hamilton-Smith, E. (2002). Terrestrial Ecoregions of the Indo-Pacific: A Conservation Assessment. *Electronic Green Journal*, 1(17). DOI: http://dx.doi.org/10.5070/G311710489.

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Agrobiodiversity
is having a
diverse range of
plants, animals
& microorganisms
in our agricultural
landscapes.

Chapter 12

Ecosystem Services to Support the Diversification of Agricultural Production

By Alla Pecheniuk, Valentyna Borkovska, Andrii Pecheniuk and Iryna Mushenyk

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Ecosystem Services to Support the Diversification of Agricultural Production

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Abstract
The issue of diversification of the agricultural sector in the context of providing environmental, social and economic components is on the agenda of governments of many countries. Ecosystem services can form a powerful direction of agricultural development inculcating the sustainable development. A significant problem lies in the lack of ecosystem conservation, the lack of realization of ecosystem services, limited understanding of the nature of ecosystem services, and the lack of available statistics. Current research focuses on assessing the contribution of ecosystem services to entire cycle of a product and how it overcomes the business risks. As a result, new sources of income are foregone. That is why effective environmental management must take into account new income opportunities flowing in from various ecosystem services if conserved properly. This article is to identify possible areas for diversification of the agricultural sector in the context of ecosystem services. Some factors that determine ecosystem services are suggested. Correlation models are used to understand the relationship between ecosystem services and the agricultural productivity. Based on secondary data, the optimal directions of diversification of agricultural producers are determined. Some organizational aspects of opening new avenues in given legislation framework are identified.

Keywords
Diversification; Agricultural sector; Agricultural production; Ecosystem services

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1. Introduction

Addressing local and global food security issues, together with balancing the negative impact on the environment, requires the introduction of a new paradigm of agricultural production based on diversification of agriculture. A recommended direction is the introduction of ecosystem services into the practice of economic activities conforming the sustainable development. This topic has paramount importance due to current environmental challenges and the challenges of socio-economic nature. For a long time, ecosystem services obtained from the natural environment were not taken into account in the economic valuation of the production processes of a final product. This has led to an irrational use and pollution of land, reduction of forest areas, reduction of honey crops[1], irrational use of water resources, significant reduction of biodiversity and other negative effects of economic activities. The issue of accounting and economic evaluation of ecosystem services leads to broad discussions on the need to determine their final value and further diversification in the context of the agricultural sector. The natural ecosystems have a decisive influence on agribusiness. Therefore, significant efforts of modern scientific research are aimed at escaping their degradation (Williams *et al.*, 2020; Zeng *et al.*, 2020). According to Hanson *et al.* (2012), enterprises often cannot link the health of the ecosystem with the final outcome of economic activities. A significant amount of research focuses on the impact of economic activities on the environment and its risks. As a consequence, corporations may lose new sources of income as part of rapid ecosystem change. Thus, the practice of environmental management should take into account not only the risks for corporate activities, but also focus on new business opportunities.

Based on the scientific findings of Hanson *et al.* (2012), the main possible areas for diversification or starting a new business respecting the ecosystem services are presented in table 1. In this tabulated data, the operational, regulatory and legal, reputational, market and financial aspects that meet certain essential characteristics of ecosystem services are highlighted.

Table 1: Opportunities for business diversification in the context of ecosystem services

Direction	*Operational*	*Regulatory and legal*	*Reputational*	*Market*	*Financial*
Characteristic	Improving the efficiency of water use or development of wetlands, forest protection, improving soil quality, promoting pollination of plants	Involving governments in developing policies and incentives to protect or restore ecosystems	Introduction and dissemination of sustainable methods of procurement, operations or investments in order to differentiate corporate brands	Launching new products and services that reduce customer impact on ecosystems, participating in carbon sequestration and watershed protection markets, income from natural assets, eco-labeled products, etc.	Offering more favorable lending conditions, or investment climate to companies that improve resource efficiency or restore degraded ecosystems

[1] Honeybees usually collect nectar, pollen, or both from a large number of species of plants, which are called *honey plants*, for making honey. Examples include buckwheat, sunflower, rapeseed, etc. A comprehensive list of the families covered under this category of plants is given on the link https://en.wikipedia.org/wiki/List_of_honey_plants

Bagstad *et al.* (2013) argue that most decision support tools for quantifying and evaluating ecosystem services are too resource-intensive to routinely use in decision- making. Chaplin-Kramer *et al.* (2019) developed a global modeling of ecosystem services, focusing on water quality regulation, coastal protection and crop pollination. The focus of this study is on an empirical assessment of the relationship between factors that determine ecosystem services and the performance of the agricultural sector to find optimal ways to expand agricultural production process. This will allow the conceptualization of new areas of economic activities or diversifying existing production in order to comply with sustainable development goals. The objective of this research is to establish the links between individual ecosystem services and the output of the agricultural sector. It is to identify the possible areas for diversification of the agricultural sector keeping in consideration the ecosystem services.

2. Material and Methods

This chapter included those components for which statistics can be obtained. The information was accessed from the State Statistics Service of Ukraine for the period of 2010-2019. The list of ecosystem services was derived from a study by Landsberg *et al.* (2013). The ecosystem services considered for this study include the regulatory and control services provided by honey plants or nature reserve fund in the form of , for instance, neutralizing the wastes or CO_2 emissions. Next is the ancillary service that is obtained through the application of mineral and organic fertilizers, protection and rehabilitation of soil, groundwater and surface water, protection and reproduction of wild animals and birds, including biotechnical measures.

The method of correlation analysis, in particular, pairwise correlation, to determine the degree of density of relationships between the performance indicators (gross output of agricultural products and services and individual ecosystem services) was employed. This allowed to select those indicators that have high or medium degrees of correlation. Such selected ones can be taken into account in further research. It helps identify potential areas for diversification of the agricultural sector integrating the ecosystem services. Calculations and graphical interpretation of the results were performed in the EXEL environment, using a correlation analysis package.

3. Results and Discussions

3.1 Research of ecosystem services in the context of the agricultural sector

In Ukraine, as a result of transformational changes, a dual agrarian structure has emerged combining the individual farmers and corporate sectors. Undoubtedly, the individual farmer is more inclined to implement the principles of sustainable development. In contrast, the corporate farming emphasizes business scaling, the wholesale production, intensification of farming, and selling in international markets.

Low level of competitiveness of small agricultural producers in the European context and their non-compliance with the objectives set out in the Decree[2] of the President of Ukraine "On Sustainable Development Goals of Ukraine until 2030" No. 722/2019 of 30 September 2019 lead to new threats to the sustainable development of the agricultural sector as per the provisions of the EU's Common Agriculture Policy[3]. The problem of

[2] Decree of the President of Ukraine (2019) on the Goals of Sustainable Development of Ukraine until 2030. Available online at: https://www.president.gov.ua/documents/7222019-29825 [accessed on 23 January 2022] (in Ukrainian). Also available on: https://zakon.rada.gov.ua/laws/show/722/2019#Text

[3] https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy_en

discrediting the ecosystem services arose due to the inability of mankind to prevent the degradation of nature. Negative environmental consequences can be prevented by non-traditional methods through introducing a payment mechanism for ecosystem services). Ecosystem services can be grouped into the following main areas: provisioning services (e.g., food, water, wood, etc.); regulatory and control services (e.g., control of plant growth by pollination, flood control, carbon control, etc.); ancillary services (e.g., water cycle, photosynthesis and nutrient cycle between organisms and soil); cultural services (e.g., recreation, culture, art, etc.) (Birkhofer *et al.*, 2015; Mengist *et al.*, 2020). Sometimes these functions remain invisible and run at the risk of being insufficiently provided if their contribution to the final services is not identified. A number of scientific studies conducted by Cordier *et al.* (2014), Murillo *et al.* (2014), Bennett *et al.* (2014) and Vysotska *et al.* (2021) argue that monetization of natural services can lead to better management of natural resources. Modern industrial agriculture considers only a narrow range of agroecosystem services, namely food and industrial raw materials. Contrary to this, a range of services can be expanded by supporting and enhancing other important ecosystem services, such as climate regulation, water protection and biodiversity conservation, which are essential for the maintenance of human life and social well-being.

This chapter defines that the ecosystem services can be measured in two forms: physical and monetary. Physical form measures the impact in terms of physical units: for example, the number of tourist visits to nature per year, number of protected areas, the amount of precipitation per year, the quantity of fertilizers and agrochemicals used, and so on. The contribution of the ecosystem to the total crop yields in the EU countries is, on average, 21%, and the remaining 79% of crop yields are attributed to the use of fossil fuels, agrochemicals, fertilizers, irrigation and other inputs (Vysna *et al.*, 2021). The monetary form of ecosystem service is determined on the basis of the value of the ecosystem service that the specific ecosystem is expected to provide. The contribution of the ecosystem in 2012 to crop production was estimated to be at 20.8 billion Euros (Vysna *et al.*, 2021). Research by Gao *et al.* (2020) focuses on the evolution of market-based instruments for ecosystem services. Emphasis is placed on an ownership of the ecosystem services. It is said that this would be useful for creating markets for carbon emission credits, storm water retention credits, and wetland mitigation loans.

However, there is a number of challenges to the concept of ecosystem services in modern times. The first challenge is the lack of a proper management of ecosystem. In order to propose optimal methods for the benefit from ecosystem services, the impact of anthropogenic interventions on ecosystems should be determined. The challenge is to assess the relationships between different indicators of ecosystem services while taking into account the uncertainty of environmental processes. The third challenge is the limited understanding of the nature of ecosystem links and the lack of a common statistical base. In order to effectively manage the assessment and delivery of ecosystem services, it is necessary to determine whether these services have common features and relationships.

The activity of the agricultural sector is characterized by a number of indicators. In generalized form, it is measured in terms of the gross output of products and services. But, it is important to establish links between this indicator and other factors expressed as ecosystem services. Initial statistical information for the study was obtained from the State Statistics Service of Ukraine (SSSU, 2019a; SSSU, 2019b; SSSU, 2020a; SSSU, 2020b; SSSU, 2020c; SSSU, 2021a; SSSU, 2021b) and entered in the relevant data tables 2, 3, 4, 5, 6, 7, 8, 9 and 10.

Table 2: Gross output of agricultural products and services (in million USD)

2010	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
12567.0	31696.1	32729.4	38381.8	30978.5	24736.6	24530.4	26214.5	31392.1	32414.1

Source: SSSU (2019a)

In theoretical terms, the nature reserve fund is part of the ecosystem process, which led to its inclusion in this study (Table 3). In Ukraine, creation of a nature reserve fund is an effective mechanism for maintaining the overall ecological balance, preservation of natural areas, and gene pool of fauna and flora. The area of the nature reserve fund is one of the indicators of the progress of green growth. It is believed that in order to ensure a stable state of biodiversity, it is necessary to allocate at least 15% of the country's territory to protected areas (Andrusevych *et al.,* 2014). The available statistical data (Table 3) show the positive dynamics of growth of the nature reserve fund in Ukraine. In Ukraine, there are two main trends in the dynamics of nature reserves: 1) the network of protected areas is increasing, but 2) their quality is deteriorating. The main connects are related to the illegal use of natural resources of protected areas and non-compliance with protection regimes.

Table 3: Area of lands of the nature reserve fund (thousand hectares)

2010	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
1310.5	1382.8	1565.2	1576.1	1688.5	1769.1	1997.4	1997. 4	1997.4	2063.9

Source: SSSU (2020a)

The correlation coefficient of 0.26 between the gross output of agriculture and the land area of the nature reserve fund indicates that there is no significant relationship between the factors. Thus, according to the study, the change in the area of nature reserves can not be considered as an effective direction of diversification. The optimal sustainable land use in agricultural landscapes, from which the highest ecological and economic outcome can be obtained, can be established through a combination of crops, pastures and bioenergy plantations (Solovii and Kuleshnyk, 2021). Hence, the agricultural areas can be sown with honey plants, such as sunflower (*Helianthus*), buckwheat (*Fagopyrum*), clover (*Trifolium repens*), rapeseed (*Brassica napus* L.), perennial and annual grasses (Table 4).

Table 4: Areas sown with agricultural honey plants (thousand hectares)

2010	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
7525.0	7723.0	7754.0	7878.0	8730.0	7340.0	8051.0	8329.0	8529.0	8512.0

Source: SSSU (2019a)

A correlation coefficient of 0.38 was obtained when estimating the relationship between the gross output of agricultural products and services and the areas sown with honey plants. It indicates the presence of a medium degree of density between the two traits and makes it necessary to take into account the areas sown with honey crops (in a bid to further value the ecosystem services) and to identify areas for diversification (Figure 1).

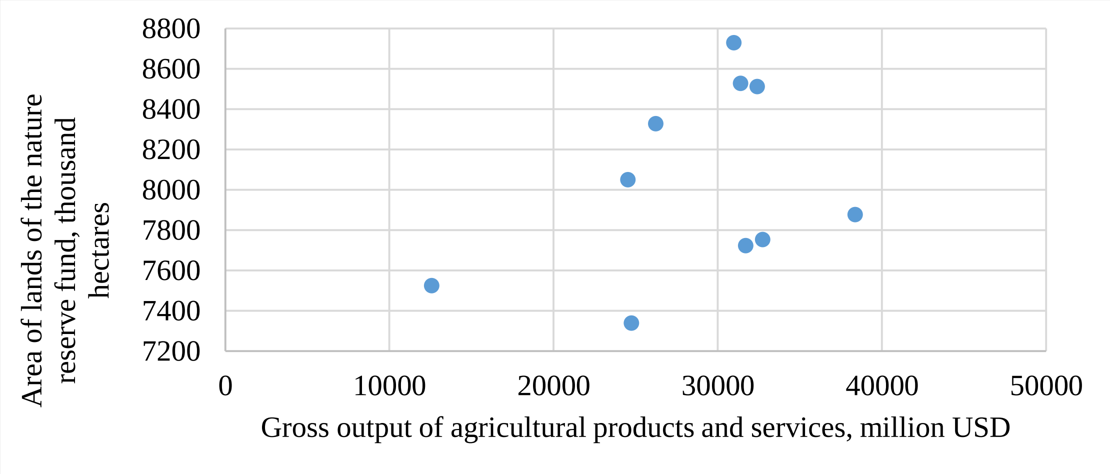

Figure 1: Correlation between gross output of agricultural products and areas of honey plants

The agricultural sector accounts for up to 15% of global greenhouse gas emissions and almost half of global nitrogen and methane emissions. The United Nations Economic Commission for Europe has recognized manure management systems as the main source of ammonia (NH_3) emissions in agriculture (Drebot, 2021). At the same time, agriculture can help reduce the negative impact of economic activity. Reducing greenhouse gas emissions can be done through rehabilitation of depleted arable lands and pastures; improving the fodder base for livestock; improving ruminant genetics; improvement of compost harvesting and storage technologies; biogas production from the agricultural waste.

Correlation analysis of the relationship between gross agricultural output and total gas emission (correlation coefficient 0.04) indicates a lack of links between them. Hence, this factor should not be taken into account in further studies related to the valuation of ecosystem services (Table 5).

Table 5: Total gases emissions (thousand tons)

2010	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
6678.0	6877.3	6821.1	6719.8	5346.2	4521.3	4686.6	4230.6	4121.2	4108.3

Source: SSSU (2021a)

According to the International Monetary Fund, by 2030 the world needs to impose a carbon tax of $75 per ton of carbon dioxide equivalent in order to reduce the emissions to a level that it meets the target of reducing 2 degrees Celsius. Many countries have begun already to introduce carbon pricing (Gulati and Singh, 2022). Sweden leads with a carbon price of up to $137 per ton of carbon dioxide equivalent, while the EU leads with $50 per ton of carbon dioxide equivalent (Gulati and Singh, 2022). Changes in the agricultural sector are also needed to combat global warming. It should reach zero emissions. In this context, reforestation and increased humus in the soil are promising measures.

The correlation coefficient of 0.19 found between the gross output of agricultural products and services and the volume of CO_2 emissions indicates a weak correlation between the factors (Table 6). Thus, this does not provide grounds for further consideration in the context of this study.

Table 6: CO_2 emissions (thousand tons)

2010	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
198.2	236.0	232.0	230.7	194.7	162.0	150.6	124.2	126.4	121.3

Source: SSSU (2021b)

Much attention in agricultural activities is given to the adequacy and efficiency of fertilizer use. This applies to the dynamics of nutrients in the scheme "soil-water-nutrients-root". Plant nutrition can be improved by returning nutrients to circulation or by adding additives (mineral chemicals) or organic fertilizers. Application of mineral fertilizers is an important component of ecosystem services. In the research of Khabatiuk and Andrusevych (2021) on "fertilizers", it is proposed to include nitric and sulfonic nitric acid, ammonia, potassium nitrates, nitrogen fertilizers, complex fertilizers with the content of two or three nutrients from nitrogen, phosphorus and potassium (NPK), and other fertilizers. The initial data for correlation analysis of fertilizer as a factor are shown in table 7.

Table 7: Mineral fertilizers (thousand tons)

2010	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
1064.2	1266.9	1346.6	1493.8	1471.7	1415.0	1728.9	2028.1	2346.3	2338.3

Source: SSSU (2019b)

The calculated correlation coefficient of 0.32 indicates the average degree of correlation between the gross output of agricultural products and services and the quantity of mineral fertilizers applied in the farms (Figure 2). This indicator can be included in further studies on the valuation of ecosystem services and identifying areas for diversification.

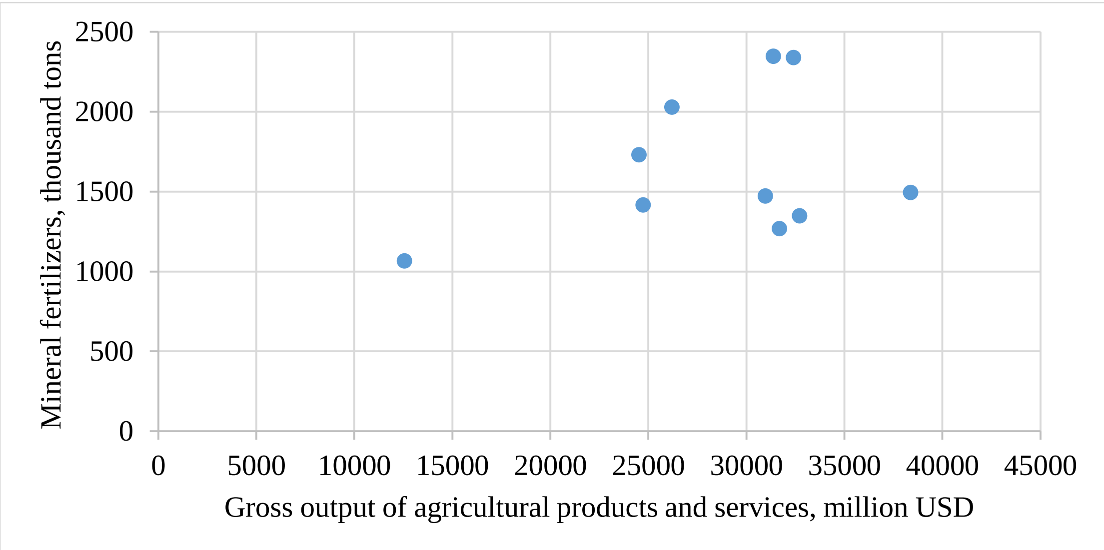

Figure 2: Correlation between the volume of agricultural products and the volume of mineral fertilizers

The presence of sufficient amounts of organic matter in the soil helps preserve its functions and prevents degradation. Irrational methods of crop production lead to lower quality and deterioration of soil structure and increased erosion. As a result, carbon emissions increase. Therefore, the world's reserves of organic matter must be stabilized or increased. This can be achieved by using crop rotations with legumes, application of green manure, plowing of plant mass of crops in combination with the minimum mechanical cultivation, reducing the number of herbicides, and adopting the agroforestry. The best results in providing the soil with nutrients can be obtained in integrated systems that combine crop, livestock and forestry (FAO and NSC ISSAR, 2019). In this study (Table 8), the correlation between the gross output of agricultural products and services and the amount of applied organic fertilizers (coefficient 0.22) has a weak density. This does not form grounds for defining this indicator as a direction of possible diversification.

Table 8: Organic fertilizers (thousand tons)

2010	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
9963.6	9954.2	9685.2	9652.9	9898.4	9662.7	9162.9	9273.9	11648.9	11382.5

Source: SSSU (2019b)

The capital investment in the protection and rehabilitation of soil, and in groundwater and surface water is important (Table 9). In general, in Ukraine, "green" investment is carried out at the expense of public funds and funds from other sources, including the private sector and international financial institutions. Significant political and economic instability creates obstacles to the development of "green" investment in Ukraine. The analysis of statistical information shows the dynamics of sharp fluctuations in this indicator during the period covered by this study. It indicates the instability of capital investment and the lack of strategic vision and consistent government policy in this area.

Table 9: Capital investments in protection and rehabilitation of soil, and in the groundwater and surface water (million USD)

2010	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
40.0	79.9	67.6	40.6	30.0	17.6	16.1	47.6	53.5	66.2

Source: SSSU (2020b)

The obtained correlation coefficient of 0.38 indicates the existing average degree of correlation between the gross output of products and services and investments in the protection and rehabilitation of soil, groundwater and surface water (Figure 3). This factor is recommended for further consideration in the context of this study. The formation of an appropriate investment climate in the "green" economy will make financial instruments of "green" investment more effective.

When forming the directions of ecosystem services, it is important to take into account the costs of protection and reproduction of wild animals and birds, including biotechnical measures (Table 10). The problem is that much of Ukraine's agricultural land is important for the conservation of birds of prey, as it forms a powerful forage base for the rodent population. Modern economic practice actively uses a significant number of plant protection chemical products. This poses a threat to biodiversity. However, the owners or tenants of these lands are not obliged to protect or finance biodiversity.

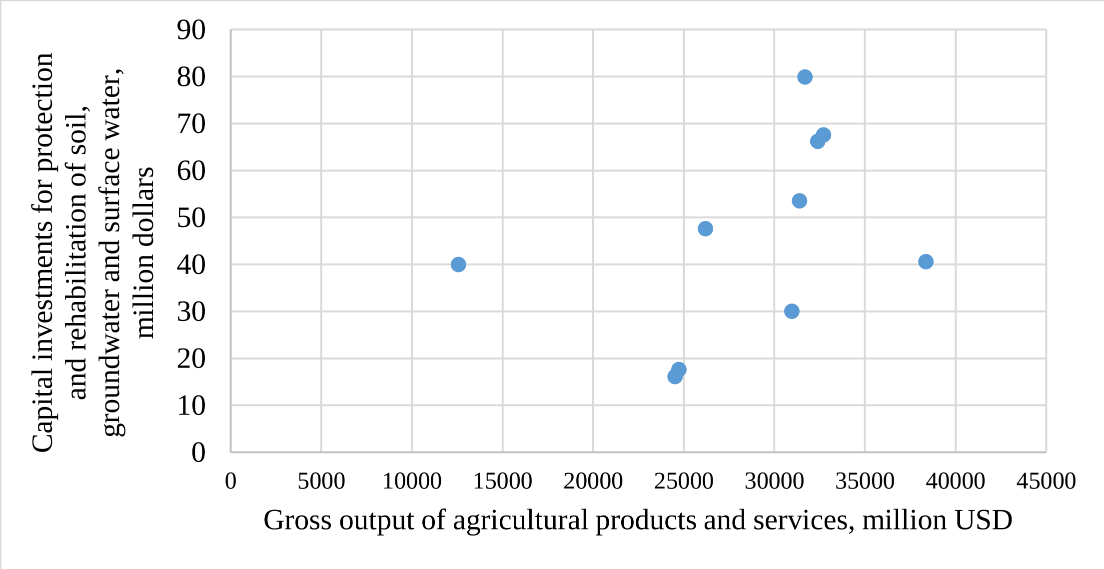

Figure 3: Correlation between gross output and investments in protection, rehabilitation of soil, groundwater and surface water

Table 10: Expenditures on protection and reproduction of wild animals and birds, including biotechnical measures (million USD)

2010	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
8.4	10.3	10.3	10.1	7.2	4.8	4.8	5.3	10.9	13.1

Source: SSSU (2020c)

The study has found a relationship between the medium density (correlation coefficient 0.48) between gross output of products and services and the cost of protection and reproduction of wild animals and birds, including biotechnical measures (Figure 4). These measures are possible ways to diversify the activities of agricultural producers. With the appropriate legislative regulation, the direction identified in the study can be continued in practical economic activities in the context of ecosystem services.

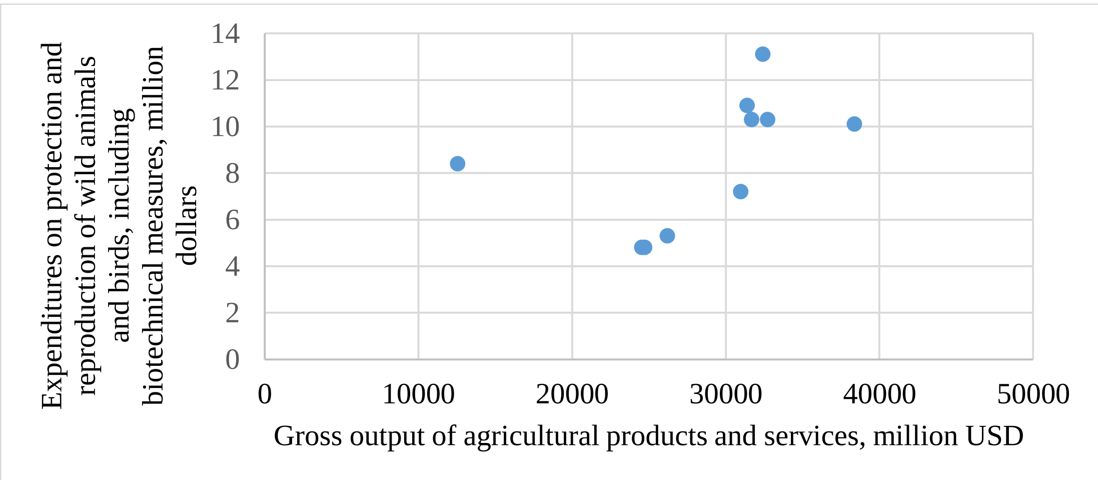

Figure 4: Correlation between gross output and costs for the protection of animals and birds (biotechnical measures) (million USD)

The analysis of pair correlations allowed to identify the degree of correlations between random factor and performance traits, to identify dependencies with the highest degree of impact and, on this basis, to identify areas for diversification of the agrarian sector in the context of ecosystem services.

3.2 Diversification and its implications for the agricultural sector

The theme of diversification is reflected in the scientific works of many authors. For example, Bilousko and Bilousko (2018) considers diversification as a direction of strengthening competitive advantages. In this context, the transition to the production of environmentally friendly products is considered optimal. Research by Kiani *et al.* (2021) in 3 areas located in different agri-environmental zones of Punjab (Pakistan) show that the losses of farmers who have adopted agricultural diversification to mitigate the effects of climate change have been lower. An average of $635 per year was lost by those who adopted diversification, while the farmers who did not adopt had lost their farm income by an average of $772 (Kiani *et al.*, 2021). Bellon *et al.* (2020) explore the relationship between crop diversity and consumption in northern Ghana. The authors conclude that increasing crop diversity opens up market opportunities for households, and diversifying agricultural production seems more beneficial to the farmers than specialization of agriculture. Research by Giller *et al.* (2015) shows the pragmatic introduction of conservation agriculture on large, mechanized farms and limited use on small farms in developing countries. In addition, the authors present evidence that denies the direct impact of conservation agriculture on increasing crop yields and carbon sequestration in the soil. Studies described by Tamburini *et al.* (2020) indicate that the impact of agricultural diversification on biodiversity and ecosystem services was mostly positive (67% positive effect, 23% neutral effect and 10% negative effect). At the same time, soil fertility and nutrient cycle had the most positive effects. The positive impact of the diversification strategy is also confirmed by the studies of Beillouin *et al.* (2020). Beillouin *et al.* (2021) determine that diversification increases not only the production of crops and biodiversity of uncultivated plants and animals, but also the support and regulation of ecosystem services (e.g., water quality by +51%; pest and disease control by +63%; and soil quality by +11%).

In general, based on table 11, the benefits of diversification can be grouped by achievement goals. These include economic goals, social goals and environmental goals. Each of them corresponds to a number of characteristic features (Fraier, 2018; Pecheniuk and Pecheniuk, 2019). The economic component is manifested by a reduction in production costs and minimization of risks, reducing dependence on the resource base; social component determines new jobs and mitigation of the negative impact of seasonality of agricultural production; ecological goal is manifested in the reduction of dependence on climatic conditions, improving soil fertility, reducing pollution, conservation of natural resources.

Table 11: Advantages of diversification for agricultural producers

Goals to achieve	*Content*
Economic goals	• Increased profits due to the lack of those production costs that are unnecessarily incurred in the cultivation of conventional crops; • Expanding the range of crops minimizes market risks and creates resistance to market fluctuations; • Providing fodder base with minimal costs;

	• Cost optimization over time, which is associated with different periods of growth and maturation of crops; • Reducing dependence on the external inputs (fertilizers, pesticides, etc.).
Social goals	• Creating additional jobs; • Balancing the seasonality of production.
Environmental goals	• Reducing dependence on climatic conditions and harvesting in extreme weather conditions; • Increasing soil fertility: legumes enrich the soil with nitrogen, cereals provide access to oxygen due to the developed root system, biomass after harvesting helps to fertilize the soil. Conservation of natural resources; • Reducing the level of pollution of natural resources; • Reducing pests and weeds and increasing the plant resistance to diseases.

The introduction of new activities related to ecosystem services can be linked to the innovative component of the agricultural enterprise. This requires a clear organizational algorithm. Research conducted by Andrushko *et al.* (2021) determines the main stages of diversification and implementation of new activities for agricultural enterprises. Shvets and Shara (2021) determine the current legal framework of Ukraine on this particular issue (Table 12).

Table 12: Organizational stages of implementation of new activities

The name of the stage	*The name of the legal act*	*Description of actions*
1. Obtaining a license	Article 7 of the Law of Ukraine[4] "On Licensing of Economic Activities" of 02.03.2015 № 222-VIII; Part 2 of Article 2 of this same law (list of economic activities)	Determining the need for a license
2. Obtaining a permit on emission of pollutants into the atmosphere	Law of Ukraine[5] "On Protection of Atmospheric Air" of 16.10.1992 № 2707-XII.	The need for a permit is due to the operation of stationary facilities that pollute the air
2.1. Emission inventory, assessment of the impact of emissions on air, etc.	The procedure for conducting and paying for work related to the issuance of permits for emissions of pollutants into the atmosphere by stationary sources, and accounting of the enterprises, institutions, organizations and citizens. The entrepreneurs who receive such permits	

[4] https://zakon.rada.gov.ua/laws/show/222-19
[5] https://documents1.worldbank.org/curated/es/289901537161303609/pdf/P132741-ESMP-Kharkiv-Disclosure-Version-English.pdf

The name of the stage	*The name of the legal act*	*Description of actions*
	are approved by the Cabinet of Ministers under Resolution № 302 of 13.03.2002.	
2.2. Permit for special use of water resources	Article 49 of the Water Code of Ukraine[6]; The permits for special water use are approved by the Cabinet of Ministers under Resolution № 321 of March 13, 2002.	
2.3. Subsoil use permit	Art. 19 of the Subsoil Code[7]; Art. 21 of the Subsoil Code[8]; Article 16 of the Subsoil Code[9]; Special permits for subsoil use are approved under the Resolution № 615 of the Cabinet of Ministers of 30.05.2011.	If the economic activity is related to the use of subsoil, a permit is required for groundwater extraction.
2.4. Permit to carry out operations in the field of waste management	Art. 17 of the Law of Ukraine[10] "On Waste" of 05.03.1998 № 187/98-VR; Under Clause 8 of the Procedure for Maintaining the Register of Waste Generation, Treatment and Utilization Facilities, permits are approved under the Resolution № 1360 of the Cabinet of Ministers of Ukraine of August 31, 1998	Permit is obtained when the total waste generation exceeds 1000 tons.
3. Compliance of the Classification of Economic Activities with the new type of activity	Art. 19, 43, 44 of the Commercial Code of Ukraine[11]; paragraph 298.2 of the Tax Code of Ukraine[12]	To avoid misunderstandings, it is necessary to register Classification of Economic Activities codes for all types of activities that the agricultural enterprise carries out or plans to carry out.

These organizational stages characterize the general aspects. When carrying out a new type of activity, the agricultural producer must take into account the peculiarities of the future business and determine the feasibility of the stages presented in the study.

[6] https://www.ecolex.org/details/legislation/water-code-no21395-vr-of-1995-lex-faoc043460/
[7] https://www.ecolex.org/details/legislation/subsoil-code-no13294-vr-of-1994-lex-faoc043462/
[8] https://www.resourcedata.org/dataset/rgi-subsoil-code-of-ukraine/resource/66ed20cb-e226-4ca3-83e9-8f445be36767
[9] https://leap.unep.org/countries/ua/national-legislation/subsoil-code-no13294-vr-1994
[10] https://cis-legislation.com/document.fwx?rgn=16883
[11] https://wipolex.wipo.int/en/legislation/details/19453
[12] https://www.wto.org/english/thewto_e/acc_e/ukr_e/wtaccukr88_leg_3.pdf

4. Conclusions

The analysis of correlations allowed identifying promising areas for diversification of the agricultural sector in relation to ecosystem services. The study covered 8 factors related to ecosystem services. The most suitable for further research and for diversification of the agricultural sector of Ukraine in in relation to ecosystem services are: 1) expanding the area under honey crops; 2) increasing the mineral fertilizer application; 3) ensuring the protection and rehabilitation of soil, groundwater and surface water; and 4) the protection and reproduction of wild animals and birds, including biotechnical measures. Diversification of the agricultural sector in relation to ecosystem services will have positive consequences in the context of solving economic, social and environmental challenges. It should be noted that the opening of new activities under Ukrainian law requires certain organizational stages. Their expediency will be determined directly by the direction in which future economic activity is expected. Therefore, it is a subjective to the activities chosen and the existing legal environment in the country.

5. References

Andrusevych, A., Andrusevych, N., Kozak, Z. and Khomiakova, O. (2014). Towards green growth: monitoring progress in Ukraine. Lviv, p.76. Available online at: https://www.rac.org.ua/uploads/content/100/files/ggiukrainefinal.pdf [accessed on 23 January 2022] (in Ukrainian).

Andrushko, R.P., Hnatyshyn, L.B. and Pecheniuk, A.P. (2021). Current issues of accounting for the quality of agricultural products and innovative solutions. Hnatyshyn, L.B. (ed), *Accounting and analytical support of innovative development of agro-industrial complex: collective monograph*. Lviv: Spolom, 84-98 (in Ukrainian).

Bagstad, K.J., Semmens, D.J., Waage, S. and Winthrop, R. (2013). A comparative assessment of decision-support tools for ecosystem services quantification and valuation. *Ecosystem Services*, 5: 27-39. DOI: https://doi.org/10.1016/j.ecoser.2013.07.004.

Beillouin, D., Ben-Ari, T., Malézieux, E., Seufert, V .and Makowski, D. (2020). Benefits of crop diversification for biodiversity and ecosystem services. bioRxiv, 4 February 2021: 1-36. DOI: https://doi.org/10.1101/2020.09.30.320309.

Beillouin, D., Ben-Ari, T., Malézieux, E., Seufert, V. and Makowski, D. (2021). Positive but variable effects of crop diversification on biodive rsity and ecosystem services. *Global Change Biology*, 27(19): 4697-4710. DOI: https://doi.org/10.1111/gcb.15747.

Bellon, M.R., Kotu, B.H., Azzarri, C. and Caracciolo, F. (2020). To diversify or not to diversify, that is the question. Pursuing agricultural development for smallholder farmers in marginal areas of Ghana. *World Development*, 125: 1-10. DOI: https://doi.org/10.1016/j.worlddev.2019.104682.

Bennett, D.E., Gosnel, H., Lurie, S. and Duncan, S. (2014). Utility engagement with payments for watershed services in the United States. *Ecosystem Services*, 8: 56-64. DOI: https://doi.org/10.1016/j.ecoser.2014.02.001.

Bilousko, T.Y. and Bilousko, R.S. (2018). Diversification of entrepreneurial activity of agricultural enterprises in ensuring their competitiveness. *Bulletin of KhNAU. Economic Sciences Series*, 3: 353-360. Available online at: https://visen.knau.kharkov.ua/2018338.html [accessed on 13 December 2021] (in Ukrainian).

Birkhofer, K., Diehl, E., Andersson, J., Ekroos, J., Früh-Müller, A., Machnikowski, F., Mader, V.L., Nilsson, L., Sasaki, K., Rundlöf, M., Wolters, V. and Smith, H.G. (2015). Ecosystem services — current challenges and opportunities for ecological research. *Frontiers*, 2: 1-12. DOI: https://doi.org/10.3389/fevo.2014.00087.

Chaplin-Kramer, R., Sharp, R.P., Weil, C., Bennett, E.M., Pascual, U., Arkema, K.K., Brauman, K.A,. Bryant, B.P., Guerry, A.D., Haddad, N.M., Hamann, M., Hamel, P., Johnson, J.A., Mandle, L., Pereira, H.M., Polasky, S., Ruckelshaus, M., Shaw, M.R., Silver, J.M., Vogl, A.L. and Daily, G.C. (2019). Global modeling of nature's contributions to people. *Science*, 366(6462): 255-258. DOI: https://doi.org/10.1126/science.aaw3372.

Cordier, M., Agúndez, J.A.P., Hecq, W. and Hamaide, B. (2014). A guiding framework for ecosystem services monetization in ecological–economic modeling. *Ecosystem Services*, 8: 86-96. DOI: https://doi.org/10.1016/j.ecoser.2014.03.003.

Drebot, O.I. (2021). Discussion of the report of the President of NAAS. Hadzala Ya.M., National Academy of Agrarian Sciences of Ukraine. Available online at: http://naas.gov.ua/content/publichna-informaciya/ogoloshennya/7389/ [accessed on 28 January 2022] (in Ukrainian).

FAO and NSC ISSAR (2019). Voluntary Guidelines for Sustainable Soil Management. FAO, Rome. Available online at: http://issar.com.ua/downloads/vgssm_ua_web_005.pdf [accessed on 28 January 2022].

Fraier, O. (2018). Crop diversification to maintain the sustainability of agricultural development. *Bulletin of Sumy National Agrarian University. Economics and Management*, 6(76): 134-137. Available online at: https://snaujournal.com.ua/index.php/journal/article/view/30 [accessed on 28 January 2022] (in Ukrainian).

Gao, X., Xu, W., Hou, Y. and Ouyang, Z. (2020). Market-based instruments for ecosystem services: framework and case study in Lishui City, China. *Ecosystem Health and Sustainability*, 6(1): 1-13. DOI: https://doi.org/10.1080/20964129.2020.1835445.

Giller, K.E., Andersson, J.A., Corbeels, M., Kirkegaard, J., Mortensen, D., Erenstein, O. and Vanlauwe, B. (2015). Beyond conservation agriculture. *Frontiers in Plant Science*, 6: 1-14. Avilable online at*:* https://www.frontiersin.org/article/10.3389/fpls.2015.00870 [accessed on 2 February 2022].

Gulati, A. and Singh, R. (2022). For 'climate smart' agriculture. *The Indian Exspress*, 14 February 2022. Available online at: https://indianexpress.com/article/opinion/columns/for-climate-smart-agriculture-cop26-budget-7771379/ [accessed on 28 February 2022].

Hanson, C., Ranganathan J., Iceland, C. and Finisdore, J. (2012). The Corporate Ecosystem Services. A Review. World Resources Institute, USA. Available online at: https://www.wri.org/research/corporate-ecosystem-services-review [accessed on 1 February 2022].

Khabatiuk, O. and Andrusevych, A. (2021) Impact of the Carbon Adjustment Mechanism (CBAM) on Ukraine's trade with the EU. Analytical document. *Resource and Analytical Center "Society and Environment"*. Available online at: https://www.rac.org.ua/uploads/content/624/files/cbamukraineua.pdf [accessed on 1 February 2022] (in Ukrainian).

Kiani, A.K., Sardar, A., Khan, W.U., He, Y., Bilgic, A., Kuslu, Y., Raja, M.A.Z. (2021). Role of Agricultural Diversification in Improving Resilience to Climate Change: An Empirical

Analysis with Gaussian Paradigm. *Sustainability*, 13(17): 9539. DOI: https://doi.org/10.3390/su13179539.

Landsberg, F., Stickler, M., Henninger, N. and Treweek, J. (2013). Weaving Ecosystem Services into Impact Assessment. Report. Available online at: https://www.wri.org/research/weaving-ecosystem-services-impact-assessment [accessed on 10 January 2022].

Mengist, W., Soromessa, T. and Feyisa, G.L. (2020). A global view of regulatory ecosystem services: existed knowledge, trends, and research gaps. *Ecol. Process.*, 9: 40. DOI: https://doi.org/10.1186/s13717-020-00241-w.

Murillo, S.A.M., Castillo, J.P.P. and Ugalde, M.E.H. (2014). Assessment of environmental payments on indigenous territories: The case of Cabecar-Talamanca, Costa Rica. *Ecosystem Services*, 8: 35-43. DOI: https://doi.org/10.1016/j.ecoser.2014.02.003.

Shvets O. and Shara O. (2021). How to organize a new type of activity for an agricultural enterprise. *Chief Accountant of Agro*, 18: 15. Available online at: https://agro.mcfr.ua/923259 [accessed on 1 February 2022] (in Ukrainian).

Solovii, I. P. and Kuleshnyk, T. Ya. (2021) Comprehensive assessment of forest landscape ecosystem services. Proceedings of the Forestry Academy of Sciences of Ukraine, 22: 209-216. Available online at: http://fasu.nltu.edu.ua/index.php/nplanu/article/view/659/544 [accessed on 26 January 2022] (in Ukrainian).

SSSU (2019a). Statistical collection Agriculture of Ukraine. State Statistics Service of Ukraine, Kyiv. Available online at: http://www.ukrstat.gov.ua/druk/publicat/Arhiv_u/07/Arch_sg_zb.htm [accessed on 18 January 2022] (in Ukrainian).

SSSU (2019b). Statistical collection Agriculture of Ukraine. State Statistics Service of Ukraine, Kyiv. Available online at: http://www.ukrstat.gov.ua/druk/publicat/Arhiv_u/07/Arch_sg_zb.htm [accessed on 12 January 2022] (in Ukrainian).

SSSU (2020a). The environment of Ukraine. Nature reserve fund. State Statistics Service of Ukraine, Kyiv. Available online at: http://www.ukrstat.gov.ua/druk/publicat/kat_u/publnav_ser_u.htm [accessed on 13 January 2022] (in Ukrainian).

SSSU (2020b). Economic statistics. The natural environment. Capital investments in environmental protection by types of environmental protection measures (2006-2020). State Statistics Service of Ukraine, Kyiv. Available online at: http://www.ukrstat.gov.ua/operativ/menu/menu_u/ns.htm [accessed on 23 January 2022] (in Ukrainian).

SSSU (2020c). The environment of Ukraine. State Statistics Service of Ukraine, Kyiv. Available online at: http://www.ukrstat.gov.ua/druk/publicat/kat_u/publnav_ser_u.htm [accessed on 23 January 2022] (in Ukrainian).

SSSU (2021a). Waste generation and management (1995-2020). Economic statistics. The natural environment. State Statistics Service of Ukraine, Kyiv. Available online at: http://www.ukrstat.gov.ua/operativ/menu/menu_u/ns.htm [accessed on 10 February 2022] (in Ukrainian)

SSSU (2021b). Economic statistics. The natural environment. Emissions of pollutants and carbon dioxide into the atmosphere (1990-2020). State Statistics Service of Ukraine, Kyiv.

Available online at: http://www.ukrstat.gov.ua/operativ/menu/menu_u/ns.htm [accessed on 10 February 2022] (in Ukrainian).

Tamburini, G., Bommarco, R., Wanger, T., Kremen, C., Heijden, G., Liebman, M. and Hallin, S. (2020). Agricultural diversification promotes multiple ecosystem services without compromising yield. *Sci. Adv.*, 6(45): eaba1715. DOI: https://doi.org/10.1126/sciadv.aba1715.

Pecheniuk, A. and Pecheniuk, A. (2019). Environmental marketing as a tool for sustainable rural development. *Business Navigator*, 6.1(56): 113-117. Available online at: http://www.business-navigator.ks.ua/journals/2019/56_2_2019/56_2_2019.pdf [accessed on 9 January 2022] (in Ukrainian).

Vysna, V., Maes, J., Petersen, J.E., La Notte, A., Vallecillo, S., Aizpurua, N., Ivits, E. and Teller, A. (2021). Accounting for ecosystems and their services in the European Union (INCA). Final report from phase II of the INCA project aiming to develop a pilot for an integrated system of ecosystem accounts for the EU. Statistical report. Publications Office of the European Union, Luxembourg. Available online at: https://ec.europa.eu/eurostat/documents/7870049/12943935/KS-FT-20-002-EN-N.pdf/de44610d-79e5-010a-5675-14fc4d8527d9?t=1624528835061 [accessed on 10 January 2022].

Vysotska, N., Kalashnikov, A., Sydorenko, S., Sydorenko, S. and Yurchenko, V., (2021). Ecosystem services of field protective forest strips as a basis of compensatory mechanisms of their creation and maintenance. Proceedings of the Forestry Academy of Sciences of Ukraine, 22: 199-208. Available online at: http://fasu.nltu.edu.ua/index.php/nplanu/article/view/658/543 [accessed on 9 January 2022] (in Ukrainian).

Williams, B.A., Grantham, H.S., Watson, J.E.M., Alvarez, S.J., Simmonds, J.S., Rogéliz, C.A, Silva, M.D., Forero-Medina, G., Etter, A., Nogales, J., Walschburger, T., Hyman, G. and Beyer, H.L (2020). Minimising the loss of biodiversity and ecosystem services in an intact landscape under risk of rapid agricultural development. *Environmental Research Letters*, 15(1): 1-13. Available online at: https://iopscience.iop.org/article/10.1088/1748-9326/ab5ff7 [accessed on 4 January 2022].

Zeng, Y., Maxwell, S., Runting, R.K., Venter, O., Watson, J.E.M. and Carrasco, L.R. (2020). Environmental destruction not avoided with the Sustainable Development Goals. *Nat. Sustain.*, 3: 795–798. DOI: https://doi.org/10.1038/s41893-020-0555-0.

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Chapter 13

Indigenous Seeds, Seed Selection and National Seed Banks for Sustainable Agriculture

By Bal Krishna Joshi

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Indigenous Seeds, Seed Selection and National Seed Banks for Sustainable Agriculture

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Abstract
Indigenous seeds are grown by the farmers over the years with a strong influence from local natural factors. Such seeds have a higher level of intra-population variations and the capacity of buffering the adverse factors. Understanding indigenous seeds along with their diversity are useful to diversify their uses, to assess conservation status, to know the factors making farming areas red zone, and to improve their performance. Selection is the simplest and most common method for the improvement of crop varieties. The variation must be created and maintained to impose selection. Different types of selection can be considered depending on the mode of reproduction of crops. Response to selection and correlated response are estimated to make the selection process more effective. Many different selection approaches can target either developing monomorphic or polymorphic varieties. There are five selection units and can be applied in five crop stages. Farmers' criteria need to be considered during selection process. Based on the genotypic classes, there are three types of selection namely stabilizing selection, directional selection, and disruptive selection. The most simple and common selection methods are pure lines, mass selection, and class-bulking selection. Orthodox seeds in short, medium, and long-term storage facilities are conserved as a seed bank. Major types are household seed banks, community seed banks, national seeds, natural seed banks, and global seed banks. A seed bank is for assuring the availability of crop diversity for research, study, and production. The common works in seed banks are diversity collection, regeneration, characterization, multiplication, and distribution along with online database management.

Keywords
Conservation; Endangered; Native seed; Red zone; Selection method; Workflow

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Edited by Dr. Hasrat Arjjumend

1. Introduction

Seed is the heart of agriculture and a major source of energy for living beings on the Earth. Thousands of native seeds of different crop species are being created and maintained by farmers (Dwivedi *et al*., 2016; Joshi *et al*., 2018). Before the agricultural green revolution, localized Indigenous seeds were grown for grain production, and were produced at the same locality. Diverse and robust local seed systems which involve many native crop landraces are central to sustainable food systems that are renewable, resilient, equitable, diverse, healthy, and interconnected (Global Alliance for the Future of Food, 2016). But after the establishment of international research centers, crop diversity is being stored in the room and very few uniform varieties are grown widely. This has resulted in the loss of many native seeds (Joshi, 2017; Roy, 2000). Seeds and grain products are now in different domains[1]. Seeds are produced in one site and transported to other sites for cultivation. Seeds grown in new areas sometimes do not perform well and there are many cases of crop failure across the world. Selection is the main method of shaping diversity, developing new uniform varieties, and narrowing the genetic base of newly developed varieties (Roy, 2000; Singh and Chaudhary, 1977; Sthapit *et al*., 2019). Modified selection methods are needed so that this method could develop a variety with high intra level genetic diversity as well site-specific polymorphic variety. Commercialization of agriculture and negligence of native seeds are the major drivers leading to loss of a large number of native crop landraces. Realizing the importance of native crop diversity and a higher rate of genetic erosion, many different kinds of seed banks have been established (FAO, 1994; IRRI, 2000; Joshi *et al*., 2020b, 2017). Indigenous seeds, selection, and conservation are the key players in agriculture for sustainable food and nutrition security. This paper elaborates on the importance of Indigenous seeds, selection methods for developing polymorphic varieties, and conservation methods.

2. Indigenous Seeds

Seeds are planting materials produced by sexual reproduction. They are capable of reproduction and act as source of energy for many living beings in the world. Over the years, many different types of seeds of plant species have been evolved. Indigenous seeds are those that are produced, grown, or living naturally in a particular location. They are selected and managed by local people in the local environment, and they possess a high-level intra diversity. Therefore, they are heterogenous, polymorphic in nature (Joshi, 2017; Marone *et al*., 2021; Shiva, Ramprasad and Bhar, 1994). They are well adapted to the growing areas, and they produce high nutrition yield (Joshi *et al.*, 2020c) and health index yield. Farmers have a crucial role in maintaining and improving such seeds (Global Alliance for the Future of Food, 2016). Seeds produced from the same production areas (seeds are well familiar with the production and environmental factors) are far better for a sustainable production system. They are the sources of many different genes and the foundation of agricultural science.

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[1] Earlier many farmers produce themselves seeds for theirs need to produce grains. But trend is now increasingly changing from single producers of seeds and grains in to two different types of producers, one is seed producer and another one is grain producer. They are generally from different areas, districts, provinces or countries. This resulted in the production of seeds from other than grain production areas, called grain production domain.

3. Types of Seeds, Features and Uses

Seeds are of many different types based on breeding, conservation, and botanical perspectives. Types of seeds along with their features are explained in table 1. Indigenous seeds are used mainly for production and in research studies. This is the basis of developing modern high-yielding varieties (Dwivedi *et al.*, 2016; Marone *et al.*, 2021). Green revolution in agriculture is because of their role in contributing specific genes. Any different types of varieties are possible only using such indigenous seeds. As an example, a popular rice variety, called Khumal-4 in Nepal, has been developed using 13 different landraces originated in 8 countries (namely USA, India, Indonesia, Taiwan, China, Pakistan, Thailand, and Nepal (Joshi *et al.*, 2017).

Table 1. Types of seeds and varieties based on different criteria

S.N.	*Types (seed or variety)*	*Feature*	*Synonym*
Based on the breeding perspective			
1.	Indigenous seed	Landrace of a particular site where this was originated	Native seed
2.	Local variety	Landrace not introduced from other areas, if introduced, localized after growing several generations	Heirloom
3.	Landrace	Genotype not altered by breeders but grown continuously by farmers over years	Traditional, farmer's variety
4.	High yielding variety	Developed by selecting and following principles of genetics	Improved, modern variety
5.	Hybrid seed	Produced by crossing two different parents	F1 seed
6.	Genetically modified seed	Seeds of genotype having distantly related genes	GMO seed
Based on the conservation perspective			
1.	Orthodox seed	Successfully dried to moisture contents <12% without injury and can tolerate freezing	Desiccation tolerant seed
2.	Recalcitrant seed	Do not tolerate drying tent below 12% without injury and are unable to tolerate freezing	Desiccation sensitive seeds, unorthodox seed
Based on the botanical perspective			
1.	Monocot seed	A single (mono) embryonic leaf or cotyledon	Albuminous seed
2.	Dicot seed	Two embryonic leaves or cotyledons	Symmetrical seed

4. Status Assessment

The status of landraces concerning trends in their population size over sites and years is called conservation status. Among many different methods of status assessment, five cell analysis (also called landrace distribution analysis) is practically simple and very useful

(Joshi and Gauchan, 2017). This method is based on areas and the number of growers which are measured through focus group discussion. Another approach is trait distribution analysis which helps identify rare and unique landraces based on the distribution of a particular trait in different landraces (Joshi and Gauchan, 2017).

4.1 Endangered (red-listed) landraces

The size and distribution of many native landraces are decreasing rapidly due to many factors (Shrestha *et al.*, 2005). Landraces that are expected to be extinct in the near future from a particular site are called endangered landraces. In general, all landraces from the red zone are defined as endangered. Red zones are those areas where native technologies and germplasm are at the risk of being lost due to both natural and human-made factors e.g., earthquakes, changes in land use, distribution of modern variety, commercialization, etc. (Figure 1). All landraces that are endangered and rare are defined as a red list. Many different approaches can be used to assess the status of crop diversity called conservation status.

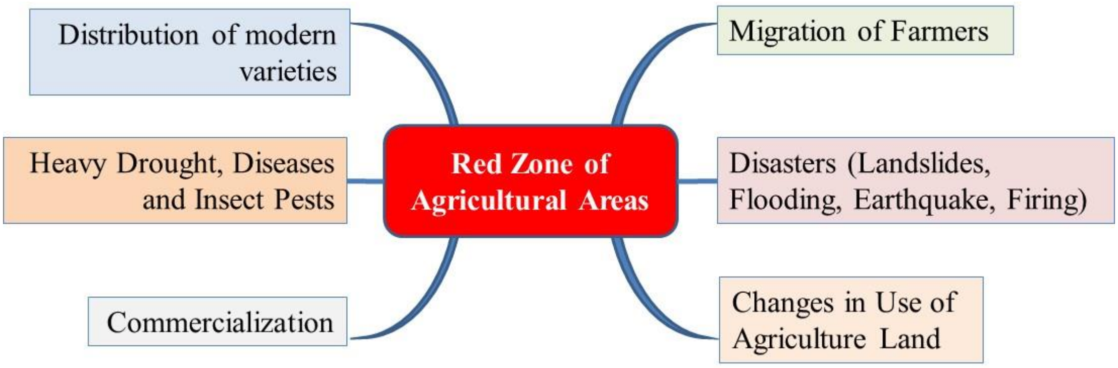

Figure 1: Possible causes of making agricultural land to the red zone and ultimately agricultural genetic resources endangered. (Source: Joshi and Gauchan, 2017)

4.2 How to conserve

Crop diversity can be conserved in three different ways. The first one is growing landraces or diversity continuously. Continued cultivation, harvesting, storing, and using are the dynamic process of conservation of crop diversity. The second method is using landraces in a breeding program. Use in breeding helps conserve some portion of the genome of landraces. The third one is conserving seeds in a seed bank. This is a long-term approach for the conservation of seeds. All three methods should be adopted for sustainable agricultural research and development (Joshi *et al.*, 2020b).

5. Seed Selection

5.1 Basis of selection and mode of reproduction

Genetic variation within species, varieties or population is the basis of selection. Major events for creating variation are meiosis, mutation, and cross-pollination. Heritability of specific traits is very important to estimate the response to selection. The genetic variation depends on the mode of reproduction e.g., the evolutionary rate is higher in sexually propagated genetic resources as compared to asexually propagated species. Seed selection applies only to self and cross-pollinated plant/ crop species. Depending on the mode of reproduction, the selection target may be either homogenous or heterogeneous (Figure 2). In autogamy species, the selected populations are homogenous and homozygotes, whereas, in allogamy, the selected populations are heterogeneous and heterozygotes. Selection always favors increasing the frequency of favorable alleles, genes, traits, and genotypes.

5.2 Response to selection and correlated response

Selection is the main and simple method for the genetic improvement of an individual or a population. Response to selection is how much gain we achieved in a particular trait (e.g., grain yield) from choosing some individuals over the original population. Response to selection is also called genetic gain (ΔG) or genetic progress. Based on the performance of the base population, selected individuals, and progeny of selected individuals, the following different parameters related to response to selection can be calculated (Figure 3) (Roy, 2000; Singh and Chaudhary, 1977).

S (selection differential) = Mean of selected individuals – mean of the base population

For prediction of selection differential (S'), S' = (Z/p); where Z is the height of the ordinate, p is the proportion of selected individuals, and σp is phenotypic standard deviation.

R (response to selection) = Mean of the progeny of selected individuals – mean of the base population.

For prediction of response to selection (R'), R' = $i.h^2. \sigma p$; where i is standardized selection differential, h^2 is heritability.

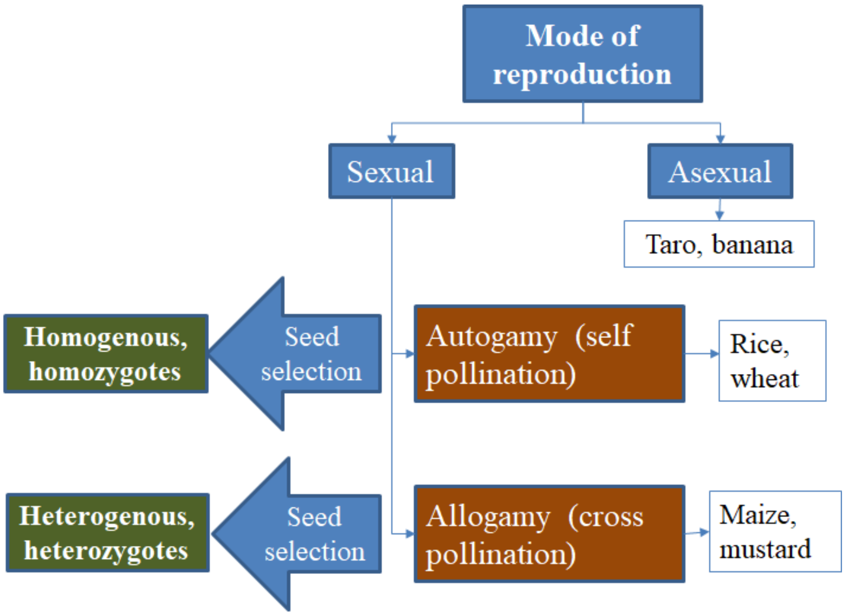

Figure 2: Mode of crop reproduction and selection targets

During selection of an individual based on a particular trait, it also affects other traits. Many traits are correlated with each other. The change in one character (say 'y') through indirect selection on an associated character (say 'x') is called correlated response (CRy), which is estimated using the following formula (Singh and Chaudhary, 1977),

CR_y

where i_x is standardized selection intensity of x character, h_x and h_y are the square roots of heritability of x, and y, respectively, r_g is a genetic correlation between x and y, δp_y is the phenotypic standard deviation of y character.

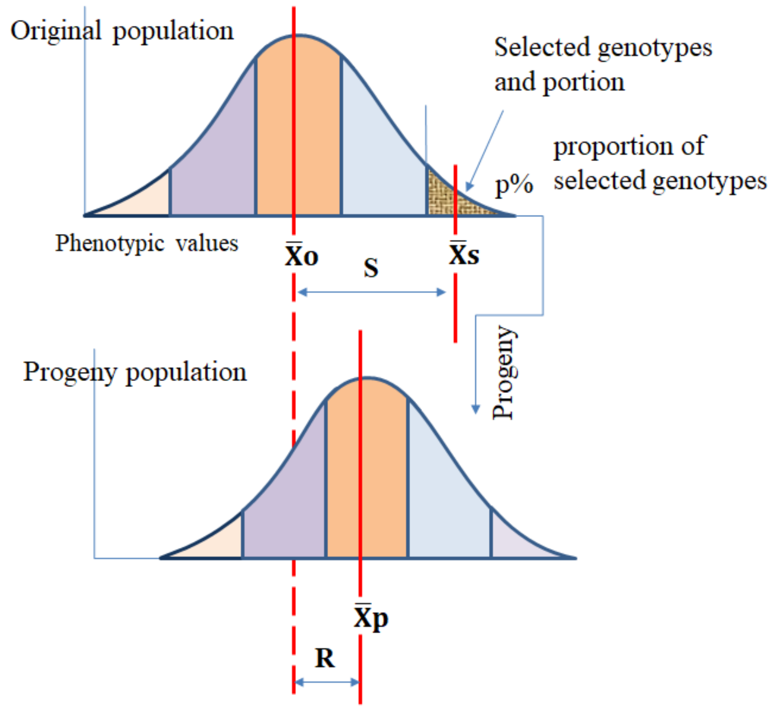

Figure 3: Different selection parameters associated with response to selection

5.3 Selection approaches

Six different selection approaches are in practice. Anyone or a combination of more than one approach can be adopted. These are: a) participatory vs. non-participatory selection approach; b) on-farm vs. on-station selection; c) native vs. exotic variety selection; d) natural vs. artificial crossing-based selection; e) population vs. individual selection, and f) direct vs. indirect selection. On-farm selection is generally carried out in a participatory way, whereas on-station selection is non-participatory. Genetic diversity can be collected either from within a country or from a foreign country. Selection based on this material, it may be native seed selection, which is found more effective in term of its adaptability and consistence performance over the years. Naturally, almost all seed-bearing species cross at least few percentages among genotypes. Selection can be pressured on such a naturally crossed population or a human-assisted crossed population. In general, the population is considered as a selection unit in cross-pollinated species and an individual selection is in self-pollinated species. Direct selection is a very common approach that considers the target trait during selection (Joshi, 2017; Sthapit *et al.*, 2019). Indirect selection is effective based on correlation and path coefficients.

5.4 Selection target: Monomorphic vs. polymorphic

The selection target is always to develop better variety at least for a target trait. In many cases, selection output is to get monomorphic and genetically uniform variety.

Genetic uniformity leads to genetic vulnerability to both biotic and abiotic stresses and decreases intra level diversity. In contrast, polymorphic variety has a higher level intra varietal diversity, poly genotypes, and, therefore, is called heterogeneous population. Increased diversity reduces losses from pests and diseases, keeps evolving from generation to generation, decreases vulnerability to both biotic and abiotic stresses (Joshi *et al.*, 2020a). Therefore, the selection target should be to develop a variety with a higher level of intra varietal diversity.

5.5 Selection units and crop stages

Selection is a continuous process, and there are five selection units. These are crop fields, a specific area within a crop field, plant or hill (all tillers emerged from the same point) from within a selection area, flower or spikelet within a plant, fruit or seed within an inflorescence. All units should be selected based on pre-defined criteria and targets. Selection then should be carried out in five different stages of the crop, namely seedling stage, vegetative stage, flowering stage, maturity stage, and storage stage. In many cases, one-stage selection (i.e., at the maturity stage) is very common but five stages selection is more effective, and genetic gain is relatively high.

5.6 Selection tools and aids

Selection involves many different factors, and it is complex in terms of getting significant genetic gain. To accelerate the selection process more effectively and efficiently, many different tools and aids should be considered. Some of them are correlation coefficients, heritability, path coefficients, check variety, control variety, yield, yield components, selection index, criteria and objective, target environment, and software. The software, which are useful for the selection of genotypes, are:

GGEBiplot: It is a graphical tool for breeders, geneticists, and agronomists for conducting biplot analysis of research data. It is available from http://ggebiplot.com/.

GGEBiplotGUI: It is an R package that provides a graphical user interface for the construction of, interaction with, and manipulation of GGE biplots. It is available from https://cran.r-project.org/web/packages/GGEBiplotGUI/index.html.

Agrobase: It is a plant breeding software with selection index estimation. It is available from https://www.agronomix.com/AGROBASE.aspx.

Selection index: It is an R package for analysis of selection index in plant breeding. It is available from https://cran.rstudio.com/web/packages/selection.index/index.html.

RIndSel: It is an R package with a graphical unit interface that uses selection index theory to select individual candidates. It is available from https://data.cimmyt.org/dataset.xhtml?persistentId=hdl:11529/10854.

SI-R: This is a collection of R codes to compute several selection indices in R. It is available from https://data.cimmyt.org/dataset.xhtml?persistentId=hdl:11529/10352.

ViTSel: It is R-based software to visualize results of multi-environmental multi-trait analysis for selection in plant breeding. It is available from https://data.cimmyt.org/dataverse/cimmytswdvn.

5.7 Generalized selection traits (farmers' criteria)

Farmers always consider multiple traits in any variety. However, many researchers target to increase grain yield. Nutrition yield and health index yield are also very important and need to be considered during the selection of varieties. Farmers' criteria are high yielding without external inputs, early maturity, good cooking and eating quality, pest resistance, medium height, drought-resistance, strong stem, good tillering capacity, erect leaves, large seed sizes, non-shattering, cost benefits and fodder value (Shiva *et al.*, 1994).

5.8 Types of selection based on classes

In diploid species, there are three types of genotypes, e.g., AA, Aa, and aa, for a particular trait and can also be called three classes (in one locus with two alleles systems) (Roy, 2000). Genotypes of AA and aa represent extreme types and Aa represent the intermediate type. Almost all quantitative traits follow a normal distribution. In such a normally distributed curve, two tails are representing the two extreme expressions of a trait, and the third represents the average expression of a trait. Depending on the favoring of such classes during selection, there are three types of selection, as given in figure 4. Stabilizing selection includes individuals with mean equal or close to population means. The selection of individuals with either higher mean or lower mean is called directional selection. Disruptive selection includes individuals from more than one class and the progeny of selected individuals make two picks. In the majority of crop breeding, directional selection is very common and effective.

5.9 Simple selection methods

Many specific selection methods have been developed for self and cross-pollinated and vegetatively propagated crops. Selection methods are applicable to both segregating population and farmers' varieties. The simple methods among other complex selection procedures are pure line selection, mass selection, and class-bulking selection methods. The pure line selection method involves the selection of a single best genotype for several generations until a pure line of a variety with desired characters is established. This method is more applicable to self-pollinated and clonally propagated crops. Mass selection is the oldest method of crop improvement in which many different individual plants are selected based on phenotypic performance, their seeds are bulked and used to grow in next generation. This cycle is repeated until the desired population is established.

Another modified bulk selection method is the class-bulking selection (CBS). In this CBS, individuals are selected from different classes, categories, or groups of varieties or landraces or within cultivar and mix them. This mixture or bulked materials are grown, and selection pressure is imposed. These processes are repeated for getting a heterogeneous population having desired characters. Such variety is relatively more resilient to climate changes and less vulnerable to both abiotic and biotic stresses. A better result can be obtained if selection and bulking could be done based on the mixing ability (general mixing ability and specific mixing ability) of different selected genotypes.

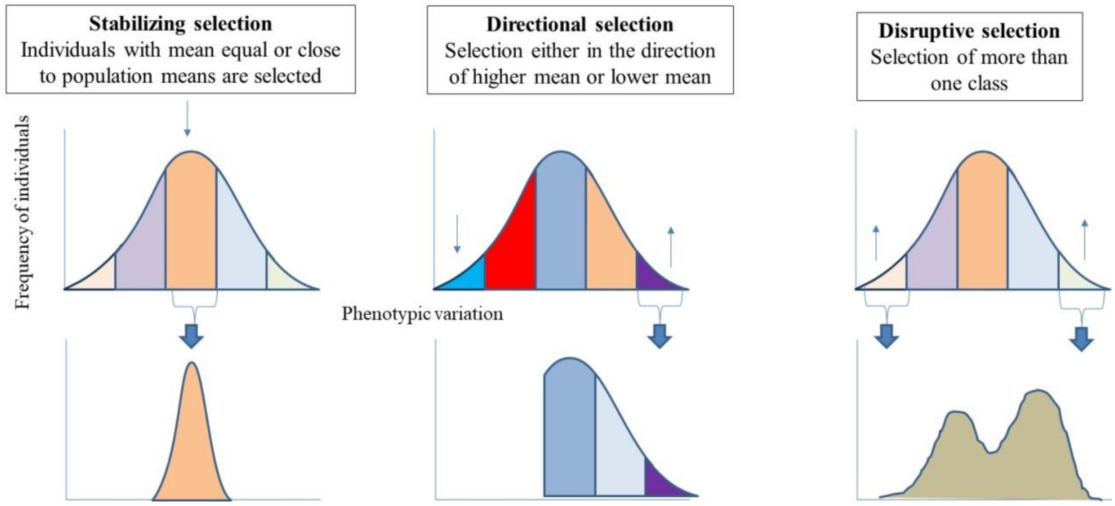

Figure 4: Types of selection based on different genotypic classes

6. Seed Bank

Seed bank is a place where the orthodox seeds of many different crops are stored to preserve genetic diversity along with information for present and future use. Orthodox seeds are long-lived seeds and can be successfully dried to moisture contents as low as 5% without injury and can tolerate freezing e.g., rice, maize, and soybean. Non-orthodox (recalcitrant) seeds cannot be stored for a long term and, therefore, seed bank is associated with only orthodox seeds. Some features of general seed banks are banking of different kinds of seeds, making access to all stakeholders and long-term security. Seeds from such banks are only used for reproduction, multiplication, and research, and not for consumption (FAO, 1994; IRRI, 2000; Joshi *et al.*, 2020b, 2018, 2017; Rao *et al.*, 2006; Rao and Paula, 2000).

6.1 Types of a seed bank

Seed banks are of three types based on conservation strategies, they are on-farm seed banks, *ex-situ* seed banks, and in-situ seed banks (Figure 5) (Joshi et al., 2017; Joshi and Upadhya, 2019). The on-farm seed bank is where seeds are stored for few months to few years in a man-made store or house e.g., community seed bank (Shrestha, Vernooy and Chaudhary, 2013), household seed bank, and village level seed bank. The whole life period of seeds does not get a chance to interact with natural factors. Seeds are stored at normal room temperature and for a short term. In village level seed bank, each household maintains different specific crop seeds, and, in aggregate, all households i.e., the village, conserve the maximum crop diversity. *Ex-situ* banks may be national, regional, or global, and seeds stored in such banks do not get a chance to interact with natural factors. Seeds are stored in an advanced structure with a controlled environment targeting medium and long terms. If seeds and all their stages interact with natural factors, such a system of storage is called as *in-situ* seed bank. Seeds of crop's wild relatives are stored in such conditions and called natural seed banks. Similarly, the domesticated crop can be kept all the time in a certain field, called agro gene sanctuary. In such sanctuary, crop seeds are grown in the field and their matured seeds remain in the same field in natural condition.

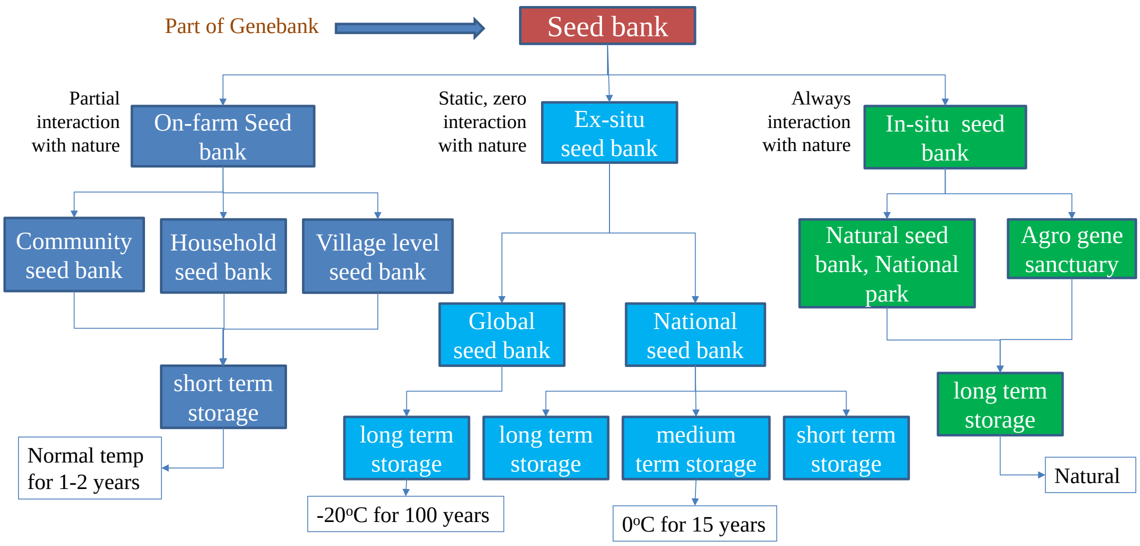

Figure 5: Types of seed banks and storage environment (not colored box)

6.2 Storage condition

Community seed banks and household seed banks are being maintained at room temperature and natural relative humidity (RH) (Joshi *et al.*, 2018). Seeds can be stored either in air-tight containers or in any local containers. The *ex-situ* seed bank is maintained with two systems, one is called active collection where seeds are kept in air-tight containers at 0-10°C temperature and 35-45% RH (FAO, 1994; IRRI, 2000). Second is a base collection, which is maintained at -20°C and seeds are generally kept in vacuum-sealed aluminum foil. In many cases, RH is not considered to maintain in base collection. Everything in a natural seed bank is naturally maintained. Therefore, it is also called 'seeds in the soil', 'soil seed bank', etc.

6.3 Workflow in the seed bank

Genebank handles different types of genetic materials e.g., orthodox seeds, recalcitrant seeds, and vegetatively propagating materials. For conserving all such types of materials, genebank consists of the seed bank, field genebank, and tissue bank. The work and germplasm flows are given in figure 6. The major works in seed banks are exploration and collection, registration, seed testing and processing, conservation, regeneration and multiplication, viability monitoring, characterization, evaluation, genotyping, screening and pre-breeding, distribution and exchange of materials, and database management.

6.4 Seeds flow, regeneration and distribution

Seeds flow in seed bank is given in figure 7. Seed quality and amount are major considerations during the storage process in the seed bank. Germination should be more than 80% for storing seeds in the seed bank. If both quality and quantity do not meet the standard of the seed bank, then regeneration and multiplication are carried out at suitable locations. Regeneration should be done in a similar environment to that of the original collection site. During seed multiplication and regeneration, sample size (more than 40 seeds) should be maintained to minimize the loss of genetic diversity within an accession. Small amounts of seeds are distributed to researchers and farmers from *ex-situ* seed banks especially from the active collection.

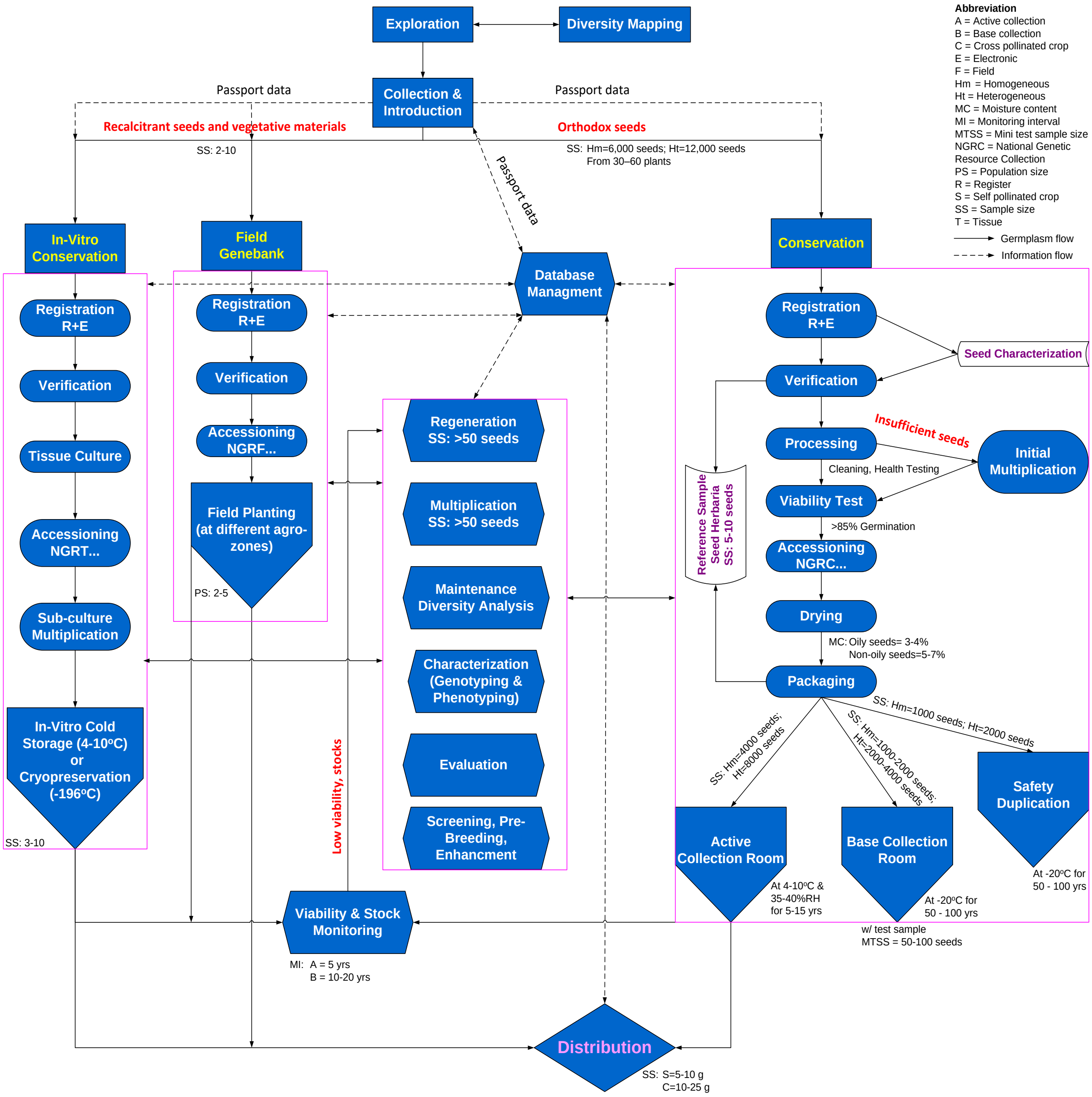

Figure 6: Works and germplasm flows in genebank. (*Source:* Engels and Visser, 2003; FAO, 1994; IRRI, 2000; Joshi *et al.*, 2017; Rao *et al.*, 2006; Rao and Paula, 2000)

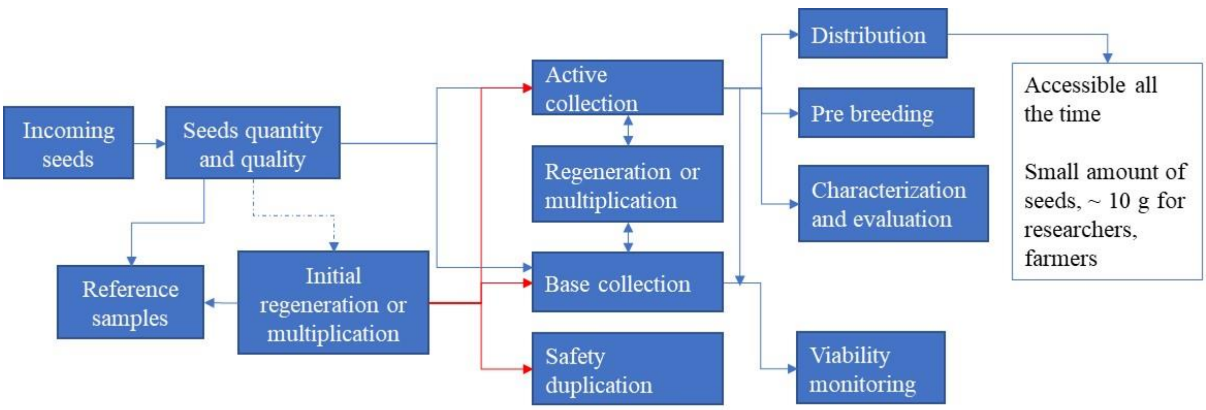

Figure 7: Seeds flow in the seed bank. (*Source:* Joshi *et al.*, 2017)

6.5 Seed database and online access

The details of seeds materials along with the availability of seeds of many global and country-level genebanks are searchable online. Some searchable platforms are given below.

- Genesys: This is an online platform where one can find information about plant genetic resources conserved in genebanks worldwide. Its website is https://www.genesys-pgr.org/.
- GRIN-Global (USDA): This is a database application that enables genebanks to store and manage information associated with plant genetic resources (germplasm). Its website is https://npgsweb.ars-grin.gov/gringlobal/search.
- NIAS Genebank: This is the main repository of genetic resources of plants, animals, and microorganisms of agricultural importance in Japan. Its website is https://www.gene.affrc.go.jp/databases_en.php.
- Svalbard Global Seed Vault: This is a long-term seed storage facility representing the world's largest collection of crop diversity. The official website is https://seedvault.nordgen.org/.
- EURISCO: It is an online platform that provides information at the accession level of PGR conserved in European genebanks or other collections. Its website is https://eurisco.ipk-gatersleben.de/apex/f?p=103:55.

7. Conclusion

Localized seed diversity performs consistently over a long period. These Indigenous seeds are the sources of many genes and the foundation of agricultural science. Due to the high level of intra landrace diversity, Indigenous crop varieties respond well to selecting with the specifically targeted trait. Participatory selection following the class-bulking method is more effective for developing nature-responsive varieties. Crop diversity is generally being conserved in human-made buildings and a single uniform variety is grown in wider areas. This resulted in the loss of a higher percentage of genetic diversity. Crop diversity should also be maintained in the field not only in static conditions for sustainable agriculture. Different conservation strategies, as well as types of seed banks, should be considered for conservation and utilization of nature-gifted diversity over a longer period.

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9. References

Dwivedi, S.L., Ceccarelli, S., Blair, M.W., Upadhyaya, H.D., Are, A.K. and Ortiz, R. (2016). Landrace germplasm for improving yield and abiotic stress adaptation. *Trends Plant Sci*, 21: 31–42. DOI: https://doi.org/10.1016/j.tplants.2015.10.012.

Engels, J.M.M. and Visser, L. (eds.) (2003). *A guide to effective management of germplasm collections*. IPGRI, Rome, Italy. Available online at:

https://www.bioversityinternational.org/e-library/publications/detail/a-guide-to-effective-management-of-germplasm-collections/ [Accessed on 7 November 2021].

FAO (1994). *Genebank standard*. Food and Agriculture Organization of the United Nations (FAO), International Plant Genetic Resources Institute, Rome. Available online at: https://cgspace.cgiar.org/handle/10568/104243 [Accessed on 7 November 2021].

Global Alliance for the Future of Food (2016). *The Future of Food: Seeds of Resilience*, A Compendium of Perspectives on Agricultural Biodiversity from Around the World. Available online at: https://futureoffood.org/wp-content/uploads/2021/02/Seeds-of-Resilience_Full-Compendium.pdf [Accessed on 27 November 2021].

IRRI (2000). *Operations manual*. International Rice Genebank. TT Chang Genetic Resources Center, International Rice Research Institute (IRRI), Los Baños, Philippines. Available online at: https://cropgenebank.sgrp.cgiar.org/images/file/learning_space/IRRI_genebank_manual.pdf [Accessed on 27 November 2021].

Joshi, B.K. (2017). Plant Breeding in Nepal: Past, Present and Future. *Journal of Agriculture and Forestry University*, 1: 1–33. Available online at: http://afu.edu.np/sites/default/files/Plant_breeding_in_Nepal_Past_Present_and_Future_BK_Joshi.pdf [Accessed on 25 October 2021]".

Joshi, B.K. and Gauchan, D. (2017). Germplasm Rescue: Why and How? In: Joshi, B.K., Gauchan, D. (eds.), *Rebuilding Local Seed System of Native Crops in Earthquake Affected Areas of Nepal*. Proceedings of a National Sharingshop. NAGRC, Bioversity International and Crop Trust, Kathmandu, Nepal, pp. 41–50. Available online at: https://www.bioversityinternational.org/e-library/publications/detail/rebuilding-local-seed-system-of-native-crops-in-earthquake-affected-areas-of-nepal/ [Accessed on 25 October 2021].

Joshi, B.K. and Upadhya, D. (2019). On-farm Conservation Approaches for Agricultural Biodiversity in Nepal. *Journal of Agriculture and Natural Resources*, 2: 14–35. DOI: https://doi.org/10.3126/janr.v2i1.26012.

Joshi, B.K., Acharya, A.K., Gauchan, D. and Bhatta, M.R. (2017). Agrobiodiversity status and conservation options and methods. In: Joshi, B.K., KC, H.B., Acharya, A.K. (eds.), *Conservation and Utilization of Agricultural Plant Genetic Resources in Nepal*. NAGARC, FDD, DoA and MoAD, Dhulikhel, Kathmandu, Nepal, pp. 21–38. Available online at: https://nepalindata.com/media/resources/bulkuploaded/Plant_Genetic_Resources_CUAPGR_Nepal_OCT17.pdf [Accessed on 7 November 2021].

Joshi, B.K., Ayer, D.K., Gauchan, D. and Jarvis, D. (2020a). Concept and rationale of evolutionary plant breeding and its status in Nepal. *Journal of AFU*, 4: 1-11. Available online at: https://cgspace.cgiar.org/handle/10568/110762 [Accessed on 25 October 2021].

Joshi, B.K., Gorkhali, N.A., Pradhan, N., Ghimire, K.H., Gotame, T.P., KC, P., Mainali, R.P., Karkee, A. and Paneru, R.B. (2020b). Agrobiodiversity and its Conservation in Nepal. *Journal of Nepal Agricultural Research Council*, 6: 14–33. DOI: https://doi.org/10.3126/jnarc.v6i0.28111.

Joshi, B.K., Ojha, P., Gauchan, D., Ghimire, K.H., Bhandari, B. and HB, K.C. (2020c). Nutritionally unique native crop landraces from mountain Nepal for geographical indication right. In: Gauchan, D., Joshi, B.K., Bhandari, B., Manandhar, H.K., Jarvis, D. (eds.), *Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal*. NARC, LI-BIRD, Bioversity

International, Kathmandu, Nepal, pp. 87–99. Available online at: https://himalayancrops.org/project/traditional-crop-biodiversity-for-mountain-food-and-nutrition-security-in-nepal/ [Accessed on 25 October 2021].

Joshi, B.K., Shrestha, P., Gauchan, D. and Vernooy, R. (eds.) (2018). *Community Seed Banks in Nepal*. 2nd National Workshop Proceedings. NARC, LI-BIRD and Bioversity International, Kathmandu Nepal. Available online at: https://cgspace.cgiar.org/handle/10568/99141 [Accessed on 7 August 2021].

Marone, D., Russo, M.A., Mores, A., Ficco, D.B.M., Laidò, G., Mastrangelo, A.M. and Borrelli, G.M. (2021). Importance of Landraces in Cereal Breeding for Stress Tolerance. *Plants*, 10(7): 1267. DOI: https://doi.org/10.3390/plants10071267.

Rao, N.K. and Paula, B.J. (eds.) (2000). *Manual of genebank operations and procedures*. International Crops Research Institute for the Semi-Arid Tropics, India. Available online at: http://oar.icrisat.org/1086/1/RA_00356.pdf [Accessed on 12 September 2021].

Rao, N.K., Hanson, J., Dulloo, M.E., Ghosh, K., Nowell, D. and Larinde, M. (2006). *Manual of seed handling in genebanks*. Biodiversity International, Rome, Italy. Available online at: https://www.bioversityinternational.org/e-library/publications/detail/manual-of-seed-handling-in-genebanks/ [Accessed on 12 September 2021].

Roy, D. (2000). *Plant breeding: Analysis and exploration of variation*. New Delhi, India: Narosa Publishing House.

Shiva, V., Ramprasad, V. and Bhar, R.H. (1994). *Sustaining diversity*. New Delhi, India: Navdanya.

Shrestha, P., Vernooy, V. and Chaudhary, P. (eds.). (2013). *Community Seed Banks in Nepal: Past, Present, Future*. Proceedings of a National Workshop, LI-BIRD/USC Canada Asia/Oxfam/The Development Fund/IFAD/Bioversity International, 14-15 June 2012, Pokhara, Nepal. Available online at: https://www.bioversityinternational.org/e-library/publications/detail/community-seed-banks-in-nepal-past-present-and-future/ [Accessed on 12 September 2021].

Singh, R.K. and Chaudhary, B.D. (1977). *Biometrical methods in quantitative genetic analysis*. New Delhi, India: Kalyani Publishers.

Sthapit, B., Gauchan, D., Sthapit, S., Ghimire, K.H., Joshi, B.K., Santis, P.D. and Jarvis, D. (2019). Sourcing and deploying new crop varieties in Mountain Production Systems. In: O.T. Westengen, T. Winge (eds.), *Farmers and Plant Breeding: Current Approaches and Perspectives*, London: Routledge, pp. 196–216.

Sthapit, B.R., Upadhyay, M.P., Shrestha, P.K. and Jarvis, D.I. (eds.). (2005). *On-farm conservation of agricultural biodiversity in Nepal*. Volume II. Managing diversity and promoting its benefits. Proceedings of the Second National Workshop, 25–27 August 2004, Nagarkot, Nepal. International Plant Genetic Resources Institute, Rome, Italy. Available online at: http://sebina.iamb.it/sebina/repository/catalogazione/immagini/pdf/On-farm_conservation_vol%202.pdf [accessed on 27 November 2021].

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Chapter 14

Enhancing Farmers' Seed Systems through Empowerment of Women: A Case Study from mountain areas of SW China

By Yanyan Zhang, Xin Song, Yiching Song and Milin Tian

Enhancing Farmers' Seed Systems through Empowerment of Women: A Case Study from mountain areas of SW China

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Abstract

Maintaining farmer's seed systems is important to secure the adaptive capacity both ecologically and socially for global food systems, and to secure genetic diversity. In a mountain village of southwest China, a Participatory Action Research Team has carried out action research for more than 20 years to support women's participation in participatory breeding and to enhance the farmers' seed system. In this case study, the team assisted women in the conservation of local varieties and establishment of community seed banks to enhance farmers' seed systems. The women-led agricultural cooperatives promoted the economic development of the community and improved the sustainability of farmers' seed system through eco-circular agriculture and the community supported agriculture (CSA) model. In this participatory process, the empowerment of women improved women's comprehensive ability and provided the guarantee of human resources for enhancing farmers' seed system. Multi-stakeholder processes also extended important support to this model work.

Keywords

Participatory plant breeding; Community seed bank; Farmers' cooperative; Ecocircular agriculture

Citation

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1. Introduction

Maintaining farmer's seed systems contributes to securing the adaptive capacity both ecologically and socially for global food systems, and to securing genetic diversity. A wide range of local varieties, through years of selection and optimization by farmers, possess strong resistance to risks. It is crucial to explore effective pathways to enhance farmers' seed system under the current pressure of the commercialization of seeds and market monopoly. In this article, one example from Guangxi, China is presented; it incubates changes to enhance the farmers' seed system through women empowerment process.

Over the past half-century, the commercialization of seeds driven by the Green Revolution has led to the abandonment of local crop varieties, leading to a 75% loss of genetic diversity worldwide (Xu *et al.,* 2012). In China, the number of local varieties of major food crops observed 71.8% decrease, from 11,590 in 1956 to 3,271 in 2014 (Liang, 2018).

Being one of the most culturally diverse provinces of China, Guangxi also belongs to the ecologically fragile region due to its widespread karst mountainous rocks. Environmental constraints are coupled with social issues such as poverty and feminization of agriculture. Conserving the rich germplasm resources of farming families, improving the fragile ecosystems and achieving a local development present challenge. Solutions with a feature of joint development of nature and people could inform those who rely on mountainous areas for their livelihood and well-being, which accounts for approximately 12% of the global population (Xu, 2018).

Photo 1: A view of Guzhai Village (Photo by Qiubi)

The Participatory Action Research Team (hereafter referred to as "the Project Team") of the Chinese Academy of Sciences coordinated the implementation of a series of interventions including participatory plant breeding (PPB) in 6 villages in Guangxi province, and Guzhai Village was one of those 6 villages. One of the objectives of the interventions was to strengthen farmers' seed systems through empowering farmers, especially women farmers as they are the dominant labour forces in farming as men migrates to cities for wage earning jobs. All activities were implemented in multidisciplinary collaborations with the research institutes at both national and provincial levels, such as the Chinese Academy of Agricultural Sciences (CAAS) and the Guangxi Academy of Agricultural Sciences (GAAS), and with strong support from the local authorities. Involvement of private sector and local NGOs were also very important to the success of the project.

2. Conservation of Local Varieties

2.1. Improvement, selection and technology dissemination of local varieties:

Women have been breeding traditional crop varieties since the beginning, ensuring the continuation and development of local maize, soybean and other crops, and working with outside specialists on PPB trials to produce new varieties. The Project Team coordinates frequent visits from domestic and international experts for knowledge sharing and capacity building in this regard. Meanwhile, good experiences and knowledge are also shared with other villages through the farmer's seed network.

Photo 2: A farmer seed fair at Guzhai Village (Photo by Simon Lim)

2.2. Community seed bank:

In 2006, the preliminary resource registry began documenting both the biological and cultural heritages of the communities with texts and pictures, which were to be the vehicles for sustainable nature-community development. The establishment of the Community Seed Bank (CSB) in 2018 marks a new era for the sustainable usage of natural resources. Like the thousands of CSBs found in over 20 countries, it started out a self-managed entity aimed at strengthening the local seed system. But it grew in size soon and linked up with government germplasm banks and other institutions, which makes it possible for local varieties to be preserved and disseminated at much larger scales. Today the Guzhai community seed bank has 124 local varieties in its registry and 63 local varieties in its physical inventory. It is a source for the diverse ecological vegetable production, which is now the community's main industry.

Photo 3: Farmer's participatory evaluation of Maize PPB&PVS trial (Photo by FSN)

Photo 4: LU Rong-Yan examines seeds in the Community Seed Bank (Photo by Qiubi)

3. From Conservation to Community Development

3.1. Eco-circular agriculture and the CSA model:

Around 2008, as people's awareness for ecological environmental protection and food safety rose, the Project Team introduced Farmers' Friends (a local NGO) and the Community Supported Agriculture (CSA) model in Guzhai village. Gradually, the Project Team created the "maize—pig—vegetable" eco-circular agriculture model. The wide adoption of eco-circular methods improved the local environment and led to the direct supply of their vegetables to an organic restaurant in Nanning City.

Photo 5: Ecological vegetables (Photo by Qiubi)

3.2. The women-led agricultural cooperatives:

From the initially established women's group to an officially registered professional cooperative, the scale has grown three-fold since its hatch, receiving continued support from external parties and multiple levels of the government. The Cooperative has nearly 100 households, with women a backbone of the Cooperative, accounting for 85% of its working members. Its total annual income is expected to rise to approximately 1.57 million yuan (equivalent to 0.23 million USD) in 2020, with an average annual household income of 15,000 yuan (or USD 2225). At the same time, the Cooperative actively assumes social responsibility to alleviate poverty and encourages the inclusion of poor households. It also facilitates a better comprehension of an eco-friendly and healthy way of production and life.

4. The Ways Forward

4.1. Multidisciplinary and multi-level participation:

Under the coordination of the Project Team, links were established between communities and different levels of research institutions, civil society organizations, hotels, government agricultural extension services, etc. The involvement and support of local governments has also played an important role in the process. Not only was it an important means of strengthening farmers' seed systems, but the resources also pulled by having stakeholders at various levels made it possible for the Cooperative, which is a special form of enterprise to adapt to the rural communities. The diversified and integrated development of farmers' cooperatives can become an important rural development path in China.

4.2. Empowerment of women:

In the process of the development, the Cooperative leader, once an ordinary rural woman has now become a pillar of the community. The process also strengthens the leadership and social and economic empowerment of rural women, awakens the ordinary sense of ownership of rural women, whose overall capacity to contribute to and benefit from the sustainable development of their communities is enhanced.

Photo 6: Local seed passed down through generations (Photo by Qiubi)

4.3. Policy advocacy:

The Project Team translated the results of the research into policy through dialogues, proposals and media publicity. Project Team also submitted policy proposals to the multiple levels of government agencies through different channels, calling for the promotion of the healthy development of farmers' seed systems in China, enhancing the influence of farmers' seed systems through multi-faceted crossover cooperation platforms, promoting agricultural biodiversity conservation, and making long-term strategic reserves for food security.

5. Conclusion

From the participatory breeding activities in 2000 to the sustainable use of agrobiodiversity, the farmers' seed system in the community has been enhanced and developed sustainably in the whole process. In the process of participatory action research, strengthening rural women's leadership, comprehensive ability and breeding technology has awakened women's sense of ownership, and improved their overall ability to strengthen farmers' seed system and women's benefit from it. Under the coordination of the participatory action research project team, the community has established cooperative relations with multiple institutions, and the diversified support has played an important role in women's empowerment, strengthening farmers' seed system and policy advocacy.

6. References

Liang, B. (2018). China faces the predicament of "preserving seeds". *Seed Science & Technology* (Shanxi), 36(10): 2. Available online at: https://kns.cnki.net/kcms/detail/detail.aspx?FileName=ZJKJ201810002&DbName=CJFQ2018 [Accessed on 19 July 2022]

Xu, J. (2018). Mountain Future and Green Silk Road. *Bulletin of Chinese Academy of Sciences*, 33(Z2): 14-17. Available online at: http://www.bulletin.cas.cn/publish_article/2018/z2/2018z204.htm [Accessed on 19 July 2022]

Xu, F.R., Yang, Y.Y., Zhang, E.L., Xin-Xiang, A, Tang, C.F., Dong, C., Zhang, F.F., Liu, X. and Dai, L.Y. (2012). On-farm conservation and utilization of paddy rice, wheat and maize landrace varieties in 15 unique ethnic groups in Yunnan, China. *Hereditas (Bjing)*, 34(11): 1465-1474. DOI: https://doi.org/10.3724/SP.J.1005.2012.01465.

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Chapter 15

Issues of Declining Livestock Breeds: Revisiting Domestic Animal Diversity in Pastoral Systems

By Saverio Krätli

Photo Credit: Dr. Saverio Krätli

Issues of Declining Livestock Breeds: Revisiting Domestic Animal Diversity in Pastoral Systems

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Abstract

Concerns for the disappearance of local breeds, including in highlands and mountain areas, go back to the beginning of scientific breeding and the early national policies of agriculture intensification in Europe at the time of the industrial revolution. Against this background, 'local' breeds were understood as a natural resource, both necessary to the new breeding techniques and threatened by agriculture intensification. This early perspective rooted in European history remains dominant; today it informs a global debate on domestic animal diversity where the majority of so-called 'local breeds' were developed in livestock systems *outside* the European experience. This paper looks at domestic animal diversity through the lenses of one of such systems: cattle breeding among the Wodaabe pastoralists in Niger. The research is based on a combination of qualitative methodologies standard in social anthropology and quantitative analysis of memorized herd genealogies over a 20-year period. Results show that a competent herder can control cattle mating in over 90 percent of cases. Complex learned behaviour in cattle, particularly related to feeding competence, is a major selection criterion. The Wodaabe specialize in using the short-lived and unpredictable grazing opportunities, which is characteristic of Sahelian rangelands. To favourably interface the unpredictable variability in potential inputs, they breed herds with exceptional levels of within-breed diversity, crucially including epigenetic traits. The common practice of conflating Domestic Animal Diversity (DAD) with Animal Genetic Resources (AnGR), therefore, falls short of adequately representing the relationship between 'local breeds' and livelihood in pastoral systems.

Keywords

Domestic animal diversity; Breeding; Wodaabe; Pastoralism; Animal genetic resources

Citation

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1. Introduction

Concern for the erosion of Domestic Animal Diversity (from now on referred to as DAD) formally entered the global stage in 1946, when the then newly created FAO was charged with cataloguing, maintaining, and utilizing livestock biodiversity (Phillips, 1981)[1]. Today, the FAO publishes the *State of the World's Report on Animal Genetic Resources for Food and Agriculture,* in collaboration with some 150 scientists around the world (Rischkowsky and Pilling, 2007; Scherf and Pilling, 2015). According to the most recent of these reports, 17% of known breeds are classified as 'at risk of extinction'. The actual proportion could be higher, as for about half of the known breeds there is no sufficient information to assess the risk level. The risk of loss of domestic animal diversity is mainly seen as triggered by changes within the livestock sector, driven by economic, social, demographic and political factors. Domestic animal diversity is included in the Convention on Biological Diversity, which outlined its roots in 'traditional knowledge, innovations and practices', emphasizing the necessity of conserving domestic animal species 'in the surroundings where they have developed their distinctive properties' (UN, 1992: Art. 2).

Concerns about the disappearance of 'local breeds' go back to the early days of animal science, in the context of the industrial revolution and the burgeoning policies of agricultural intensification. The new discipline of animal science conceptualized the animal as a machine, within a model of production that saw the natural environment as a constraint and reduced animal-environment interaction to natural selection[2]. The first comprehensive description of livestock breeds in the British islands (Low, 1842) worried about the preservation of 'centuries old environmental fitness'. Local breeds were seen as 'raw material', a potentially useful base for the new practice of scientific breeding (Hall and Clutton-Brook, 1989).

That early Eurocentric perspective never stopped dominating the debate on domestic animal diversity[3]. Today, it is at the root of the common practice of using the concepts of 'Domestic Animal Diversity' (DAD) and 'Animal Genetic Resources' (AnGR) interchangeably. DAD/AnGR conservation is often promoted on the ground that many livelihood systems depend on it. Even though mobilized with good intentions, this argument remains captive of the Eurocentric view of domestic animal diversity as a natural resource: the result of adaptation to the environmental conditions of a given location; and with the natural environment essentially seen as a constraint to production.

Conservation strategies focusing on AnGR target a representative sample of genotype-environment adaptation, with priority given to breeds presenting particularly desirable and rare traits — for example, a resistance to certain diseases (FAO-CGRFA, 2004; Reist-Marti *et al.*, 2003). But what about the livestock-based livelihood systems that have developed *outside* the European experience? What about the livestock systems that produce without building artificially stable environments and instead operate *as part of the natural*

[1] A series of seminal reference works followed, on cattle breeds in India and Pakistan (Joshi & Philips, 1953), Africa (Joshi *et al.*, 1957), Europe (French *et al.*, 1966), and on Mediterranean sheep breeds (Mason, 1967).
[2] The description of livestock as 'machine' goes back to Robert Bakewell, the pioneer of modern breeding in the late 18th century England. By the mid-19th century, the model of animal-machine had become fundamental to animal science (FAO, 2021: footnote 16). An analysis of 'cattle husbandry' in thousands of 18th-19th century agronomy texts in France finds almost no reference to the animals' behaviour or their interaction with the environment (Reynaud, 2010).
[3] A recently published book on domestic animal diversity, by Lauvie *et al.* (2023), still calls for widening the analysis to include animals' interaction with humans and environment.

environment. What about systems that specialize not in *sheltering* from climate variability but *in making it work* for livestock production (FAO, 2021)? And how can the analysis of domestic animal diversity also represent mobile systems where 'local conditions' are not given, but largely the outcome of management, as in pastoralism?

This chapter looks at these issues from the vantage point of the study of cattle breeding among Peul Wodaabe pastoralists in Niger. It shows how the importance of domestic animal diversity for livelihood systems worldwide goes well beyond the tradition of scientific livestock breeding and the current analytic focus on animal genetic resources.

2. Methodology

This chapter is based on *i.* research among the Wodaabe in Niger carried out in 2000-2005 (19 months of fieldwork) and 2008 (3 months); *ii.* qualitative data on cattle breeding and feeding selectivity using semi-structured interviews among Turkana and Karamojong pastoralists in Kenya and Uganda, Arab pastoralists in Chad and Sudan, and Somali, Boran, and Dassenetch pastoralists in Ethiopia between 1999 and 2020; and *iii.* ten years of work (since 2013) on pastoralism and pastoral development in relation to the role of mobility in environments characterized by high levels of unpredictable variability.

The study of the cattle breeding system among the Wodaabe used standard methods from social anthropology[4] and a tailor-made method for analyzing herd genealogies and herders' breeding decisions. The latter was developed for handling memorized cattle genealogies and, therefore, embedding multiple cross-checking mechanisms to limit error from misremembering. Data collection included the year of birth, sale or death — and, where relevant, the year of borrowing or lending — for each animal in the herd (males and females) over a 20-year period (1985-2005). It also included the name of the mother and father of each animal; the name of the owner of the father in case of a borrowed bull; the reason for selling the animal; and, in case of animals, whether had been borrowed or lent, the nature of the herder's relationship with the owner or receiver. Two herds, for a total of 101 head of cattle as of 2005, were analyzed with this genealogical method. Genealogical maps built in this way were immediately used in the process of data collection, to crosscheck every additional input. Crosschecking was also done by asking the same questions a second time, about random animals, during interviews weeks apart from one another. A quantitative analysis of this data using a commercial database, later enabled the production of 'snapshots' showing all the animals in the herd, their age and gender and their kinship relations, and whether they were sold, lent, returned or died, in each of the 20 years covered by the study. Finally, herders' breeding decisions and their explanations were analyzed in light of scientific literature from a range of disciplines, including animal science, rangeland management, animal behaviour science, evolutionary biology and social anthropology.

The bulk of findings in the next section are from Krätli (2008a)[5], otherwise references are provided.

[4] Participatory observation, focus-group discussions, semi-structured interviews, and Participatory Rural Appraisal (PRA) techniques.
[5] Published as synthesis in Krätli (2008b).

3. Results: Domestic Animal Diversity and Pastoralism

3.1 What is pastoralism?

On about 40 per cent of land on Earth, rainfall is highly unpredictable. For food producers who specialize in being in the right place at the right time, these unpredictable environments offer important opportunities. Mobile pastoralists are such producers (FAO, 2021; Kaufmann *et al.*, 2018).

Pastoral systems all over the world are highly diverse, but they all share the same adaptive approach: working closely with livestock interacting with rangelands, and making decisions based on learning from such interaction (Sharifian *et al.*, 2022). From the Sahel to the Arctic, pastoral systems developed as an integral part of their natural environment, not by trying to separate from it. This works by managing livestock's grazing itineraries so that the animals feed better — more sustainably and taking in more nutrients — than they would without the herder (Krätli and Schareika, 2010; Meuret and Provenza, 2014; Molnár *et al.*, 2020).

Pastoral systems all over the world, including in highlands and mountain areas, specialize in making use of highly unpredictable environments, using livestock to take advantage of the important, but scattered and short-lived opportunities offered by the rangelands. When the functional processes in the pastoral system can be kept variable enough to match the pace of unpredictable change in the environment, the system's outputs are relatively stable even in highly variable conditions (FAO, 2021).

In the face of the uncertainty associated with making use of a highly unpredictable environment, the logic of pastoralism is to keep options open: flexibility of options compensates for lack of certainty (Krätli and Schareika, 2010; Scoones, 2022). Promoting and maintaining high levels of domestic animal diversity in the herds is part of this logic. With a few exceptions (especially in the Arctic region), pastoralists typically keep several species in their herds — for example cattle, camels, sheep, goats and donkeys; or goats, horses, and yaks — and even different lineages within the same breed. This helps them match the diversity of opportunities in their environment. But the most important strategy in this regard is by fostering variability within the breeding population itself.

Hall (2004) finds that some of the highest levels of within-breed diversity are found in pastoral systems. In his description, 'within-breed variation provides the flexibility that the breeds need to have if they are to respond to changing conditions'. We will see that pastoralists foster within-breed diversity in their own way. A livestock breeding population developed to perform under pastoral management conditions is a different entity compared to a breed developed to maximize a single trait. Despite the long interest in local breeds by the international community, livestock breeding in the most specialized 'local' contexts — pastoral systems — has so far received surprisingly little attention.

3.2 Wodaabe pastoralism in Niger

The Wodaabe in Niger breed perhaps the largest cattle in Sub-Saharan Africa, the long-horned *na'i bodeeji* ('red cows' in Fulfulde, Wodaabe's vernacular language). These animals were formally characterized as 'Red Bororo zebu' in the early 20th century, during the French colonial administration (Krätli, 2009; Mornet and Koné, 1941). The cattle of the Wodaabe have been recorded to feed on more than 60 varieties of plants, including bushes, trees and grasses — often thorny and and/or toxic at certain stages of their life cycle (Bonfiglioli, 1981). The Wodaabe and their livestock operate in a natural environment where the temperature reaches 50°C, with precipitations between 0 and 400 mm in one rainy season stretching over a maximum of four months. By comparison, in 2021, livestock experts in the United Kingdom warned that "with temperatures now regularly reaching 20°C and beyond… [our] cows are extremely susceptible to heat stress"[6].

The Wodaabe's herd management strategy is equally remarkable. In order to keep their animals on the best possible pasture also during the nine-month-long dry season, they camp as far as 30 kilometers away from the water point. Watering is done every other day during most of the dry season, and every second day in the last couple of months. This strategy also exploits the ability in cattle to keep them in a positive energy balance when a low-protein roughage diet is combined with a degree of water restriction (Granier, 1968; Rogerson, 1963).

The Wodaabe literally live with their livestock. Their camp includes a space for the herd, unfenced, where a fire is lit every evening only for animals. At night, the cattle leave the camp on their own and return after a few hours of grazing. When moving with their herders, these animals *follow* the herder rather than being herded from behind, and are able to respond to numerous commands. All this contributes to optimizing feeding efficiency and facilitating management in conditions where even the smallest advantage can make an important difference (Breman and De Witt, 1983; Krätli and Schareika, 2010).

3.3 Engaging with the natural environment: variability in nutrients over time and space

In the Sahel, the rain falls in itinerant showers. In most of these rangelands, it is impossible to predict from one year to the next where pasture will grow. Nutrients for livestock are distributed unevenly and unpredictably. Variability rules at all scales, both in time and space. Variations between seasons (time) and between macro-ecological zones (space) are the most obvious examples. Following the rains, the concentration of nutrients in pasture also *increases* as one moves north towards the Sahara — drier areas have less pasture biomass but of higher quality (Breman & De Wit, 1983). The concentration of nutrients also varies between plants and between the parts of a plant (Breman & de Ridder, 1991). In terms of variability in time, during the life cycle of a plant, nutrients first peak and then decrease as the plant uses them for its own reproduction (Alimaev, 2003; Ball *et al.*, 2001; Ronga *et al.*, 2020). Nutrient content in pasture also changes between day and night, peaking in the evening after a day of photosynthesis (Ball *et al.*, 2001; Burns *et al.*, 2005; Scialdone and Howard, 2015).

Livestock feeding opportunities also expand and contract at unpredictable intervals between years, often dramatically. In order to keep productivity as high as possible on highly variable resources, livestock need to feed in the right place at the right time, and be able to select the best bites. For all that to happen, herders need the right herd: animals capable of moving quickly even over long distances, and capable of feeding discerningly and efficiently once presented with an opportunity. In other words, they need herds highly skilled in interacting successfully with the natural environment. So, what makes a pastoral herd 'right'?

3.4 Breeding cattle among the Wodaabe

Wodaabe's pastoralism rests on a sophisticated cattle breeding system supported by several customary institutions — most importantly, a matrilineal cattle naming system

[6] Dairy Global, https://www.dairyglobal.net/health-and-nutrition/health/a-greater-issue-in-uk-heat-stress-impact-on-dmi/

shared among all Wodaabe clans and Peul/Fulani livestock-keepers more broadly, from Senegal to Sudan. New born calves, males and females, are named after the mother. This naming system organizes the herd into matrilineal families and makes it possible to track the outputs of breeding, both across herds and across human generations. A name refers to a cattle lineage as well as each one of its members. For example, while pointing at a cow named 'Guddel', a herder might say 'Guddel was already in the herd of my grandfather when my father was a child'— although at that time the actual cow had not yet been born (interview with Jiima bi Ardi, March 2004).

Cattle genealogies are systematically memorized, although of course this is not achieved by all herders to the same degree. Close monitoring and a short period of heat (oestrus) in these cattle[7], allow for a strict control of reproduction. In 2005, the analysis of herd genealogy showed that a competent herder can control mating in over 90 percent of cases (Krätli, 2009).

Non-productive animals are systematically sold. Breeders borrow reproductive bulls and lend cows across networks including tens of herds. Lending of heifers between friends and relatives is institutionalized. These animals remain in the receiving herd for the time it takes to deliver one or two calves, and are returned pregnant. Crossbreeding is a traditional practice, used to expand the range of production strategies available to the household, or to adapt the herd when moving into entirely new areas or when facing new socio-economic conditions (Boutrais, 2007).

3.5 A particular attention to learned behaviour

Animals in a pastoral system need to be productive and sufficiently robust to reproduce under demanding conditions of environment and management. To date, Wodaabe's livestock achieve this with minimal inputs of feed supplement or veterinary services. Besides matching the basic requirements for survival and reproduction, selective mating is aimed at building and maintaining diversity within the herd. In order to thrive in the highly variable environmental conditions of the Sahel, building a capacity for variability into the herd takes priority for the Wodaabe over maximizing a single trait. The following statement is enlightening:

> 'We have preferred lineages but do not maximise their number in the herd. If we did that, the entire herd would be made of similar animals and we don't want that. We need different lineages with a variety of functional skills' (focus group discussion with herders, May 2004).

A major criterion for selection is *behaviour*, including complex learned behaviours passed from mothers to calves and between peers. Feeding competence is crucial. Social behaviour within the herd, and an animal's attachment to the herders, are also important as they can have positive outcomes on the animals' health, learning ability and feeding efficiency, for example by reducing antagonism and stress. Social interactions can jeopardise or favour cattle feeding performance in various ways (Bouissou *et al.,* 2001; Dumont & Boissy, 1999; Waiblinger *et al.*, 2006). The mere proximity of dominants can cause subordinates to slow down their bite rate and even stop feeding (Bennet & Holmes, 1987). Work on African buffalo revealed that an animal's physical condition is heavily affected by the herd's social organisation and its position within it (Prins, 1996).

[7] This information from the herders matches general descriptions of oestrus cycle in zebus. Cuq (1973) reports a much wider difference between extremes compared to *Bos Taurus*, with an average time of acceptance of a male spanning between 4 and 8 hours.

In the herds of the Wodaabe, antagonistic and aggressive behaviours are minimized by removing most of the males above a certain age, and by actively promoting bonding relationships between the animals. For example, at night the calves are tethered to both sides of the 'calf-rope' stretched north-south across the camp; they are always attached in the same position relative to one another. The herders explain that this is in order to favour the creation of bonds between the animals (called 'preferential relationship' by animal behaviour specialists) at a time when they most need reassurance as the mothers (dams) leave for night grazing.

Having a high number of preferential relationships within the herd results into reduced aggressiveness, increased tolerance in competitive situations, and enhanced positive interactions such as grooming. Research from applied animal behaviour science highlights the potential economic return of management strategies that minimize negative social interaction within the herd, and recommends measures apt to stabilize dominance and favour preferential relationships (Boissy *et al.*, 2001; Bouissou *et al.* 2001). Preferential relationships between animals are described by Wodaabe herders with the same vernacular word also used to talk about friendship between people. Their cattle management system also enhances calf-dam bonds. Calves are allowed to spend several hours per day with their mothers, both around the camp in the evening and during the morning grazing — also a critical learning opportunity.

Wodaabe herds are complex social organizations not dissimilar to the herds of wild herbivores but with lower levels of internal antagonism. Favouring the number of bonds within the herd works towards improving herd nutrition: more even feeding patterns across ranks without cost for the high-ranking ones, and, therefore, a better feeding performance of the herd as a whole. Here below are some other examples of learned behaviour, the functionality of which Wodaabe herders appreciate and strive to build into their herds through their breeding practices:

- *noppina*: feeding on new grass when it is still young, ingesting only minimum sand by pinching the short grass with the muzzle as sheep would — gives extra days feeding on green pasture at the beginning of the rainy season.
- *geeti*: being very attached to the household's members and ferociously mistrustful of strangers and unfamiliar practices — helps managing the herd and makes it hard to steal.
- *dikku* (also *halhonge*): to have 'character', for example a cow that has collapsed on the ground out of exhaustion yet that when helped to stand up does not collapse again but starts feeding;
- *gamtudi*: on the range, these animals are always some distance from the group, exploring for better pasture — when managed by the herder, they can improve overall feeding performance of the herd.

Herders welcome some behavioural patterns to a higher degree, but lineages showing exceptional levels of such traits are not maximised within the herd at the expenses of the other lineages.

4. Discussion: Breeding for Variability

Working on camel breeding among the Rendille in Kenya, Brigitte Kaufmann found that the animals producing most milk during the rainy season — those that animal science would see as the best milk producers in the herd — were considered by the herders to be the 'weakest animals' (Kaufmann, 2007). This was because they were barely able to feed their calves during the dry season and the first ones to day in a drought. On the other hand, animals that did not perform particularly well during the rainy season were the best milk producers during the dry season. Kaufmann found that Rendille herders valued multiple *types* of performance — to match variability of conditions — over absolute best performance in best conditions.

In the case of cattle breeding among the Wodaabe, multiple *types* of performance are actively pursued and maintained. The role of within-breed genetic variation is important, but clearly within-breed diversity used in pastoralism stretches well beyond genetic traits. This is a breeding system aimed at embedding not only variability of genetic resources, but also epigenetic gene-expression that complements complex learned behaviour functional to interfacing with the environment (Krätli, 2008a; Jablonka and Lamb, 2006; Day *et al.*, 2003; Lewontin, 2000). In other words, breeding practices are aimed at introducing and maintaining particular learned behaviours. The focus of the breeders is more on the herd and its lineages than on individual animals. We know, from decades of research on ruminants' feeding behaviour, that the mother's influence begins in the womb (as flavors of foods she eats reach her amniotic fluid), and continues after birth (through flavors in her milk). When offspring begin to forage, the mother is a model for what and what not to eat, and where and where not to go. Learned behaviors and abilities involve anatomical and physiological changes in organ systems, including the microbiome (Landau and Provenza, 2020). Many of such changes are inheritable, if in epigenetic ways, and, therefore, subject to breeding strategies.

Besides feeding competence, animals' attachment to the herders and social organization within the herd are very important. Other examples of sought-after behavioural traits include knowledge of the territory and orientation, and experience in managing difficult terrains or heat stress. Combinations of learned behaviours create the pastoral herds adapted to successful interaction with the multiple, biodiverse and variable landscapes they inhabit.

The primary objective of breeding under these variable conditions is not to maximise a trait or set of traits towards some absolute optimum with the right combination of genes. The primary objective is to keep as high as possible the capacity of a given herd to function as a matching interface with ever-changing landscapes. Pastoral breeds are constantly in the making; they are developed to interface production with landscapes that are also constantly in the making; these breeds *are defined* by their variability.

This peculiar approach to breeding — *breeding for variability* in interacting with a variable environment — now offers an important lesson in the face of climate change (FAO, 2021). In this light, livestock breeding in pastoral systems, and the different meaning it gives to domestic animal diversity beyond the current focus on genetic material, carries new relevance also beyond the study of pastoralism.

5. Conclusion

The analysis of Wodaabe cattle breeding shows high levels of systematic monitoring and control of mating and routine culling. It also shows a strong emphasis on the generation and maintenance of domestic animal diversity, especially within-breed diversity including both genetic and epigenetic traits. Of particular importance to the herders are multiple types of complex learned behaviour that are functional to the animals' interaction with the natural environment. Both the reproduction and the effectiveness of these learned behaviours depend on the social organization within the herd: mother-calf and peer-to-peer learning; and on low-stress feeding conditions. Within this approach, the breeding unit is the herd rather than the individual animal.

The 'domestic animal diversity' *economically relevant* in pastoralism using drylands, highlands and mountain regions — and most likely in many traditional livestock breeding systems in family-farming contexts (Provenza, 2008) — is, therefore, not limited to genetic resources and to individual animals' performance. In fact, this particular kind of DAD found in pastoral systems remains largely outside the conventional, genetic notion of domestic animal diversity — which for the time being continues to focus at the level of the individual animal in isolation from the environment or with the environment merely seen as a constraint[8].

The common practice of conflating DAD with AnGR with its narrow focus on 'adaptation to local conditions' is inadequate to represent the relationship between livestock breeds and livelihood in pastoral systems.

6. References

Alimaev, I.I. (2003). Transhuman ecosystems: fluctuations in seasonal pasture productivity. In: Kerven, C. (ed.), *Prospects for Pastoralism in Kazakstan and Turkmenistan: From State Farms to Private Flocks*. London: Routledge-Curzon.

Ball, D.M., Collins, M., Lacefield, G.D., Martin, N.P., Mertens, D.A., Olson, K.E., Putnam, D.H., Undersander, D.J. and Wolf, M.W. (2001). *Understanding Forage Quality*. Park Ridge, IL: American Farm Bureau Federation Publication 1-01.

Bennett, I.L. and Holmes C.R. (1987). Formation of a feeding order in a group of cattle and its relationship with grazing behaviour, heat-tolerance and production. *Applied Animal Behaviour Science*, 17: 9-18.

Boissy, A., Nowak, R., Orgeur, P. and Veissier, I. (2001). Les liens sociaux chez les ruminants d'élevage: limites et moyens d'action pour favoriser l'intégration de l'animal dans son milieu. *Productions Animales* (INRA), 14: 79-90.

Bonfiglioli, M.A. (1981). *Ngaynaaka. Herding According to the WoDaaBe*. Niger Range and Livestock Project, Discussion Paper n. 2. Tahoua: Republic of Niger, Ministry of Rural Development and USAID.

Bouissou, M.F., Boissy, A., Le Neindre, P. and Veissier, I. (2001). The social behaviour of cattle. In: L. Keeling & H. Gonyou (eds.), *Social Behaviour of Farm Animals*. Wallingford, UK: CAB International.

Boutrais, J. (2007). The Fulani and Cattle Breeds: Crossbreeding and heritage strategies. *Africa*, 77(1): 18-36.

Breman, H. and de Ridder, N. (eds.) (1991). *Manuel sur les pâturages des pays sahéliens*. Paris: Editions Karthala.

Breman, H. and De Wit, C.T. (1983). Rangeland Productivity and Exploitation in the Sahel. *Science, New Series*, 221(4618): 1341-1347.

Burns, J.C., Mayland, H.F. and Fisher, D.S. (2005). Dry matter intake and digestion of alfalfa harvested at sunset and sunrise. *Journal of Animal Science*, 83: 262–270.

[8] In the face of climate change, this model of food production based on externalizing nature has itself become a critical distinguishing trait in the current call to rethink agricultural systems before it is too late (FAO, 2021; Pretty, 2002; Scherr & McNeeley, 2007; Shiva *et al.*, 2019; UNEP, 2021).

Cuq, P. (1973). Bases anatomiques et fonctionnelles de la reproduction chez le zébu (Bos indicus). *Revue d'Élevage et de Médecine Vétérinaire des Pays Tropicaux,* 26(4): 21a-48a.

Day, R.L., Laland, K.N. and Odling-Smee, J. (2003). The Niche Construction Perspective. *Perspectives in Biology and Medicine*, 46(1): 80–95.

Dumont, B. and Boissy, A. (1999). Rélations sociales et comportement alimentaire au pâturage. *INRA Productions Animales*, 12(1): 3-10.

FAO (2021). *Pastoralism: Making Variability Work*, Animal Production and Health Paper No. 185. Rome: Food and Agriculture Organization of the United Nations (FAO).

FAO-CGRFA (2004). *Measurement of Domestic Animal Diversity. A review of recent diversity studies*. Commission on Genetic Resources for Food and Agriculture. Working Group on Animal Genetic Resources for Food and Agriculture, Third Session Rome, 31 March – 2 April 2004. Rome: Food and Agriculture Organization of the United Nations (FAO).

French, M.H., Johansson, I., Joshi, N.R. and McLaughlin, E.A. (1966). *European breeds of cattle* Vol. I and II, FAO Agricultural Studies No. 67. Rome: Food and Agriculture Organization of the United Nations (FAO).

Granier, P. (1968). Etude sur la digestibilité chez le zébu. *Terre Malgache*, 2: 139-159.

Hall, S.J.G. (2004). *Livestock Biodiversity. Genetic Resources for the Farming of the Future*. Oxford, UK: Blackwell Publishing.

Hall, S.J.G. and Clutton-Brock, J. (1989). *Two Hundred Years of British farm Livestock*. London: British Museum of Natural History.

IPCC (Intergovernmental Panel on Climate Change) (2021). Summary for Policymakers. In: V. Masson-Delmotte, P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.), *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, UK: Cambridge University Press.

Jablonka, E. and Lamb, M.J. (2006). *Evolution in Four Dimensions. Genetic, Epigenetic, Behavioral, and Symbolic Variation in the History of Life*. Cambridge, MA, US: The MIT Press.

Joshi, N.R. and Phillips, R.W. (1953). *Zebu Cattle of India and Pakistan*, FAO Agricultural Studies No. 19. Rome: Food and Agriculture Organization of the United Nations.

Joshi, N.R., McLaughlin, E.A. and Phillips, R.W. (1957). *Types and Breeds of African Cattle*, FAO Agricultural Studies No. 37. Rome: Food and Agriculture Organization of the United Nations.

Kaufmann, B.A. (2007). *Cybernetic Analysis of Socio-biological Systems: The Case of Livestock Management in Resource-Poor Environments.* Weikersheim, Germany: Margraf Publishers GmbH.

Kaufmann, B.A., Hülsebusch, C.G. and Krätli, S. (2018). Pastoral Livestock Systems. In: Ferranti, P., Berry, E.M., Anderson, J.R. (eds.), *Encyclopedia of Food Security and Sustainability*, vol. 3. Amsterdam, The Netherlands: Elsevier.

Krätli, S. (2008a). Cows Who Choose Domestication. Generation and management of domestic animal diversity by WoDaaBe pastoralists (Niger), PhD thesis. Brighton, UK: Institute of Development Studies, University of Sussex.

Krätli, S. (2008b). *Time to outbreed animal science? A cattle-breeding system exploiting structural unpredictability: the WoDaaBe herders in Niger*, STEPS Working Paper 7, Brighton, UK: STEPS Centre, Institute of Development Studies, University of Sussex.

Krätli, S. (2009). Animal Science and the Representation of Local Breeds: Looking into the Sources of Current Characterisation of Bororo Zebu. In: K. Brown and D. Gilfoyle (eds.), *Healing the Herds: Essays on Livestock Economies and the Globalization of Veterinary Medicine*. Athens, Ohio, US: Ohio University Press.

Krätli, S. and Schareika, N. (2010). Living off Uncertainty. The Intelligent Animal Production of Dryland Pastoralists. *European Journal of Development Research*, 22(5): 605-622.

Landau, S.Y. and Provenza, F.D. (2020). Of browse, goats, and men: Contribution to the debate on animal traditions and cultures. *Applied Animal Behaviour Science*, 232: 1-12.

Lauvie, A., Audiot, A. and Verrier, E. (eds.) (2023). *La biodiversité domestique. Vers de nouveaux liens entre élevage, territoires et société*. Versailles, France: Éditions Quæ.

Lewontin, R.C. (2000). *The Triple Helix*. Cambridge MA, US: Harvard University Press.

Low, D. (1842). *The Breeds of the Domestic Animals of the British Isles*. Vol. I. The Horse and the Ox. Vol. II. The Sheep, the Goat, and the Hog. London: Longman, Orme, Brown, Green & Longmans.

Mason, I.L. (1967). *Sheep Breeds of the Mediterranean*. Rome: Food and Agriculture Organization of the United Nations (FAO).

Meuret, M. and Provenza, F. (eds.) (2014). *The Art and Science of Shepherding*. Tapping the Wisdom of French Herders. Austin, TX, US: ACRES.

Molnár, Z., Kelemen, A., Kun, R., Máté, J., Sáfián, L., Provenza, F., Díaz, S., Barani, H., Biró, M., Máté, A. and Vadász, C. (2020). Knowledge co-production with traditional herders on cattle grazing behaviour for better management of species-rich grasslands. *Journal of Applied Ecology*, 57: 1677–1687.

Mornet, P. and Koné, K. (1941). Le zébu peulh bororo. *Bulletin des Services Zootechniques et des Épizooties de l'Afrique Occidentale Française*, 4(3-4): 167-180.

Phillips, C.J.C. (1981). The identification, conservation and effective use of valuable animal genetic resources. In: *Animal genetic resources. Conservation and management. Proceedings of FAO/UNEP Technical Consultation*. Rome: Food and Agriculture Organization of the United Nations (FAO).

Pretty, J. (2002). *Agri-Culture: Reconnecting People, Land and Nature*. London: Earthscan.

Prins, H.H.T. (1996). *Ecology and Behaviour of the African Buffalo: Social Inequality and Decision Making*. London: Chapman & Hall.

Provenza, F.D. (2008). What does it mean to be locally adapted and who cares anyway? *Journal of Animal Sciencei,* 86: E271-E284.

Reist-Marti, S.B., Simianer, H., Gibson, J., Hanotte, O. and Rege, J.E.O. (2003). Weitzman's Approach and Conservation of Breed Diversity: an Application to African Cattle Breeds. *Conservation Biology*, 17(5): 1299-1311.

Reynaud, F. (2010). *L'élevage bovin. De l'agronome au paysan (1700-1850).* Rennes, France: Presse Universitaire de Rennes.

Rischkowsky, B. and Pilling, D. (eds.) (2007). *The State of the World's Animal Genetic Resources for Food and Agriculture*. Rome: Food and Agriculture Organization of the United Nations (FAO).

Rogerson, A. (1963). Energy utilization of poor-quality roughage by water-deprived steers. *Nature*, 197: 1222.

Ronga, D., Dal Prà, A., Immovilli, A., Ruozzi, F., Davolio, R. and Pacchioli, M.T. (2020). Effects of Harvest Time on the Yield and Quality of Winter Wheat Hay Produced in Northern Italy. *Agronomy*, 10(917). https://doi.org/10.3390/agronomy10060917.

Scherf, B.D. and Pilling, D. (eds.) (2015). *The Second Report on the State of the World's Animal Genetic Resources for Food and Agriculture*. Rome: Commission on Genetic Resources for Food and Agriculture Assessments, Food and Agriculture Organization of the United Nations (FAO).

Scherr, S.J, and McNeely, J.A. (2007). *Farming with Nature. The Science and Practice of Ecoagriculture.* Washington, Covelo, London: Island Press.

Scialdone, A. and Howard, M. (2015). How plants manage food reserves at night: quantitative models and open questions. *Frontiers in Plant Science*, 6(204). https://doi.org/10.3389/fpls.2015.00204.

Scoones, I. (2022). *Livestock, Climate and the Politics of Resources: a Primer*. Amsterdam : Transnational Institute.

Sharifian, A., Gantuya, B., Wario, H.T. Kotowski, M.A., Barani, H., Manzano, P., Krätli, S., Babai, D., Biró, M., Sáfián, L., Erdenetsogt, J., Qabel, Q.M. and Molnár, Z. (2022). Global principles in local traditional knowledge: a review of forage plant-livestock-herder interactions. *Journal of Environmental Management*, 328(2023): 116966.

Shiva, V., Scialabba, N. El Hage, Ceccarelli, S., Masucci, M., Hohenstein, K., Hertoge, K., Cabaleiro, F., Oliveira de Souza, M.M., Pacheco Rodriguez, F., Alvarez Mora, M., Bassey, N., Anilkumar, P., Raj Singh, N., Ackerman-Leist, P., Jacob, M. and Latham, J. (2019). *The Future of Food. Farming with Nature, Cultivating the Future.* Rome: Navdanya International.

UN (1992). *Convention on biological diversity (with annexes). Concluded at Rio de Janeiro on 5 June 1992*. Rio De Janeiro, Brasil: United Nations.

UNEP (2021). *Making Peace with Nature: A scientific blueprint to tackle the climate, biodiversity and pollution emergencies*. Nairobi: United Nations Environment Programme (UNEP).

Waiblinger, S., Boivin, X., Pedersen, V., Tosi, M. V., Janczak, A. M., Visser, E. K. and Jonesg, R.B. (2006). Assessing the human–animal relationship in farmed species: A critical review. *Applied Animal Behaviour Science*, 101(3-4): 185-242.

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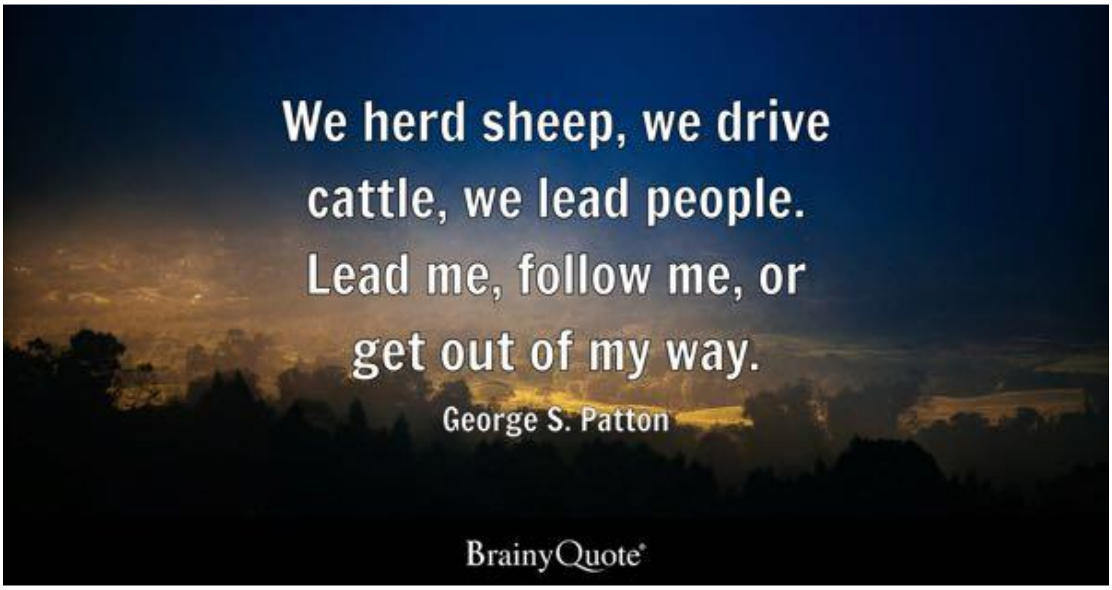
Dr. Saverio Krätli is a freelance researcher and consultant, and *honorary editor* of the peer reviewed journal *Nomadic Peoples* (since 2010). He has a hybrid background. He started with studying philosophy in Italy (Bologna). Then he moved to the UK to study anthropology of development. He worked for a few years at the Institute of Development Studies doing research on pastoralism in East Africa, with Jeremy Swift, starting from Turkana (Kenya) and Karamoja (Uganda). Eventually he did a PhD in development studies with a research on cattle breeding amongst the Peul Wodaabe in Niger, one of the most specialised groups of mobile pastoralists in the world. For the last 16 years, he worked on pastoralism as a freelance, engaging with the whole spectrum of pastoral development agencies, from grassroots pastoral associations and local NGOs, to governmental, international and Bretton Wood organisations. He has had a long collaboration with the International Institute for Environment and Development (UK), with which he developed the 'Valuing Variability' concept and a MOOC on 'pastoralism in development'. He also had long collaborations with the German Institute for Tropical and Subtropical Agriculture (DITSL), and with Tufts University (US). Since 2014, he has helped Misereor (Germany) and their partners in Ethiopia to build their capacity to work with people in pastoral systems. This has led to the publication of the *Pastoral Development Orientation Framework*; NEP an online tool to help the critical analysis of the 2020 Ethiopia pastoral development policy; and the shortest introduction to pastoralism, a 2 minute animation realized by Misereor in partnership with Vétérinaires sans Frontières Belgium and CELEP (the Coalition of European Lobbies for Eastern African Pastoralism). Other main professional achievements include the evaluation of twenty years of water development interventions in pastoral regions of Chad by the French Development Agency (AFD), the joint evaluation FAO's and IFAD's Engagement in Pastoral Development (2003-2013), and the evaluation of the FAO-based Pastoralist Knowledge Hub. He has been the lead author of IFAD's first How to do Note on *Engaging with Pastoralists*, the FAO paper Pastoralism: Making Variability Work and the GIZ Technical Background Paper: Pastoralism and Resilience of Food Production in the Face of Climate Change. He has worked with pastoralists in Niger, Chad, Kenya, Uganda, Ethiopia, Sudan, Tanzania and Mongolia. He is committed to a trans-disciplinary perspective, which he has used in research on issues of conflict, education, livelihood and policy analysis, pastoral mobility, and total economic evaluation of pastoral systems. Current research interests focus on the use of environmental variability by dryland production systems, and the gap between drylands/pastoral development theory and methodologies.


We herd sheep, we drive cattle, we lead people. Lead me, follow me, or get out of my way.
George S. Patton
BrainyQuote

Chapter 16

Study on the Diversity of Products Obtained from Sheep in the Current Bioeconomy Context

By Lavinia Udrea, Gabriela Teodorescu, Sînziana Venera Morărita, Ivona David

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Study on the Diversity of Products Obtained from Sheep in the Current Bioeconomy Context

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Abstract
A concern for the growth and utilization of sheep is raised since ancient times in Romania. The development of livestock sector is determined by the climate and the geographical configuration with the availability of grasslands maintained by transhumants. The pastoralism founded a domestic processing of milk, wool and leather products with positive socio-economic implications on material and spiritual life of local people. The sheep breeds prevailed until the 20th century were 'Tucana' and 'Stogose' and, to a lesser extent, 'Tisigai'. These breeds, generally unimproved, have a profound fitness and resistance to harsh weather conditions. These breeds were also fit for traveling long routes in search of food. The utilization of a sheep breed is determined by the national economic demand, productivity potential of the breed, available, technology, improvement and utilization methods of the breed. The said sheep breeds were appreciated because they produce a diversity of products having superior nutritional or economic values. It is known especially for its white wool, which is used in domestic industry for making clothes and other products including artifacts, textiles, Persian carpets, etc. Considering the local natural conditions and the national economic demands, the sheep husbandry was assisted continuously to support intensive and multilateral development producing the necessary raw materials for the textile, fur, leather and food industry. Both research and the technical developments have contributed to the zootechnical field geared to resolve the problems appeared in the development of sheep. The scientific knowledge and expertise need to be combined with application skills leading to the development and modernization of complex technologies helping growth of sheep products.

Keywords: Sheep; Wool; Milk; Bioeconomy; Meat

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1. Introduction

The sheep (*Ovis vignei*) is appreciated for both the diversity of its products and its superior nutritional and economic values (Alexandru, 2009). Considering the local natural conditions and the demands of the national economy, currently the sheep breeding is an important sector of animal husbandry, which has been oriented, stimulated and supported to achieve intensive and multilateral development ensuring domestic production of raw materials for the textile, fur, leather and food industries (Alexandru, 2010). This explains why sheep had a spread to the entire globe, more in temperate areas and less in humid cold or humid hot areas. Therefore, sheep products need to be understood through the prism of economic efficiency using recent scientific literature focusing new technologies to harness the productive potential of the sheep (Ilisiu *et al.*, 2013).

Historically, special attention was paid to the practical ways of intensifying the sheep breeding and harnessing the products in the wake of new agriculture revolution in Romania. Interests in sheep increased with the development of agriculture and socio-economic aspects generating new demands for food and raw materials of animal origin (Amalia and Simona, 2019). Thus, the need arose to create new productive breeds of sheep, simultaneously with the recent advancement of breeding and exploration technologies having increased efficiency.

The research and the technical developments have contributed to rising sector of animal husbandry in order to solve the contemporary problems posing sheep breeding. Depending on the evolution of socio-economic factors and the organizational framework, the utilization of sheep evolved through many stages (Gavojdian *et al.,* 2012). However, current trends in sheep farming are based mainly on market requirements, biological characteristics of sheep breeds, and the environmental conditions (see Table 1).

Table 1: The evolution of sheep worldwide 2017-2019

Continent	*Number in 2017*	*Number in 2018*	*% Change to total in 2019*
Africa	164.859	183.562	+1.34
North America	22.410	21.961	-2.92
Asia	293.778	324.561	+21.45
South America	102.563	107.790	6.45
Europe	126.343	134.249	+5.55
Total	1,044.316	1,120.092	+4.15

As highlighted in table 1, large increases in sheep numbers have been recorded in Asia, followed by Africa and Europe, while the other continents mark a slight decrease. In some transoceanic countries, such as Australia and New Zealand, there are large sheep farmers. Until recently the production of sheep is chiefly for harnessing the wool; and now a crossbreed 'Corriedale' is raised for meat and wool. In Eastern Europe and the Balkans, the meat production has increased along with wool, milk and skins. A preferred breed of sheep is the one that has medium size, high adaptability and crossbreeding traits with other breeds, and gives mixed production, precociousness and prolificacy. With this background, in the present paper, the Indigenous sheep breeds, Tisigai and Turcana, are analyzed to understand sheep raising practices and to identify the factors that lead to an increase and improvement of wool, milk, and meat production.

2. Study Area

This study concentrates on the growth of the sheep from Prahova area situated in the Carpathian curvature. The breeding area of the two sheep breeds - Tisigai and Turcana - starts from the north of Dambovita area, adjacent to Buzau. This site stretches over an area of 30-40 km on the hilly altitude of 600-800 m.

3. Description of Sheep Breeds

The Ţisigai breed (Figure 1) comes from the *Ovis vignei arkal*. From the southeast of the Caspian Sea, where it was domesticated, it spread first into Asia Minor, then in the south of the Soviet Union, and in the Danube Mouth region and Dobrogea (Romania). From here, it spread to the rest of Romania, and to Bulgaria, Yugoslavia, Hungary, Czecho-Slovakia and Poland. Over time, because of transhumance and the geo-climatic conditions in Romania, two ecotypes within Ţisigai breed emerged. The "plain" ecotype has massive body with higher yield of wool and meat; another one is "mountain" ecotype having less body mass. The first ecotype is more popular among the herders and livestock raisers.

Figure 1: Tisigai breed of sheep

Before 1950, the Ţisigai breed grew in compact herds, in a smaller area, in the South-Eastern Plain and in the Dobrogean Plateau. Around 1950, the "ţigaizare" (crossing the Ţurcană breed with the Ţisigai breed) took place on a large scale in the Bărăgan Plain, in the hilly and plateau areas in the south of the country, inside the Carpathian arch, in Transylvanian and the south and center of Moldova. At the beginning of this century, on the slopes of the Bucegi Mountains, in the localities of Teşila and Trestienii de Sus (Prahova area), and in the submontane areas of Covasna, Harghita and Mureş counties, Ţisigai de şes breed was adapted, and crossbreed of the Ţurcană breed (Figure 2) was adopted along with the mountain ecotype of the Ţisigai breed.

Currently, the Ţisigai breed represents about 26% of the total numbers of sheep in Romania, and is raised in the hilly, plateau, depression areas, and, to a lesser extent, in some sub-mountain areas. The Ţurcană breed also comes from *Ovis vignei arkal*, having phylogenetic evolution and obvious phenotypic similarities, production, resistance and behavior resembling some breeds and other rustic breeds from Bulgaria, Greece, Yugoslavia, Italy, and former USSR. It is the oldest breed in Romania, and its evolution dates back to ancient times.

Figure 2: Turcană sheep

The Turcana (Figure 2) continues to be the breed that holds the highest proportion (40%) of the total population. 3-4 decades ago, it represented over 60% of the population, growing both in the lowland and hill and mountain areas by virtue of its exceptional resistance and adaptability to different natural environmental conditions. This was maintained until 1950-1955 when the transformation of sheep was undertaken from thick wool sheep into semi-fine and fine wool producing sheep. It was accomplished by crossing Turcana with Ţisigai in the hilly areas, and with Merinos in the plain areas. At present, it is widespread in the sub-mountainous and mountainous areas of the country, but sporadic herds continue to be increased in the hilly areas as well. Within this Turcana breed, 4 phenotypic variances are distinguished: white, black, grey and rotca. The white variety is the most frequent and widespread. It is especially appreciated for white wool from which clothes, Persian carpet and other folk-art products are made. This variety is the best milk producer breed. The black variety is raised in small numbers, especially in central and northern Romania where the sheep are crossed with Karakul rams to obtain skins. The grey variety is widespread in the hilly and sub-mountainous areas of northern Moldova, adjoining the localities of Bacău, Botoşani, Suceava and Piatra-Neamţ. Both wool and "embers" are Brumaire. Due to their distinct morphoproductive characteristics and reproductive isolation, the Brumaire variety can be considered an independent breed. The improvement of this variety is to obtain valuable skins and to increase the milk production. The rotca variety (Figure 3) differs from the other varieties, especially by its "cap" horns twisted in the shape of a corkscrew, which is why it is having a different phylogenetic evolution.

Figure 3: Rotca sheep

4. Methodology

This research was performed on Tisigai and Turcana breeds of sheep. The total number of animals was 413 heads (Table 2). The age of the sheep studied was between 5 months and 6 years. The samples were analyzed for herd, milk production, wool production, meat production, the production of skins, furs and hides, the shelters and veterinary sanitary requirements during sheep breeding.

In the table 2, data of Ţisigai and Ţurcană sheep breeds is presented. In the two breeds, a very small percentage of sheep is registered having problems. Out of total 413 sheep, 202 (49%) sheep were milking, while 100 (24%) were barren sheep. 20 sheep had problems with calving. The feeding of sheep consists of grazing during the summer at low altitude and alpine pasture, and the fodder is produced within the farm during the winter.

Table 2: The sample of the sheep Ţisigai and Ţurcană studied

Breeds	*Total No. of Animals*	*Sheep producing milk*	*Barren sheep*	*Sheep having problems*	*Rams*	*Other sheep*
Turcana	228	100	60	15	10	43

Tisigai	185	102	40	5	6	32
Total	413	202	100	20	16	75

5. Result and Discussion

5.1 Milk Production

Since the Țurcană breed among all local breeds produces more milk, the milk production, on an average, is 80-110 liters per lactation (Lavinia, 2018); whereas improved variety of this breed produces 140-160 liters. The protein content is between 5.70% and 5.83% (Table 3). The fat content of milk progressively increases as the lactation progresses. Similarly, the protein content also increases (Șonea, Maria, and Ionela, 2020), but has lower values.

Table 3: Monthly dynamics of the average protein content (n = sample size)

Year	*n*	*Average % of protein per lactation*	*Average percentage of protein per lactation per month*						
			Month 1	*Month 2*	*Month 3*	*Month 4*	*Month 5*	*Month 6*	*Month 7*
2015	45	5.83	5.69	5.86	5.10	5.86	6.13	6.38	-
2016	52	5.70	5.59	5.63	5.07	5.68	6.03	6.21	-
2017	50	5.77	5.62	5.73	5.11	5.79	5.98	6.42	-
2018	45	5.79	5.59	5.69	5.09	5.83	5.86	6.04	6.48
2019	25	5.86	5.68	5.72	5.13	5.69	6.11	6.19	6.56

In terms of fat content or protein content, the sheep reared at lower altitude are no significantly different from those raised in high-altitude (alpine) pastures. In both the cases, the protein content marked a slight decrease in the third month, which corresponds to the largest amount of milk (Lavinia, 2018). It shows that sheep raised in low altitude meadows are better than those raised in alpine pastures for the purpose of hay production (Lavinia, 2017). The use of low altitude meadows for hay production is more rational than their use as pasture.

5.2 Wool Production

The structure of the sheep hairs is important for wool production. The fibrillar composition and shape of the strands are determined by the characteristics of the follicular group. The hair follicles exist in two layers: one deeper layer correspond to the primary follicles, which generate long and thick fibers; and another superficial layer corresponds to the secondary follicles that generate short and thin fibers responsible for determining structurally the conical shape of the strand. In general, the wool produced from the hairs of Țurcană sheep is rough. When washed, it loses 30%-35% of weight (Figure 4). The washing efficiency varies between 65% and 70% in the sheep raised in mountainous conditions. The amount of wool varies depending on the feeding conditions and the growing area.

Wool production, calculated at STAS yield of 53% (Table 4), resulted on an average amount of wool per animal is given in table 4 having values of standard deviation and coefficient of variability.

Table 4: Data of wool production by Turcana breed

Year	Rams				Adult sheep			
	n	*x ± sx*	*s*	*cv*	*n*	*x ± sx*	*s*	*cv*
2015	17	3.87 ± 0.08	0.34	8.78	345	2.75 ± 0.75	0.75	27.24
2016	20	3.27 ± 0.08	0.39	11.91	395	2.33 ± 0.02	0.33	14.23
2017	23	3.18 ± 0.07	0.38	11.92	341	2.25 ± 0.01	0.28	12.47
2018	18	3.63 ± 0.11	0.46	12.66	348	2.43 ± 0.30	0.56	23.25
2019	21	3.88 ± 0.07	0.36	9.27	334	2.54 ± 0.01	0.31	12.20

n = sample size
x ± sx = average wool production per animal in kg
s = standard deviation
cv = coefficient of variability in %

Figure 4: Washed wool obtained from the Turcana breed

The wool washing efficiency (Figure 4) is influenced by hereditary characters and environmental factors. The percentage of impurities in the wool is closely related to the care and maintenance of sheep during herding, grazing and shelter care. The variation in the wool production (Table 4) is the outcome of some feeding errors. The most important physical and technological properties of wool include the length of the strands, the fineness of the fibers, their strength and extensibility. In general, the characteristics of wool differ from one ecotype of sheep breed to the another, and show a great variability in the coat, from individual to individual, both in terms of diameter and length (Figure 3). Such variation is also observed in the type of strand, pigmentation and degree of corrugation of the wool fibers. According to the absolute length of wool fibers, we have three types of fibers: long – over 16 cm; medium (9-15 cm) and short 8 cm. Short fibers have a weight of 30%, medium fibers 46.25%, and long fibers 23%. The absolute average length is determined on fiber sections and is illustrated in table 5.

Table 5: The relative and absolute length (cm) of the wool fibers

Relative length (cm)	*Absolute length (cm)*		
	n	*x ± sx*	*cv (%)*
24.0	195	12.32 ± 0.48	51.29
27.0	136	16.08 ± 0.34	43.32
20.0	149	11.73 ± 1.30	31.62
23.0	181	13.85 ± 0.31	29.38
17.0	124	9.07 ± 0.39	48.40
20.0	138	9.54 ± 0.51	59.64
18.0	117	9.52 ± 0.36	41.70
24.0	118	12.60 ± 0.56	48.80
16.0	120	9.95 ± 0.33	36.18
21.0	132	12.66 ± 0.45	39.09

n = sample size
x ± sx = average wool production per animal in kg
cv = coefficient of variability in %

The data in the table 6 summarizes that the average diameter the fibers in the middle section is 72.42 microns in the long ones, 41.22 microns in the medium sized and 37.13 microns in the short ones. The variability in the diameter of long fibers, which increases from base to tip, is explained by different feeding conditions during the year and the physiological condition of the sheep. The larger diameter is obtained in May-September period when the sheep are grazed and weaned feeding the lambs.

The average diameter is presented in the table 6. On an average, the diameter per 1500 fibres is 50.29 microns with a coefficient of variability of 30.2%. This data exhibit that the shape and structure of the strand and the degree of corrugation have correlation with the absolute average length, the average diameter, the types of fiber in the strand, and the level of wool production. The wool characteristics depend on different biotypes of the Ţurcană breed. It indicates that the future research must focus on selecting the most productive biotypes for increasing and improving the wool production. Absolute tear strength and extensibility are important properties of fiber, as they determine the strength and plasticity of wool fabrics. These properties are closely correlated with the fineness of the fiber, in the sense that the fine fibers have a lower strength and extensibility than the thick ones, thus having a correlation with the body region and environmental factors.

Table 6: The average diameter of the types of fibers in the strand of Ţurcană sheep

Specification	*Type of fiber*	*Fiber section location*	*Number of fibers*	*Diameter (in micron)*	
				x ± sx	*cv*
Sample of 10 sheep	Long	middle	500	72.42 ± 0.64	19.4
	Medium sized	middle	500	41.22 ± 0.58	31.3
	Short	middle	500	37.13 ± 0.49	29.3
Median	-	-	1500	50.26 ± 0.52	30.2

5.3. Meat Production

The research undertaken in recent years highlights that the Ţurcană and Ţisigai breeds are utilized for meat production of superior qualities. The rational use of improved adult sheep for meat production should be given due importance (Gavojdian *et al.*, 2012). 20-30% increase in meat quality was recorded if sheep was reconditioned, thus contributing to raising the economic efficiency of the meat production units based on large flocks of sheep (Figure 6).

In Romania, out of the 8 million sheep destined for meat production, annually 3 million heads represent the adult, reformed sheep, out of which over 1 million are of the Ţurcană breed. Therefore, the rational use of reformed adult sheep for meat production is an action that should be given due importance. Only by reconditioning the reformed sheep can increase the meat by 20-30% with improvement of its quality, thus contributing to raising the economic efficiency of the units with large flocks of sheep (Figure 7).

5.4 Production of Hides, Skins and Furs

The Ţurcană breed produces high-quality leathers. The skin from Ţurcană is more resistant because the collagen fibers are woven together in a denser structure. The skin is also more resistant to elongation and tearing. This resistance of the skin is the result of the lower number of hair follicles per unit area. The thickness of the skin is in two layers: the primary follicles are deeper, and the secondary follicles are closer to the surface of the skin (Figure 6). The quality of the skins is determined by the conditioning by a series of natural and genetic factors e.g., individuality, sex, health, skin size during pruning, physiological condition of the animal, slaughtering season, age, feeding conditions, care and shelter.

Ţurcană lambs are slaughtered for fur before the wool exceeds 3-5 cm length. Fur is produced under strict compliance of the sanitary-veterinary measures.

Calendar of sanitary-veterinary actions

Sheep utilization systems guide to take measures to prevent and combat different diseases.

In sheep, morbidity and losses are the consequence of diseases caused by non-sanitary conditions. Such diseases are chiefly parasitic diseases, especially those come from pasture (Figure 9). Therefore, to ensure better health of animals, strict supervision of sheep applying clinical observations, anatomical-pathological examinations, feed control, hygiene maintenance, etc. is necessary.

Figure 5: Sheep carcass

The sanitary-veterinary actions undertaken are grouped as follows:

Purpose: Detection / Prevention / Tackling
Specifics: Mandatory / Optional / Of necessity
Season: Stable / Pasture
Growth and exploitation: Extensive / Intensive

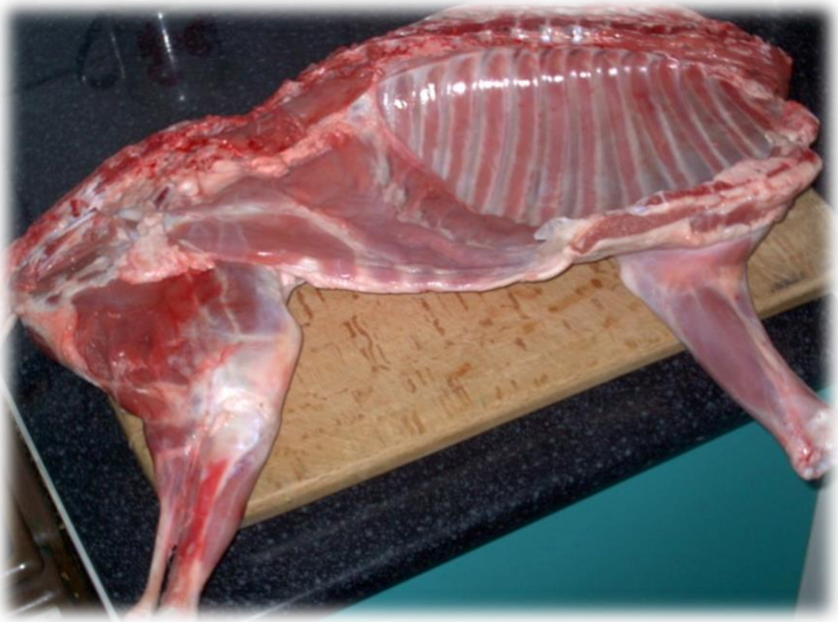

Figure 6: Sheep semi-casing Turcană

Figure 7: Sheep skin coat Figure 8: Prime wool, shearing sheep

Figure 9: Sheep fold

Figure 10: Traditional shelter for sheep

Regarding the sanitary-veterinary actions in the extensive exploitation system, they are grouped as follows:

a) In the winter season, under stable conditions, the following is performed:

1. general and permanent control of feeding in order to prevent abortions, infections such as hysteresis, hypogalaxy and lung diseases in lambs;
2. immuno-prophylactic actions, which consist of the serological examination for the detection of epididymitis and tuberculosis separately; vaccinations against anaerobiosis, salmonellar abortion and agalaxia;
3. antiparasitic actions, which consist of the detection of scabies, the isolation and treatment of animals with local lesions, and treatment against fasciolosis, estrosis.

b) In the spring season, once the grazing is done, the following is performed:

1. vaccination against anthrax and enterotoxemia in lambs;
2. organization of prophylactic grazing;
3. antiparasitic actions, such as pasture control and ameliorating and chemical interventions on them.

Regarding the sanitary-veterinary actions in the intensive fattening system, they are grouped as follows:

A) For young:

1. Organization of the in-patient and the sanitary-veterinary provider (Figure10);
2. Loss according to possible clinical signs, especially hypotrepsic ones; prophylactic treatments against pulmonary diseases and against pulmonary and gastric strongylatoses;
3. Surveillance of feed to avoid indigestion, biochemical indigestion, uro-lithiasis, listeriosis;
4. Treatments against scabies, monilioze, dictiocaulosis;
5. Vaccinations.

B) For adult sheep:

1. Treatment against scabies, fasciolosis and dictyocaulosis, pododermatitis;
2. Vaccinations against anaerobes, foot-and-mouth disease and anthrax.

The lambs are vaccinated with Evomec and the yolk treatment. The bathing is also done with Lindaved once a year in spring. Pruning is done twice a year in spring and autumn.

6. Conclusion

Sheep breeding is a traditional activity. The diversity of the products they produce, the low energy and fodder consumption make the breeding and utilization of sheep a sustainable and profitable activity. Raising traditional sheep breeds (e.g., Tisigai and Turcana) in the mountain areas has sustained for centuries. The local people consider Tisigai and Turcana sheep breeds perfectly adapting to geo-climatic and transhumance conditions, providing them with daily necessities, and producing the products for market. There are areas in Romania having preserved valuable specimens of sheep, the traditions and customs related to the breeding and harnessing these sheep. These specimens, which represent the genetic stock of the traditional breeds, can be used in the larger breeding program of sheep in the mountainous areas of Romania.

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8. References

Alexandru, T.B., Dorina, B., Ioan, G., Marcel, P., George, T., Sorin, C., Diaconescu, L.D., Amalia, G.S., Ioan., S. and Marcel. T. (2009). More Animal Production in Agrifood Green Power Development, a New Paradigm of Concepts Regarding Sustainable Rural Bioeconomics and Eco-Economics. *Bulletin of the University of Agricultural Sciences & Veterinary Medicine Cluj-Napoca: Veterinary Medicine,* 66(1): 416-423. Available online at: http://journals.usamvcluj.ro/index.php/veterinary/article/view/4031/3693 [Accessed on 11 September 2021]

Alexandru, T.B., Vioara, M., Alexandru, M., Sorin, C., Viorica, B., Ioan, S, Radu, B., Diaconescu, D. and Amalia, S. (2010). Prospects of Agrifood Green Power in 2050 and Forecasting for 2100 with Sustainable Solutions Based on Ecobioeconomics New Paradigm. *Bulletin UASVM Animal Science and Biotechnologies*, 67(1-2): 1-18.

Amalia, G.S. and Simona, S. (2018). Eco-Efficiency and Vulnerability of Agro-Ecosystems to Environmental Threats. *Annals of Valahia University of Targoviste - Agriculture*, 12(2): 25-32. Available online at: https://www.researchgate.net/publication/328866718_Eco-Efficiency_and_Vulnerability_of_Agro-Ecosystems_to_Environmental_Threats [Accessed on 12 September 2021]

Amalia, G.S. and Simona, S. (2019). Impact of the Agroforestry Biodiversity and Social Management on Food Bioresources. *Annals of Valahia University of Targoviste - Agriculture,* 13(1): 34-38. Available online at: https://www.sciencegate.app/app/document/download/10.2478/agr-2019-0008 [Accessed on 13 October 2021]

Gavojdian, D., Sauer, M., Pacala, N., Padeanu, I. and Voia, S. (2012). Improving Growth Rates in Turcana Indigenous Sheep Breed Using German Blackheaded Mutton Rams. *Scientific Papers: Animal Science and Biotechnologies,* 2011(44): 379-382.

Ilisiu, E., Drăgan, S., Raducu, R., Pădeanu, I., Călin, V., Pascal, Ilisiu, C. and Rahmann, G. (2013). The Romanian Tsigăi sheep breed, their potential and the challenges for research. *Landbauforsch – Appl. Agic. Forestry Res.,* 2(63): 161-170. DOI: https://doi.org/1032220/LBF_2013_161-170.

Lavinia, M. (2018). Obervations Regarding the Growth and Exploitation of Turcana Breed Sheep on Small and Medium Farm. *Annals of Valahia University of Targoviste - Agriculture*, 11(1): 34-40. DOI: https://doi.org/10.1515/agr-2017-0007

Lavinia, U. (2017). Directions of Growth, Improvement and Prospects for Efficiency of the Productivity of Sheep Breeds Tigaie in the Context of Zootechnical Bioeconomy.

Annals of Valahia University of Targoviste - Agriculture, 18: 29-35. DOI: https://doi.org/10.1515/agr-2017-0019

Lavinia, U. (2018). New Approach for Bio-Economic Integrated Management in Sheep Growth. *Annals of Valahia University of Targoviste - Agriculture*, 12: 1-6. DOI: https://doi.org/10.2478/agr-2018-0001.

Sonea, C., Maria, T. and Ionela, N. (2020). The quality of maize grains in organic farming System. *University of Bucharest Rom. Biotechnol. Lett.*, 25(4): 1781-1789. DOI: https://doi.org/10.25083/rbl/25.4/1781.1789.

Toader, M., Alina, M., Ionescu, C., Șonea, C. and Georgescu, E. (2020). Research on the morphology, biology, productivity and yields quality of the *Amaranthus cruentus* L. in the southern part of Romania. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca,* 48(3): 1413-1425. DOI: https://doi.org/10.15835/nbha48311973.

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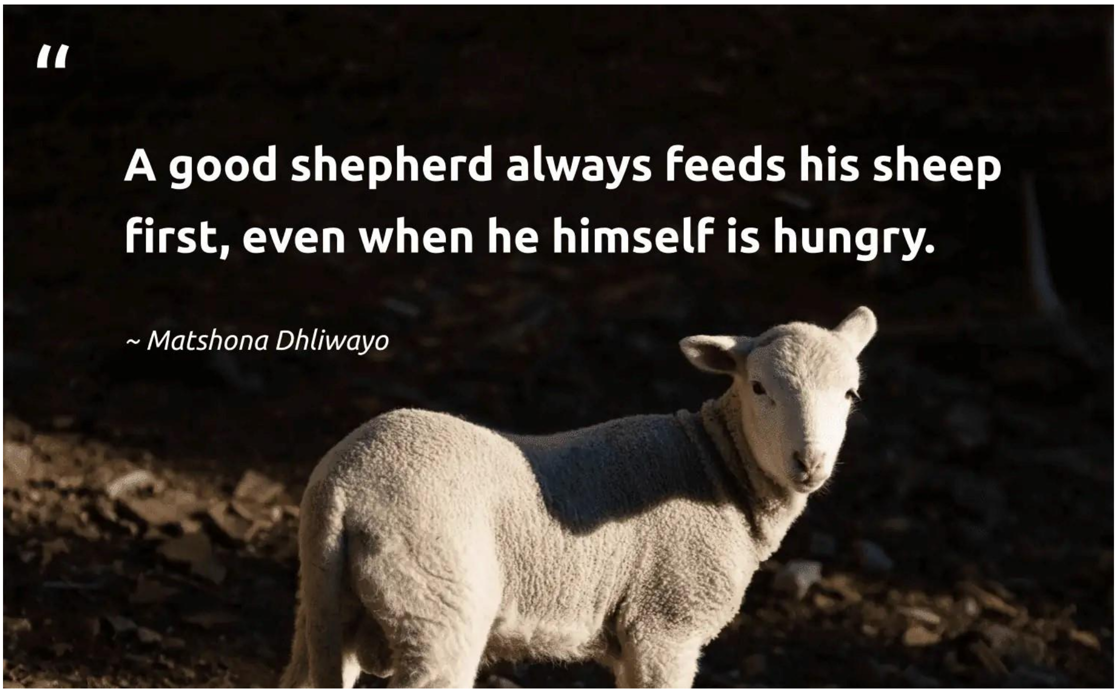
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A good shepherd always feeds his sheep first, even when he himself is hungry.
~ Matshona Dhliwayo

Chapter 17

Camel Systems and Pastoralists' Lifestyle in Semi-Deserts and Mountains: Constraints and Challenges

By Ayman Balla Mustafa and Asim Faraz

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Camel Systems and Pastoralists' Lifestyle in Semi-Deserts and Mountains: Constraints and Challenges

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Abstract
Camels are vital to the daily life of all desert dwellers, especially Bedouins, for whom they form a source of food, a means of transportation and recreation. To appreciate the unique contribution that Arabian camels make towards the community life and the history of the desert lands, in this paper, the pastoral production systems observed across three major regions - Butana, Kordofan and Darfur - are discussed. The field survey based study was conducted from August 2011 to May 2014 using structured interview method to determine the limitations and challenges faced by camel pastoral community in main camel production regions of Sudan. The results revealed that the average of calving interval was 30 months; male camel is rutting for 3 months during rainy season. She-camel gives birth to 6-8 calves throughout the life. The average milk yield was 3 liters per day with the lactation period extended to more than 10 months. The calf is weaned for 10 months or more. Social prestige and continuity of traditional heritage are the major reasons for keeping animals rather than economic revenue. However, it was found that the security issues are limiting camel breeding practices and pastoralists' movement in the semi-desert and mountain regions. Internal conflicts between farmers and pastoralists that often develop into tribal wars also affected pastoral production systems. Such constraints in addition to the lack of government support and favorable policies present major challenges to camel pastoral system in the region.

Keywords
Challenges; Camel; Mountain; Pastoralist; Pastoralism; Sudan

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1. Introduction

The camel is an important species uniquely adapted to hot and arid environments (Schwartz, 1992) and contributes significantly to the food security of nomadic pastoral households. This unique adaptability makes this species ideal for human use in the arid and semi-arid land conditions. The contributions of camels to the human welfare in the developing countries are generally obscured by several factors, which tend to underestimate their true value. Firstly, the estimates of camel populations are usually inaccurate due to the lack of a periodical census. Secondly, their products seldom enter a formal marketing system; thus, their contribution to subsistence and the national economy is rarely realized (Njiru, 1993).

Ahmed and Iqbal (2012) stated that the productivity of the animal depends on genetics, health status, and management. Proper management and health practices ultimately lead to improved production and reproduction. The existing traditional management practices of camel production require interventions for the improvement of camel productivity. Increasing human population pressure and declining per capita production of food in Africa precipitated an urgent need to develop previously marginal resources, such as the semi-arid and arid rangelands, and to optimize their utilization through appropriate livestock production systems among which camel production is certainly the most suitable (Schwartz, 1992). Despite the camel's considerable contribution to food security in semi-dry and dry zones, and existence as a major component of the agro-pastoral systems in vast pastoral areas in Africa and Asia, little is known about its production potential and production systems compared to other domestic animals. Most of the previous research conducted on camels stresses on diseases, reproductive physiology, and characterization (Mohammed, 2000). The available information on camel production potential and production systems, especially in Sudan, remains inadequate. Pastoral camel production is under pressure because of multiple changes in the production environment. Increasing human population pressure on pastoral grazing areas and the economic implications resulting from diseases and lack of veterinary services are some of the factors that adversely affect traditional camel production. Additionally, reproductive performance is low in camels due to late first parturition, long parturition intervals, and high calf mortality. Improvement in reproductive performance and reduction of animal losses by management measures that apply to a mobile system, appear to offer possibilities of increasing camel productivity and capacity to support the increasing human population. An adequate understanding of traditional camel production practices forms the foundation on which improvements and innovations could be based (Farah *et al.*, 2004). In line with this objective, current study was carried out in three main regions of camel production in Sudan. The main aim is to clarify the camel management systems, husbandry practices, and cameleer's constraints and challenges. Additionally, we also identify the socio-economic values of camel, and contribution of camel products to the improvement of overall household incomes.

2. Methodology

2.1 Study Areas

The study was conducted in major camel production regions of Sudan, which comprise Butana, Kordofan, and Darfur.Description of the regions is as follows.

2.1.1 The Butana region

Butana lies in the Sahel zone of Sudan, surrounded with mountains in the east, center, and south. It is bounded by the river Nile and Blue Nile from the west, River Atbara from north and Geddarif railways on the eastern and southern boundaries (Map 1). It covers an area of approximately 12,000 square kilometers (Abusin, 1990). The Butana is located at the cusp of climatic and ecological transition zone that has Savannah in the south and Sahara in the north. Based on the long-term average precipitation, Sahel is marked by annual precipitation of up to 100 mm in the North and 600 in the South. Duration of the rain varies from 2 to 5 months (June to September/October). The extreme spatial and temporal variability of rainfall resulting from the inter-annual fluctuations in the north-ward drift of the Inter-Tropical Convergence Zone (ITCZ) leads to unpredictability in the rainy season, and thus, to the recurring drought events at an irregular interval.

According to Al-Khouri and Majid (2000), inter-annual variability of the rainfall with the severe drought events leads to a natural shift in the vegetation pattern across several hundred kilometers. The temperature in the Butana is generally considered high all-round the year, with a drop in July and August as a result of moisture and cloudiness. It rises again by September, and then drops to a minimum with the advance of cool Northern winds during November. Highest temperature is recorded in April, while January remains the coldest month (Abusin, 1990).

There are three main types of natural vegetation found across Butana. *Acacia* trees form the major perennial vegetation, including *Acacia terlilus*, *Acacia seyal*, and *Acacia mellifera*. The shrubs are the second perennial vegetation found in Butana and it includes bushy grasses scattered all over the region. The third type includes the annual grasses and herbs. These herbaceous plants are dominant during the wet season and only a few species sustain during the dry season. During the rainy season, the low areas that remain covered in water for a long time become less vegetated due to the spoilage of seeds. The variation in the rainfall in addition to the variations in relief, drainage, and parent material produce a clear local difference in the Butana soil.

2.1.2 The Kordofan region

Kordofan region is located in an arid and semi-desert ecological zone that is surrounded by the mountains both in the north and south. It is located between 12°: 25`- 13°: 45`N and longitudes 24°:45`- 30°:30` E. The rainy season in this zone is shorter and only extends from July to October with August being the wettest month. The average annual rainfall estimated in this region was 298 mm with uniform relative humidity ranging between 22-25% in the dry season and 75% during the rainy season. Wind velocity is usually less than 8 km/hour. The vegetation cover which is a reflection of that climatic zone and soil type range from a sparse growth of drought-resistant grasses and dwarf scrub in the north through a belt of open wood and grass in semi–arid central region to open forest in the well-watered south. The common trees belong to the species of genus *Acacia*. Whereas, the vegetation covers includes grasses, herbs, shrubs, and small trees. Livestock and its product form the primary source of income for over 60% of the population in this region. A traditional system of cropping in combination with animal husbandry predominates the state (MARF, 2007). Total animal units in the state are estimated at 6 million. The animals raised mainly include sheep, goats, cattle and camel. In the northern part of the state, land use is characterized by a mobile pastoral system practiced by different nomadic tribes where each tribe has its predefined territory. In the southern part of the state, land use is characterized by a sedentary agro-pastoralist system. There are three main types of soil are widely distributed in Kordofan state: sandy soil in the northern, clay soil in the southern part, and Guarded soil distributed all over the state as stated by MOARF (2004).

2.1.3 Darfur region

Darfur is a hilly area that has rich natural resource base with fertile land suitable for grazing pasture, forest, and water sources. Relatively better rainfall and existing seasonal rivers make the region fertile and less prone to droughts (Abusin, 1990). The samples were collected from the area in the Darfur region, which lies between latitude 14.45° – 11° N and longitude 22° - 24° E. Topographically, Darfur has basement rocks and is covered with a thin layer of sandy soil. Basement rock is too infertile to be farmed but provides sporadic forest cover that can be grazed by animals. Another feature of Darfur is the Marrah Mountains i.e. the volcanic plugs created by a massif that rise up to a peak at Deriba crater where there is a small area observing temperate climate, high rainfall, and permanent springs of water (MOARF, 2004). The vegetation covering the rangeland includes grasses, shrubs, and trees (Map 2).

2.2 Survey Protocol

Data was collected through a survey that helped in identifying camel pastoralists and their views regarding the aspects including herd composition, milk production, calving management, restriction methods of calving suckling, milking times and methods, socio-economic value of camel, production and reproduction limitations, breed ecotypes, and breeding in dromedary camels under traditional management systems and nutritional evaluation of natural pasture across all the study sites. The survey was carried out using different methods as described below.

2.2.1 Questionnaire and data collection

Data was collected from 170 camel pastoralists[1], camel herders[2], and camel owners[3] in the Butana, Kordofan, and Darfur regions using structured questionnaire. The questionnaire was prepared to inquire about various aspects of camel management systems, and related constraints faced by the pastoralists. A detailed structured questionnaire was used to collect information from camel herders and owners in different regions. Simultaneously, interviews were also conducted during the field visits (Table 1). The questionnaire was pre-tested to check the clarity and appropriateness of the questions.

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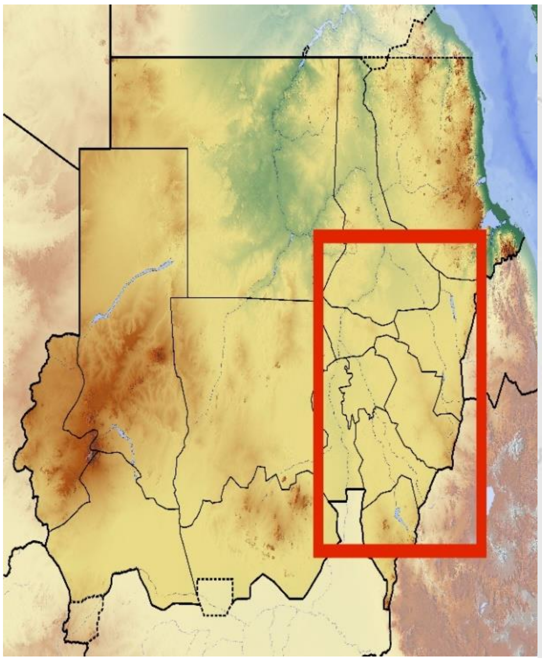
[1] Camel pastoralist: The pastoralist is the person who rear camel herd against monthly wage from owner of the herd.
[2] Camel herder: The herder is the person who owns a herd of camels and rearing of them himself.
[3] Camel owner: The owner is the person who owns a herd of camels and does not rear himself, but hires someone to rearing it.

2.2.2 Direct communication and field visits

Some of the information collected during interviews was supported by field visits and meeting with chairmen of pastoralists unions in study areas. All visits and communications were carried out during the wet and dry seasons from August 2011 to May 2014.



Map 1: Butana region

Map 2: Darfur and Kordofan regions

Table 1: The regions selected for the survey of the camel management system

Region	*Number of Interviewees*
Butana	50
Kordofan	60
Darfur	60
Total	170

In addition, the samples of straws and stoves from residues of agricultural rain-fed production crops were also collected to identify their applicability in satisfying the nutritional requirements of camels and their feasibility in formulating desirable feed concentrates.

2.2.3 Data analysis

The professional version of Statistics 10 analytical software was used to develop comparison between the three study areas. Results are represented mainly in the form of descriptive statistical summaries.

3. Results

3.1 General Information

All the pastoralists interviewed were males. The majority of respondents (76%) were illiterate followed by those who completed primary school (21%), followed by those who completed secondary school (2.5%). There were fewer university graduates (0.5%) (Table 2).

Table 2: General information about interviewers

Regions	*N*	*Level of Education (%)*				*Interviewees (%)*		
		Illiterate	*Primary*	*Secondary*	*Graduates*	*Owner*	*herder*	*Owner herder*
Butana	50	68	22	8	2	26	40	34
Kordofan	60	78	22	0	0	1	23	76
Darfur	60	80	20	0	0	28	27	45
Total	170	76	21	2.5	0.5	21	29	50

The majority of respondents were both owner and herders of the camels, followed by those who only owned a camel and then who is working as a herder of camel (Table 2). Most of the camel herders and owners (56%) were of young age ranging between 25 and 45 years, followed by below 25 years old (22%) and above 45 years old (22%). Whereas, the majority of camel herders and owners were 83% married, but fewer (14%) were single and divorced (3%) (Table 3).

Table 3: Age and marital status of interviewers

Regions	*N*	*Age (%)*			*Martial status of interviewees (%)*		
		< 25 years	*25-45 years*	*> 45 years*	*Single*	*married*	*divorced*
Butana	50	18	66	16	12	88	0
Kordofan	60	32	47	21	8	87	5
Darfur	60	16	57	27	23	73	4
Overall	170	22	56	22	14	83	3

3.2 Herd Composition and Structure

The result revealed that the size of the camel herd varies from region to region. The wide proportion of participants in Butana (60%) and Darfur (47%) held bigger herd size (more than 50 heads) compared to Kordofan region, while majority of participants in Kordofan had middle herd size (20-50 heads) compared to other regions. Generally, majority of participants (49%) had biggest herd size exceeding 50 heads of camel. Whereas, Arabi camel breed are most dominant camel herds (66%) in Sudan followed by Anafi and Bushari breed. The result of the survey (Table 4) reflects that Arabi camel breed is highly preferable breed in main camel production regions of Sudan.

Table 4: The herd size

Regions	*N*	*Herd size (%)*			*Camel breeds (%)*			
		< 20 heads	*20-50 heads*	*>50 heads*	*Anafi*	*Bishri*	*Arabi*	*others*
Butana	50	0	40	60	12	12	76	0
Kordofan	60	13	47	40	8	17	75	0
Darfur	60	18	35	47	35	15	47	3
Total	170	10	41	49	18	15	66	1

In this survey, it was recorded that female camel formed a higher percentage (46%) in the herd. Clearly, the female camel acquired highest proportion (58%) of the herd in the Butana region compared to Kordofan and Darfur. Whereas the number of male camels recorded the highest percentage (55%) of the herd in Kordofan region followed by Darfur region (45%), and very few males camels were present in the herds of Butana region. It was only one male camel in the herd as shown in table 5.

Table 5: The percentage of matured male and she-camel in the herd

Regions	*N*	*No. of females (%)*			*No. of males (%)*		
		< 15 heads	*15-40 heads*	*> 40 heads*	*1*	*2-3*	*>3*
Butana	50	0	42	58	54	40	6
Kordofan	60	20	40	40	15	30	55
Darfur	60	23	37	40	18	37	45
Total	170	14	40	46	28	35	37

The majority of respondents (70%) from Darfur region have seen an increase in the camel population. In contrast, the highest percentage of respondents (52%) from the Butana region said that camel population has decreased. Generally, the results of this study reveal the increasing trend in camel population (Table 6). The preferable color of camel was asked; and respondents indicated that red camel is the most preferable among majority (50%) of respondents in the three regions followed by dark brown camel (18%), yellow camel (17%) and white camel (12%), which is least preferred by the herders in three regions. The yellow camel is also rarely preferred in the Butana region.

Table 6: The status of the camel population and preferred color

Regions	*N*	*Status of camel population (%)*			*Preferred color (%)*				
		Increasing	*Decreasing*	*Fixed*	*Black*	*Dark brown*	*Yellow*	*Red*	*White*
Butana	50	20	52	28	8	10	0	64	18
Kordofan	60	55	28	17	0	8	28	47	17
Darfur	60	70	17	13	0	35	18	44	3
Total	170	50	31	19	3	18	17	50	12

3.3 Camel Husbandry Practices

The findings of the study revealed that (80%) of the camel herders prefer grazing in natural pastures (Table 7). The majority of the pastoralists (56%) provide camels with fodder from crop residues in specially rainfed agricultural areas of Butana region. Generally, the result revealed that the majority of participants (58%) depend on water sources from the annual river in rainy season. Majority of the herders (42%) in Butana depend on the river water and there is no irrigation canal available in Kordofan and Darfur region.

Table 7: Feeding and watering system of camel

Regions	*N*	*Feeding of camel (%)*			*Watering of camel (%)*				
		Pasture	*fodder*	*Pasture &*	*River*	*Annua*	*Half year*	*Irrigation*	*Ground*

				fodder		*l river*	*river*	*canal*	*water*
Butana	50	36	8	56	42	4	16	32	4
Kordofan	60	26	18	33	18	20	12	0	2
Darfur	60	46	18	3	0	36	23	0	1
Total	170	80	26	64	40	58	43	16	5

The majority of camel herders and owners (45%) were found to be adapted to the semi-nomadic management system in all regions (Table 8). 70% of the respondents were engaged in nomadic camel rearing system in Darfur followed by Kordofan and the low percentages (14%) were observed in Butana. Additionally, data also suggest that the majority of camel owners and herders (91%) do not prefer crossbreeding within their herd (Table 8).

Table 8: The camel breeding systems

Region	*N*	*Management system (%)*				*NBH cross-breeding (%)*	
		Transhumant	*Nomadic*	*Semi-nomadic*	*Sedentary*	*yes*	*No.*
Butana	50	0	14	66	20	18	82
Kordofan	60	0	42	48	10	7	93
Darfur	60	0	70	23	7	5	95
Total	170	0	43	45	12	9	91

This survey indicates that 55% of the camel owners do not have a clear purpose for rearing camels. It is only because they have inherited the herd from their parents they continue their traditional occupation (Table 9). However, for 33% of the respondents, camel rearing was economically profitable from trade point of view. For only 8% of them, camels were integral part of household food security and livelihood.

Table 9: The purposes of camel breeding in the traditional system (%)

Regions	*N*	*Inherited*	*Livelihood*	*Profit and export*	*Social*
Butana	50	60	8	28	4
Kordofan	60	58	5	35	2
Darfur	60	48	12	33	7
Total	170	55	8	32	5

3.4 Camel Production and Reproduction Traits

The results of the current study revealed that the majority (75%) of the female camels attain puberty at the age of 4-5 years (Table 10). The data revealed that majority of participants (60%) confirmed that a high sexual ability of Sudanese male camels; the male camel can mate more than 8 females during rutting season. Highest percentage (65%) of male camel sexual ability was recorded in Darfur region followed Butana region.

Evidently, majority of the participants (80%) confirmed 1-5% of abortions happening among their camels in base year in the Butana region. In general, wide proportion of participants (62%) had stated that 1-5% of abortions occurr annually in all regions (Table 11).

Table 10: The puberty age of female camel and the ability of male

Region	*N*	*Puberty age (%)*			*No. of female camel mated by male camel (%) in a rutting season*		
		<4 yrs	*4-5 yrs*	*>5 yrs*	*3-5*	*6-8*	*>8*
Butana	50	8	86	6	16	26	58
Kordofan	60	28	62	10	0	25	35
Darfur	60	13	80	7	17	18	65
Total	170	17	75	8	11	29	60

Table 11: The percentage of abortion among camel herds per year

Regions	*N*	*0 %*	*1 – 5%*	*> 5%*
Butana	50	4	80	16
Kordofan	60	30	53	17
Darfur	60	33	55	12
Total	170	23	62	15

During the period of this study, the majority of camel herders (57%) began milking the female camels on the third day of calving, especially in Kordofan (77%). 40% herders started milking on the first day immediately (Table 12). The result of the survey indicates that a high percentage of camel (89%) lactate for more than 9 months in all the study regions.

Table 12: The start of milking and the length of the lactation period

Regions	*N*	*Start of milking after calving (%)*			*Long lactation period (%)*	
		1st day	*2nd day*	*3rd day*	*6-9 month*	*>9 month*
Butana	50	40	36	24	14	86
Kordofan	60	11	12	77	5	95
Darfur	60	22	17	61	15	85
Total	170	23	20	57	11	89

The data shown in table 13 reflects that the majority of female camels (53%) produced 8-10 calves during the productive life in the pastoral system prevalent in all regions.

Table 13: The number of calving during the reproductive age of she-camel (%)

Regions	*N*	*5-7 calves*	*8 – 10 calves*	*>10 calves*
Butana	50	36	40	24
Kordofan	60	25	58	17
Darfur	60	13	60	27
Total	170	24	53	23

The results show a high percentage (46%) of camels produce a milk yield of less than 3 liters per day in all regions. In the Kordofan region, it was recorded that around 57% camels produced milk of 3-6 liters/day/head (Table 14). Many factors including type of breed, season, availability of feeds, and water sources were found to be affecting the milk yields. Table (15) shows the majority of calves (84%) were weaned off within 10 months postpartum in all regions. However, calves in the pastoral system were allowed a direct contact during the daylight with the dam even up to 2 years.

Table 14: The camel milk yield in free range (%)

Region	*N*	*<3 litres*	*3 - 6 litres*	*> 6 litres*
Butana	50	60	28	12
Kordofan	60	36	57	7
Darfur	60	45	38	17
Total	170	46	42	12

Table 15: The percentage of calf age at weaning

Regions	*N*	*6-7 months*	*8 – 10 months*	*>10 months*
Butana	50	0	16	84
Kordofan	60	0	9	91
Darfur	60	11	12	77
Total	170	4	12	84

The camel herders practiced traditional methods for calve weaning and restricted suckling throughout the day such as *Sawrar, Shomal, Hasaka*, as shown in table 16. The majority (50%) of camel herders practiced *Sawrar* method, followed by *Shomal* method, and little number of herders used *Hasaka* method. Very few herders just used pen to restrict calves from suckling. The *Sawrar* method is considered the main method for calve weaning in Kordofan region.

Table 16: The traditional methods of calf weaning and restricted suckling (%)

Regions	*N*	*Sawrar*[4]	*Shomal*[5]	*Hasaka*[6]	*Restricted to pens*
Butana	50	46	48	2	4
Kordofan	60	73	5	21	1
Darfur	60	30	23	5	42
Total	170	50	23	10	17

In the table 17, the results revealed that the majority (81%) of camel herders are allowing calf to suckling their dam before the beginning of the milking procedure. This method is traditional adopted in all camel regions. On the other hand, the highest percentage of participants (68%) said that lactating she-camel can be milked twice a day. This method is practiced more in Kordofan than in Darfur. Whereas camel herders in Butana milk a she-camel three times a day.

The highest percentage (58%) of respondents confirmed that the rutting season of a male camel is about 2-3 months in Kordofan (Table 18). While, almost 56% of camel herders in Butana, believed that the length of the rutting season of a male camel is more

[4] *Sawrar*: Traditional method use to cover udder teats by camel feces to restrict suckling by calve.
[5] *Shomal*: Traditional method where udder teats are covered by a piece of cloth or plastic bag to prevent calve suckling.
[6] *Hasaka*: Traditional method where a chunk ofwood is put in the calve's mouth to restrict it from suckling the dam.

than 3 months. It was found that the majority of male camels were rutting in the rainy season rather than the winter across all the study regions.

Table 17: The methods of milk letdown and milking times (%)

Regions	*N*	*Suckling of calf*	*Without calf*	*Both methods*	*1 time*	*Twice*	*3 times*
Butana	50	80	12	8	0	56	44
Kordofan	60	93	6	1	0	68	32
Darfur	60	71	20	9	28	58	16
Total	170	81	13	6	10	61	29

Table 18: The percentage of rutting season length and season of rutting

Regions	*N*	*Long of rutting season*			*The main season of rutting*	
		<2 months	*2-3 months*	*> 3 months*	*Rainy*	*Winter*
Butana	50	4	40	56	68	32
Kordofan	60	16	58	26	88	12
Darfur	60	36	33	30	71	28
Total	170	20	44	36	76	24

Generally, majority of the respondents (55%) confirmed that the calving interval of she-camels ranged from 20-30 months postpartum (Table 19). On the other hand, majority of Darfur camel herders confirmed that the period between calving ranged from 15 to 20 months.

Table 19: The percentages of calving interval in the pastoral system

Regions	*N*	*<15 months*	*15-20 months*	*20-30 months*	*>30 months*
Butana	50	0	14	64	22
Kordofan	60	0	30	62	8
Darfur	60	0	46	42	12
Total	170	0	31	55	14

The majority of the respondents from Butana (74%) and Kordofan (41%) said that the main sign of the estrus cycle is the swelling of the vulva (Table 20). In contrast, the highest percentage of camel herders confirmed that the main sign of estrus cycle is seeking male in Darfur. On the other hand, the highest percentage of herders (93%) believed that the raising of tails is the main sign of pregnancy among the camels in Kordofan, followed by Butana and Darfur region. Moreover, the highest percentage (53%) of camel pastoralists have seen a swelling of the udder is the main sign of parturition in Kordofan followed Butana region.

In the table 21, the result of the survey revealed that the highest percentage of herders (44%) in Butana mentioned more than 5% of the calving mortality ratio in their herds. The highest percentage of herders (73%) reported the ratio of mortality ranged from 1 to 5% in the herd in Kordofan.

Table 20: The reproduction signs among the camels identifiedby the herders (%)

Reproduction signs	*Butana*	*Kordofan*	*Darfur*	*Total*
Sign of estrus cycle:				
Frequent urination	12	6	20	13
Swelling of vulva	74	41	13	45
Seeking male	14	53	67	42
Sign of parturition:				
Isolation	6	33	22	20
Swelling of udder	44	53	7	35
Restlessness	36	9	53	33
Swelling of vulva	14	5	18	12
Detection of pregnancy				
Raise-up tail and coil	90	93	90	91
Refuse male	10	7	10	9

The majority of camel herders mentioned the main constraints of camel production as shown in table 22. The highest percentage of herders (78%) reported the shortage of pasture and feeding as the main problem in Butana followed by Kordofan. Similarly, the highest percentage of camel herders (50%) mentioned lack of security as the most pressing challenge for camel production in Kordofan than in Darfur.

Table 21: The percentage of calve mortality per year

Regions	*N*	*Zero*	*1-5%*	*>5%*
Butana	50	0	56	44
Kordofan	60	18	73	9
Darfur	60	52	36	12
Total	170	24	55	21

Table 22: The problems facing the rearing of camels in the pastoral system

Problems	*Butana (%)*	*Kordofan (%)*	*Darfur (%)*	*Total (%)*
Lack of veterinary services	12	5	36	18
Shortage of pasture and feeding	78	23	12	35
Shortage of water	4	18	4	9
Lack of security	0	50	43	33
Taxes	6	4	5	5

4. Discussion

4.1 Herd composition and structure

Camels play an important role in the local economy of the pastoral community and are central to the survival of pastoralists in the desert, and semi-desert regions in Sudan. The current survey emphasizes on the camel rearing practices in three main regions of Sudan. It was found that the average herd size in the region is around 50 heads. This finding is in tune with Bakhiet's (2008) findings, who reported that the average camel herd size in Sudan is 75.3 heads. Also, it was mentioned that female camels constitute around 74% of the total herd size. The insights gathered from the camel herders explain that the size of camel herds largely depend on the availability of water and food and high veterinary care rather than the changing lifestyle of pastoralists. The majority of camels in Sudan belong to the pack type (Arabi and Rashaidi camels); the Arabi camel has a wide geographic distribution in Sudan because it produces high quality meat and milk. Finding of the present study agrees with a study stating that the camel breeds in Sudan, which produced high quality of meat, are highly integrated into the regional market (Al-Khouri and Majid, 2000).

The result of the current survey highlights a decline in the camel population. This finding contradicts the finding of Faye *et al.* (2011), who stated that the camel population growth in Sudan is higher than the world growth i.e., 2% per year on an average. However, this growth is not regular. Observations from three time periods substantiate this claim. It was observed that from 1961 to 1978, a medium growth (1.3%) was recorded, from 1979 to 2000 a low growth (0.95) was recorded, and from 2001 onwards a rapid growth of 5.14% per year was recorded. These differences could be attributed to the impact of drought and flaws in the livestock census data. Additionally, the factors like lack of security, prevalence of diseases, shortage of pasture, and illegal export of female camel also impact the camel population and its growth in Sudan.

In Nigeria, the majority of the camel pastoralists prefer camel of dark brown phenotype breed (Abdelrahman *et al.*, 2011). The result of the current study coincides with the finding of Abdelrahman *et al.* (2011). The preference of camel differs according to the difference of participants' visions. They believed that good camel traits are the productivity of milk and meat. Other traits were considered insignificant. Generally, the dark brown camel is preferred by some herders, while red camel is preferable by almost all herders in camel production regions of Sudan.

4.2 Management and husbandry practices

In the current study, most of the camel herders were depended on natural rangelands for grazing their herds. The findings of current study are similar to those reported by Idriss (2003). Bakheit *et al.* (2008) mentioned that the decrease in available range land and pastures is a result of agricultural activities on natural pasture. As a result, most of the income of camel owners goes in purchasing crop residues in the Butana region. Whereas the camel owners in Kordofan solve the shortage of feed and water supply by adopting long migration routes towards the south.

The nomadic and semi-nomadic systems are well adopted systems for camel production in Sudan. The finding of current study agrees with Al-Khouri and Majid (2000) study. They reported that three camel production systems were mainly found in Sudan: Nomadic, transhumant, and sedentary system. No description for the transhumant system was mentioned in the current study as the transhumant camel herders remained unapproachable because of their long-term migrations. It was also found that crossbreeding of camels is not appreciated among all herders in the study regions as it helps them to maintain their camel traits and avoid undesirable traits. In the long run such management style can lead to a decline in positive production traits among the camels unless awareness about the benefits of crossbreeding are introduced.

The majority of participants had inherited their camel population from their parents and they were not looking forward to develop their system to be more profitable and economically dependable. The findings of this study agree with Bakheit *et al.* (2008) who mentioned about the low cost of keeping a camel. As camels are drought-tolerant animals, they are able to survive in adverse conditions compared to other livestock. This also remains one of the primary reasons for the people to rear camels.

4.3 Camel production and reproduction traits

Almost the age of female camels at first gestation ranges 4 to 5 years. This is similar to the finding of Abdelrahman *et al.* (2011), who stated that camel bull and heifer mean ages at first mating were 5.63 and 3.85 years, respectively. The maturity age of a female camel may depend upon many factors such as nutrition status, breed, ecotype, health condition, and husbandry practices. According to Wilson (1989), sexual maturity in camels may be correlated not only with absolute age and condition but also with other factors affecting the onset of the breeding season such as nutrition and climate. In addition, he reported that the mean ratio of camel cows to a camel bulls during the mating season was 47.8 cows per bull. A high percentage of the female camel mating in the rutting season of the male camel is within the range as mentioned by the author.

The percentage of abortion was high in the pastoral traditional system, especially in the Butana region, which may be attributed to lack of veterinary care, more stress among the camels that move long distances to cover nutrition requirements by grazing and browsing mostly on acacia species or grazing on unidentified poisoning plants. The findings of the present study agree with the finding of Farah *et al.* (2004) who reported that the pastoral camel production is under pressure because of multiple changes in the pastoral environment, economic implications and traditional factors of pastoral system. In current study, the lactation period is more than 9 months. Farah *et al.* (2004) found that lactation period ranged between 9 to 18 months. Our findings do not match with that of the Tezera's (1998), who stated that the lactation period was 13-15 months for Ethiopian camels. On the other hand, finding of current study indicates longer period than that of the finding by Alemayehu (2001) who reported 6 to 8 months of lactation period. This variation might have emanated from ecotype, nutrition, management practices and differences in the production system.

The findings of this study regarding the high percentage of calving range during the productive age of female camel agrees with Farah *et al.*'s (2004) findings. According to them, under normal conditions, a female camel giving birth every other year will have 8 and 10 calves in her breeding life of around 25–30 years. Contrarily, these findings do not match with the findings of Raziq *et al.* (2008) where they reported that a she-camel produces up to 12 calves in her whole life span.

The amount of milk yield was found to be affected by many factors among different regions of camel production. These factors might include breeds, health conditions, type of pasture, stage, and season of lactation. The results revealed that the high percentage of yield in Butana and Kordofan is lower than the finding of Zeleke (2007) who observed that the mean daily milk yield of a camel in pastoral system was 3.75 liters. However, this fact is in line with Ali and Majid (2006) who reported that the amount of milk declines to 1.38 litre/day in Butana area, whereas it was found to be 2.36 litre/day under nomadic management system in Western Sudan. Furthermore, the stage of lactation of camels and parity significantly affected their daily milk yield in Ethiopia camel. Despite a high percentage of milk yield in the Darfur region, this study agrees with Bakheit (2008) who states that the average daily milk yield obtained from camel under the traditional system is 3.14 litre/day. Traditionally, there are cultural restrictions on the sale of camel milk, and it is not sold in the core camel production areas. Therefore, pastoralists were not interested in milk production to get cash.

The age of calving at weaning is slightly different between areas in this study. Overall weaning age is more than 10 months. This finding is in agreement with Abdelrahman *et al.* (2011), who reported that the dromedary calf was weaned between 12 and 16 months with a mean of 12.4 months in a traditional pastoral system in Nigeria. The result of this study disagreed with the finding of Farah *et al.* (2004). His findings suggest that the weaning of calves happen at the age of 8–18 months, depending on the browsing situation, milk production of the dam, growth of the calf, and ultimate use of the calf. Delay separation and weaning of calves have coincided with poor management in the traditional pastoral system, which possibly is the main reason for an increasing interval between calving. According to Khorchani *et al.* (2004), productivity could be improved by new techniques including early separation and artificial nursing of calves by reducing the interval between calving.

The traditional methods of calving and weaning are different across the regions in this survey. These variations can be attributed to the cultural diversity among the tribes of camel breeding. Some of the weaning methods in this study are also practiced in Somalia as mentioned in the study by Farah *et al.* (2004). They have described that several different systems of weaning are practiced by the Somali camel herders, of which the most prominent are: tying the dam's teats with a softened bark (maraq); making a small incision in the skin of the calf's nose-tip and inserting Acacia thorns that will prick the dam whenever the calf tries to suckle, and making a small incision at the top of the calf's tongue and inserting a piece of wood that will hurt the calf when it tries to suckle.

The majority of pastoralist in this study practiced suckling the calf few minutes before milking. It is a good process for milk letdown. This finding agreed with Farah *et al.* (2004) and Eisa and Mustafa (2011), who reported that sucking process is adopted by camel herders in camel dairy production in Sudan. While milking frequency ranged from 1-3 times, most of the respondents emphasized on 2 times of milking per day in a pastoral system. This result was in accordance with the finding by Eisa and Mustafa (2011).

Most of the pastoralists considered the rainy season to be the main rutting season of male camel, and the length of rutting periods ranged from 2-3 months in this study. This finding is similar to Abdelrahman *et al.* (2011) who mentioned that the male camel exhibits rutting during the early-dry season between October and December coinciding with the cold period of the year. In this study, the calving interval is not less than 15 months; moreover, the majority of pastoralist respondents mentioned the parturition period ranging between 20 and 30 months. This finding agrees with the facts reported by Abdelrahman *et al.* (2011), that the mean calving interval was 23.8 months, and by Farah *et al.* (2004) who mentioned that the mean calving interval in the traditional pastoral system is 27.4 months.

The main signs of the estrus cycle, parturition, and pregnancy detection are carried out in this study; these are different among pastoral communities from one region to another. However, swelling of the vulva, swelling of the udder, and raise-up tail are common signs to identify the estrus cycle, parturition, and pregnancy in female camels respectively. This finding is in agreement with Abdelrahman *et al.* (2011), who recorded some prominent signs of estrus in the female camel including frequent urination, vulval discharge, vulval swelling, male seeking, bleating, foul vulval odour, tail raising, in appetence, grouping of camel cows, and cows mounting one another. According to Yagil (2006), a pregnant camel will show it by lifting and curving her tail (tail "cocking") when a male camel advances toward her. The male then moves away looking for another receptive female. This is the method used by nomads to determine pregnancy in she-camels.

The result reveals a high calve mortality rate ranging 1 to 5% in herds yearly. Death of calves before weaning is a critical problem in the traditional pastoral system. This finding is in agreement with Wilson (1986) who reported that in nomadic herds of dromedaries, the pregnancy losses are due to early embryonic death and abortions that vary from 3% to 33%.

4.4 Constraints in camel movement and nomadism

In this survey, many constraints were observed that limit the camel production in the study areas. First and foremost is the issue of the security in Kordofan and Darfur regions where internal conflicts between the farmers and pastoralists often lead into tribal wars. Such findings are in line with the data reported by Helen *et al.* (2009) where they found the camel-pastoralism to be under threat because of mounting insecurity inhibiting their movement patterns. Additionally, lack of desirable development efforts that could support the pastoralist lifestyles (for example, lack of water facilities on the routes), unfavorable and biased policies, pressures to settle down, and the economic incentives of maladaptive strategies make livestock rearing a less desirable and more challenging livelihood choice. At the same time, finding from the camel production system as observed in the Butana region is in agreement with the findings of Darosa (2005) where he reported the shortage of natural pasture and fodder in the region. According to him, expansion of mechanized agricultural activities is diminishing the availability of natural fodder making the herders highly dependent on crop residues. As a result of it, camel owners and herders have to bear a high price of purchasing crop residues from the farmers making the production system most competitive out of the three types discussed above.

5. Conclusion

Camel pastoral traditional system holds tremendous socio-economic potential because of its high productivity. However, that is only possible if this system is able to garner attention from the government authorities and organizations that could help them overcome the production related constraints. Based on the findings of this study, it can be concluded that the government needs to adopt appropriate policies that help in controlling the conflicts between pastoral tribes, securing their main routes of migration and spreading awareness regarding desirable camel management practices to boost the productivity of camel pastoral practices in the region.

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7. References

Abdelrahman, Y.M., Eisa, M.O., Mustafa, A.B. and Salih, A.M. (2011). Constraints of Camel pastoralists in Gadaref State, Eastern Sudan. *Research Opinion of Animal and Veterinary Sciences*, 3: 174-177. Available online at: https://www.academia.edu/34249785/Constraints_of_camel_pastoralists_in_Gedarif_state_eastern_Sudan [accessed on 11 January 2023]

Abusin, M.E. (1990). Literature survey of baseline information and Profile of central. UNDP, Khartoum, Sudan.

Ahmed, M.Y. and Iqbal, A. (2012). Farmers' Attitude towards Interventions Regarding Camel Calf Health Care and Management Practices Under Pastoralists Conditions, Proceeding of 3rd ISOCARD International Conference, Muscat, Oman, pp.158-159. Available online at: www.isocard.net [accessed on 11 January 2023]

Alemayehu, G. (2001). Breeding program and evaluation of semen characteristics of camels in the central rift valley of Ethiopia. MSc. Thesis, the School of Graduate Studies, Alemaya University, Ethiopia.

Al-Khouri, F. and Majid, A.M. (2000). Camels in Sudan: Ecology, Production Systems, Characterization and Herd Dynamics. The Camel Applied Research and Development Network, CARDN/ACSAD/Camel/P96/2000, Damascus, Syria.

Ali, Y.H. and Majid, M.A. (2006). Epidemiology of camel calf diarrhea in Sudan: seroprevalence of camel rotavirus infection. *J. of Animal and Veterinary Advance*, 4(3): 393-397. Available online at: https://medwelljournals.com/abstract/?doi=javaa.2005.393.397 [accessed on 17 January 2023]

Aljammah, R.S., Almutari, F.A., Alsayied, I. and Ayadi, M. (2012). Effect of the production system, breed, parity, and stage of lactation on milk composition of dromedary camel in Saudi Arabia. *J. of Animal and Veterinary Advance*, 11(1): 141-147. DOI: https://doi.org/10.3923/javaa.2012.141.147.

Bakheit, S.A., Majid, A.M.A. and Nikhala, A.M. (2008). Camels (*Camelus dromedarius*) under pastoral systems in North Kordofan, Sudan: Seasonal and parity effects on milk composition. *Journal of Camelid Sciences,* 1: 32-36. DOI: https://doi.org/10.3167/082279402782311202.

Darosa, A. E. M. (2005). Studies on Some Camel Production Traits and Health in Butana Area, Sudan. Ph.D. Thesis. University of Khartoum, Sudan.

Eisa, M.O. and Mustafa, A.B. (2011). Production Systems and Dairy Production of Sudan Camel (*Camelus dromedarius*): A Review. *Middle-East Journal of Scientific Research*, 7(2): 132-135. DOI: https://idosi.org/mejsr/mejsr7(2)11/1.pdf.

Farah, K.O., Nyariki, D.M., Ngugi, R.K., Noor, I.M. and Guliye A.Y. (2004). The Somali and the Camel: Ecology, Management, and Economics. *Kamla-Raj Anthropologist*, 6(1): 45-55. DOI: https://doi.org/10.1080/09720073.2004.11890828.

Faye, B., Abdelhadi, O.M.A., Ahmed, A.I. and Bakheit, S.A. (2011). Camel in Sudan: future prospects. *Livestock Research for Rural Development*, 23(10): 1-11. Available online at: https://agritrop.cirad.fr/561298/1/document_561298.pdf [accessed on 19 January 2023]

Helen, Y., Osman, A., Abusin, A.M., Asher, M. and Egemi, O. (2009). Livelihoods, Power, and Choice: The Vulnerability of the Northern Rizaygat, Darfur, Sudan. *Feinstein International Center, Tufts University*, Suite 4800 Medford, USA, p.91. Available online at: https://wikis.uit.tufts.edu/confluence/download/attachments/21931179/Darfur_livelihoods.pdf?version=1 [accessed on 21 January 2023]

Idriss, B. (2003). Marketing of camels in the Soudan, 1st Ed. Camel Applied Research and Development Network, Damascus, Syria.

Khorchani, T., Hammadi, M. and Moslah, M. (2004). *An effective technique for calve safeguards and improving herd productivity*, 1st Ed. Ashgabat: IOS Press.

MARF (2007). Statistical report of Sudanese livestock. Ministry of Animal Resources and Fisheries, Sudan.

MOARF (2004). Estimates of animal population (2000-2004). Ministry of Animal Resources and Fisheries, Sudan.

Mohammed, I. (2000). *Study of the integration of the dromedary in the smallholder crop-livestock production systems in northwestern Nigeria*, 1st Ed. Goettingen, Germany: Cuvillier Verlag.

Njiru, G.K. (1993). Economics of camel production. In: S.P. Simpkin (ed.), *Camel Production. A series of lectures given by FARM-Africa*, Nairobi University, Nairobi, Kenya.

Raziq, A., Iqbal, M.Y. and Khan, M.S. (2008). Role of camel in the pastoral economy of marri tribe in balochistan, Pakistan. *Journal of Camel Practice and Research*, *15*(1), 131-138. Available online at: https://www.researchgate.net/publication/200164015_Role_of_camel_in_the_pastoral_economy_of_Marri_tribe_in_Balochistan_Pakistan [accessed on 23 January 2023]

Schwartz, H.J. (1992). Productive performance and productivity of dromedaries (*Camelus dromedarius*). *Anim. Res. Dev.*, 35: 86–89.

Tezera, G. (1998). Characterization of camel husbandry practices and camel milk and meat utilization in Jijiga and Shnlie zone, Somali region. An MSc Thesis, School of Graduate Studies, Alemaya University, Ethiopia.

Wilson, R.T. (1989). The nutritional requirements of the camel. CIHEAM Options Méditerranéennes, Série Séminaires, No. 2, 171-179.

Yagil, R. (2006). Reproductive processes in camels (*Camelus dromedarius*). *Israel J. of Veterinary Medicine*, 61(2): 1-6. Available online at: www.scribd.com/document/142326289/ [accessed on 21 January 2023]

Zeleke, Z.M. (2007). Non-genetic factors affecting milk yield and milk composition of traditionally managed camels (*Camelus dromedarius*) in Eastern Ethiopia. *Livestock Research for Rural Development*, *19*(6). Available online at: www.irrd.org/irrd19/6/zeleke 19085.HTML [accessed on 29 January 2023].

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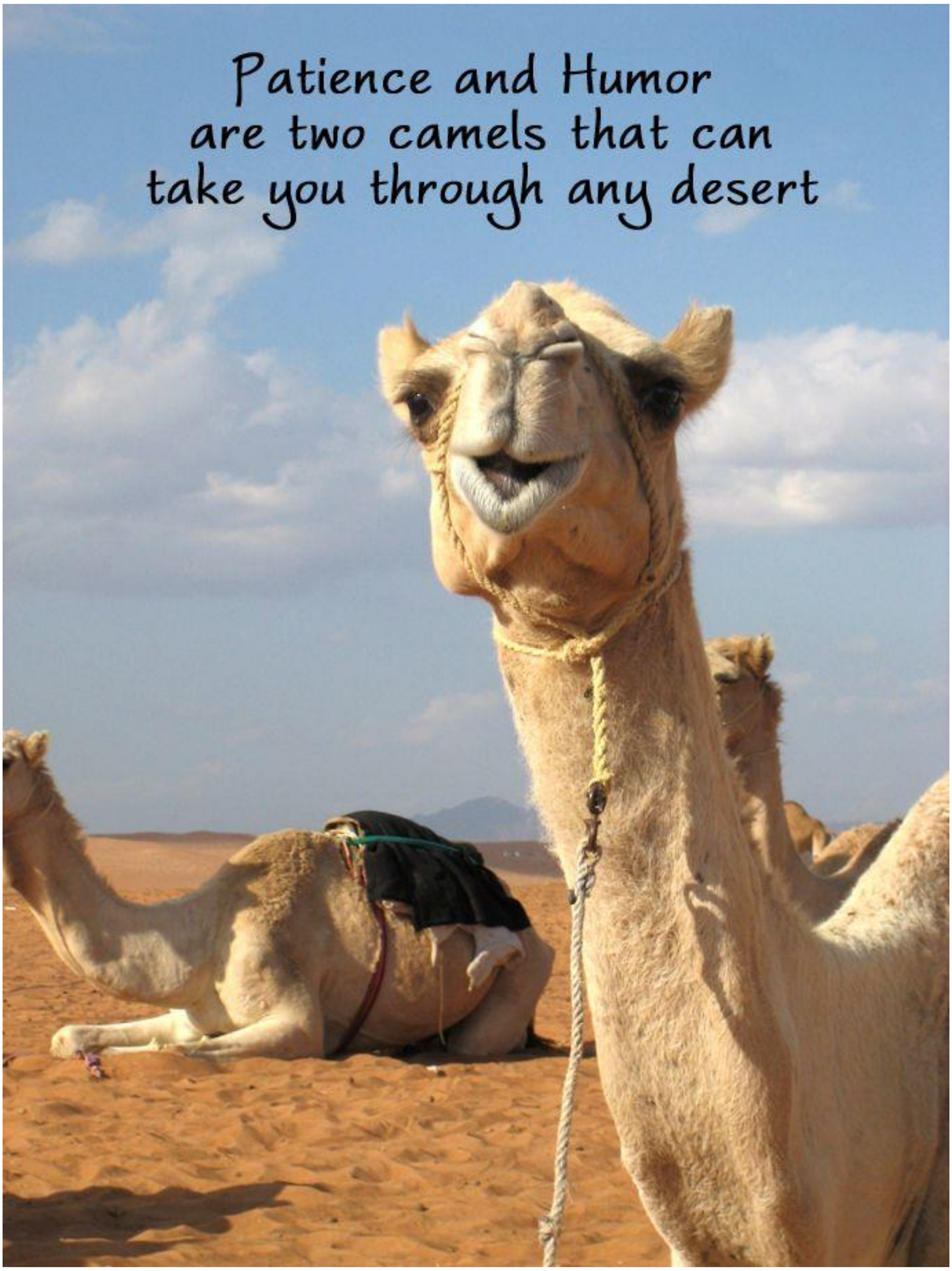
Patience and Humor
are two camels that can
take you through any desert

Chapter 18

Trends and Patterns of Scientific Publishing during 1990-2020 on Conservation Genetics in Brazilian Atlantic Rainforest

By Marcos Vinicius Bohrer Monteiro Siqueira, Gustavo Reis de Brito and Marcela Aparecida de Moraes Silvestre

Trends and Patterns of Scientific Publishing during 1990-2020 on Conservation Genetics in Brazilian Atlantic Rainforest

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Abstract
The destruction of Brazilian ecosystems is among the most alarming national and international conservation issues. It is opportune to optimize management strategies in these areas. To protect the genetic resources in the long term, it is necessary to consider the characterization (or the study) of genetic diversity of its populations. This approach has been applied to different species, population sizes, distinct biomes and wide range of ecological and molecular questions. The objective of this study was to identify trends and patterns of scientific publications in conservation genetics in Brazilian Atlantic Rainforest, historically the most devasted Brazilian biome. Through a scientometrics approach, using the Scopus database, papers published between 1990 and 2020 were selected. Total 80 papers were found corresponded to the research topics. The University of São Paulo and the State University of Santa Cruz are the most representing institutions and the sponsors of projects. The high number of microsatellite markers or the combination of other markers revealed that genomics is not implemented yet as a current framework. The molecular tools have been used to attend 109 species, with 56 related to flora and 24 to fauna. It is pointed out that the low number of published papers in Brazilian Atlantic Rainforest biome is reflection of some factors, from insufficient funding to difficulties in carrying out studies with international partnerships. In addition, in the 1990s, most scientific publications in Brazil were in the native language, so the indexing bases did not count these papers. This work is the first overview of the published literature and allowed to diagnose the studies carried out in the conservation area of the Atlantic Forest biome with molecular markers.

Keywords
Biodiversity; Conservation Strategy; Population Genetics; Tropical Ecosystem

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1. Introduction

Tropical forests are of immeasurable importance for the ecological stability of the planet; they support at least two-thirds of the world's biodiversity, despite covering less than 10% of the Earth's land surface. However, the prospects for tropical forests are becoming increasingly bleak due to continued deforestation and forest conversion (Giam, 2017). Beech *et al.* (2017) reported that there are 60,065 tree species recorded worldwide. The country with the most diverse tree flora is Brazil (8,715 species) followed by Colombia (5,776 species) and Indonesia (5,142 species). Almost 58% of all tree species are endemic to a single country, with Brazil having a prominent position with the highest number of species (4,333 species).

It has been reported that the current biota is entering a "sixth" mass extinction, because of chronic exposure to human activities (Khan *et al.*, 2016). Currently, the IPCC (Intergovernmental Panel on Climate Change) report indicated that there was an increase of 1.1°C temperature compared to the pre-industrial period, causing a decrease in glaciers and high sea levels, due to the presence of high concentrations of greenhouse gases. Consequently, we have verified a higher average temperature in several regions of the planet. It is also predicted that around 8% of the plant species around the world will be affected by climate change in the next 20 years. To reverse this scenario, it is necessary to reduce emissions of these gases by 7.6% per year, by 2030 (IPCC, 2018) and encourage biological conservation in all countries.

However, Brazil lacks the conservation of its biological heritage, as shown by data available on government websites regarding Brazilian biomes. Existing Conservation Units (CUs) in the country do not even protect 50% of the total area of each biome. In the Amazon, the Brazilian terrestrial biomes are mostly protected by CUs. There are 77 CUs of Integral Protection (PI) conserving 411,114 km^2 covering about 9.4% of the biome's area, and 237 CUs of Sustainable Use (SU) having jurisdiction of 701,212 km^2 covering just 16% of the area, totaling approximately one million km^2 (26.1% of the biome, disregarded Indigenous lands). In the other biomes, the situation is more critical since there is only 9.3% of the protected area exists in the Brazilian Atlantic Rainforest (BAF), 8.3% exists in the Brazilian Savanah (Cerrado), 6.26% exists in the Caatinga, 2.63% exists in the Pampa, and only 2.94% exists in the Pantanal (ICMBio, 2020).

Recently some researchers reported the importance of forests to conserve biodiversity, to supply ecosystem services, and to provide steppingstones, corridors, fauna and flora refuges, and to assist other key conservation elements (Arroyo-Rodríguez *et al.*, 2009; Brancalion *et al.*, 2012; Chazdon *et al.*, 2009; Viani *et al.*, 2015). In this context, there was a significant increase in the numbers of researches in BAF. However, the volume of this information is still incipient taking into account the high number of endemic species in this biome (Joly *et al.*, 2014). Less than 1% of the remnant area in BAF has been sampled, and most of the current knowledge about this domain comes from private lands and areas outside of forest reserves (Lima *et al.*, 2015). Mangueira *et al.* (2021) underscore the importance of continuing research on how to proceed with the restoration of forest remnants to improve strategies for the biodiversity conservation in BAF.

Conservation biology strives to conserve biodiversity and biological processes in ecosystems, of which genetic variation is a key component (Geffen *et al.*, 2007). With the advancement of molecular biology techniques, the manipulation of genomic DNA in the laboratory has become a routine methodology in conservation programs. In Brazil, it began in the 1980s with the use of the biochemical genetic marker of alloenzymes. In the 1990s, this marker technique started to be replaced by other techniques e.g., RAPD (*Random Amplified Polymorphism DNA*), RFLP (*Restriction Fragment Length Polymorphism*) and SSR (*Simple Sequence Repeats*). Currently, the most used markers are SSR and SNPs (*Single Nucleotide Polymorphism*), and there is a tendency to improve new methodology in accordance with advances in large-scale sequencing techniques. The clear presence of various types of molecular markers and differences in their principles, methodologies and applications require careful consideration in choosing one or more of these methods according to the application, as well as the resources (technical, financial and equipment) available in each research center (Turchetto *et al*., 2017). In the coming decades, Fischer *et al.* (2017) suggests that, although SSR are well established in conservation genetics, they show limitations in certain genetic processes and that large SNP panels will represent genome-wide patterns in a more accurate way.

In this context, researchers have adopted the conservation genetics like a new approach to biodiversity studies and have used molecular genetic analysis to elucidate relevant aspects of species biology for management and conservation purposes (Frankham *et al*., 2002). However, Holderegger *et al.* (2019) pointed out that it is necessary to establish coherence and trust between scientists and practitioners so that conservation genetics can play a more prominent role in future conservation planning and management.

Scientometry has been used to assess quantitative and qualitative aspects present in the literature in terms of science and innovation being widely used to: i) explore trends in research (Mingers and Leydesdorff, 2015); ii) to evaluate contributions from a researcher in a given discipline or group of researchers in a given area (Wainer and Vieira, 2013); iii) to compare research institutions or countries in relation to the world scientific production (Coutinho *et al*., 2012); iv) to quantify the impact of a particular article (Correia, Paredes and Fonseca, 2018) among others.

Oliveira *et al.* (2019) investigated and described the application of molecular genetic markers in specific groups as sugarcane (*Saccharum* spp.) using scientometry, and Nunes *et al.* (2020) researched on Caryocaraceae family of plants widely distributed throughout the Neotropic region. However, this methodological approach has been applied scarcely to identify the state of the art in terms of genetic conservation in the different Brazilian tropical biomes.

Given the lack of information concerned with population genetic variability in BAF, and the importance to guide future projects in this field, the aim of this study is to identify trends of scientific publications in conservation genetics in BAF and to explore the following topics: (1) recognize the main scientific topics and methodologies in studies published between 1990 and 2020; (2) show representative countries, authors, and primary institutions involved; and (3) point out the main molecular markers applied in these studies.

2. Methodology

2.1 Dataset

An automated search was conducted in the Scopus (https://www.scopus.com) databases of International Scientific Indexing (ISI) from 1990 to 2020, using a combination of keywords: "conservation genetics," "genetic conservation," and "Atlantic rainforest". The search was limited to research articles. The search results were analyzed to obtain a abstract of the articles in order to verify if conservation genetics was specifically used in BAF research. Relevant information, including authors' names, total number of publications, publication numbers by year, sponsors, countries involved in the research, affiliations, and subject areas of the papers, was extracted from the accessed works.

2.2 Pre-Processing and Classification

The exclusion of articles that did not demonstrate bias on the subjects "genetics", "conservation", or "Atlantic rainforest" as well as the removal of duplicate articles, was performed. Following data filtration, the papers were classified into six categories: total articles by year, authored paper count, affiliation, country or territory of origin, sponsoring, and subject area. Summary statistical techniques were employed to quantify and summarize data within each category. Considering the period between 1990 and 2020, a total of 80 papers met the criteria proposed in the methodology. The records contained in the Scopus database returned papers starting from 1996, indicating that either these papers were not included in Scopus database or that the keywords excluded them. All analyses were performed in R 4.1.2 (R Core Team, 2021).

3. Results and Discussion

The graphical analysis of 80 published papers is shown in figure 1. Although small peaks can be observed in 1996, 2000, 2002 and 2005, the number of papers started to increase almost exponentially from 2008, with the most prominent peaks occurring in 2011, 2013, and 2018, respectively (Figure 1).

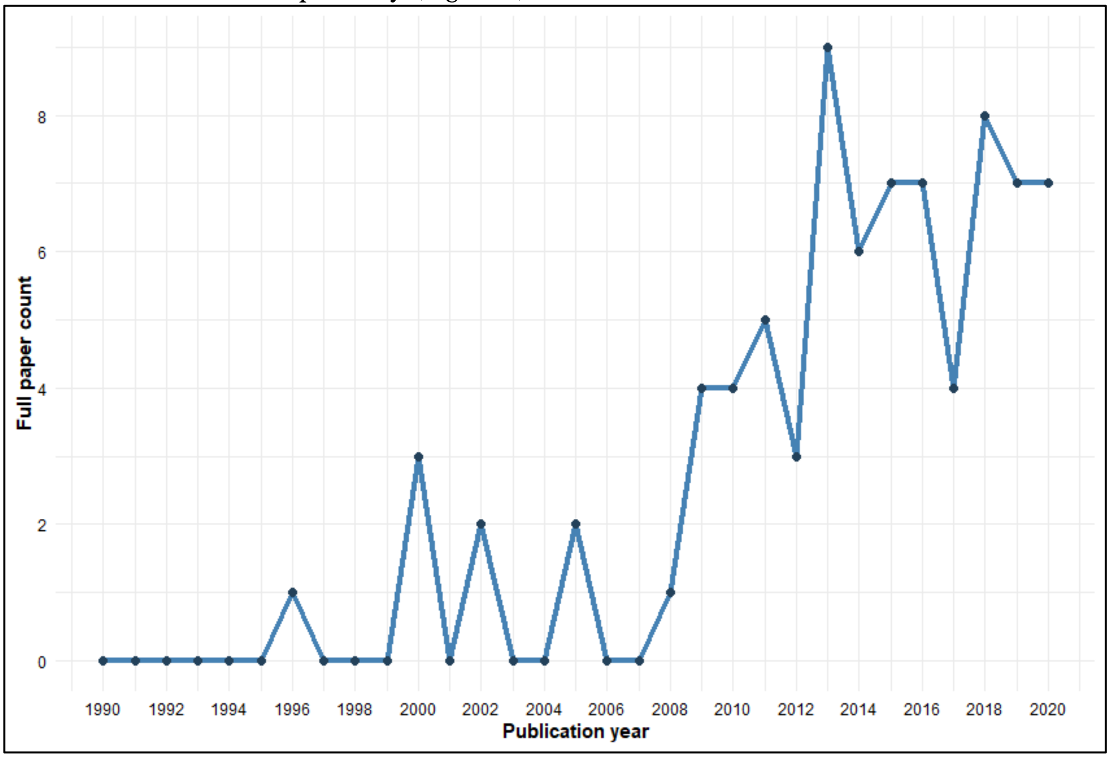

Figure 1: Number of full papers by year published in Scopus database related with genetics conservation in Brazilian Rainforest between 1990 and 2020.

Studies on genetic conservation started in Brazil in the 1990s from the studies with isoenzymes, RAPD and AFLP. These first conservationist attempts, using molecular approaches in BAF regions, took place in the state of São Paulo with the participation of the Companhia Energética de São Paulo (CESP) in partnership with researchers from public institutions with the objective of devising reforestation strategies in areas affected by hydroelectric constructions (CESP, 1992). However, at that time, research was mostly published in Portuguese, in national journals, thus reflecting a gap in the database of international journals, which includes Scopus.

However, observed publication peaks - 1996, 2000, 2002 and 2005 - may be related to investments. In Brazil, public investments in research are around 0.61% of Gross Domestic Product, which is closer to the percentage (0.69%) of the GDPs of the member countries of the Organization for Economic Cooperation and Development (OECD) (Francisco and Zucatto, 2018). After a cycle of regular and consistent spending growth until 2015 (approximately 16.8 billion USD), from 2016 onwards, investments in research and development (R&D), private and public, began to fall: 15.3 billion USD in 2016 and 15.4 billion USD in 2017. Excluding accumulated inflation (10.7%), the result for 2018 was 13.8 billion USD, which is lower than what was in 2015. Comparing Brazilian investment in R&D with OECD countries, Brazil is below the average of other countries in this bloc, and is having expenditures around 2.3% of Gross Domestic Product (GDP) (Norte, 2020). Thus, it is believed that from 2020 the volume of publications will decrease in the Scopus database. In this context, the reduction in funding for scientific research during this period is expected to result in a decline in the number of publications indexed in the Scopus database.

When clustered by country or territory, the number of papers is mainly originated in Brazil. Subsequently, the United Kingdom, the United States, and Germany are the main countries conducting studies on the subject of BAF (Figure 2). Very low number of Scopus publications on BAF topics from the countries other than Brazil indicates the lack of Brazilian international partnerships to compose research on genetic conservation of the BAF. There can be two assumptions behind this phenomenon: i) the lack of foreign interest in the BAF biome, and ii) the difficulty of Brazilian researchers in establishing partnerships with foreign countries. In the first situation, it is possible to infer the lack of knowledge of the BAF, which today is totally fragmented in the states were this biome occurs. It makes it difficult to study this topic and its dissemination.

According to Eisenlohr *et al.* (2015), the forest fragments that still exist, except in protected areas such as National Reserves and Biological Reserves, are concentrated on the tops of mountains and/or steeper slopes, where agricultural activity is difficult or unfeasible, either for access or due to the generally low soil fertility (Moreno, Nascimento and Kurtz, 2003). This biome is, however, recognized as one of the 35 world hotspots for conservation priorities (Myers *et al.*, 2000; Zachos and Habel, 2011), and has even been referred as a "hottest hotspot" (Laurance, 2009), "shrinking hotspot" (Ribeiro *et al.*, 2011), or "top hotspot" (Eisenlohr *et al.*, 2013). Nonetheless an extent of ecological finding and conservation initiatives were achieved in last years (Joly *et al.*, 2014; Lima *et al.*, 2020). Researchers have responded to this scenario, addressing important floristic and phytogeographic features of the Atlantic Forest vegetation, and producing works revealing major implications for biodiversity conservation (Eisenlohr *et al.*, 2015). Regarding the second situation, it is worth noting that not all public institutions have agreements with foreign institutions, and also, due to the country's own educational model, the vast majority of the population has difficulties with the English language (Ruiz, 2012). Because such international partnerships are of paramount importance for the enrichment of Brazilian science and the training of human resources, it is necessary to pay attention to the scientific advancement of the country.

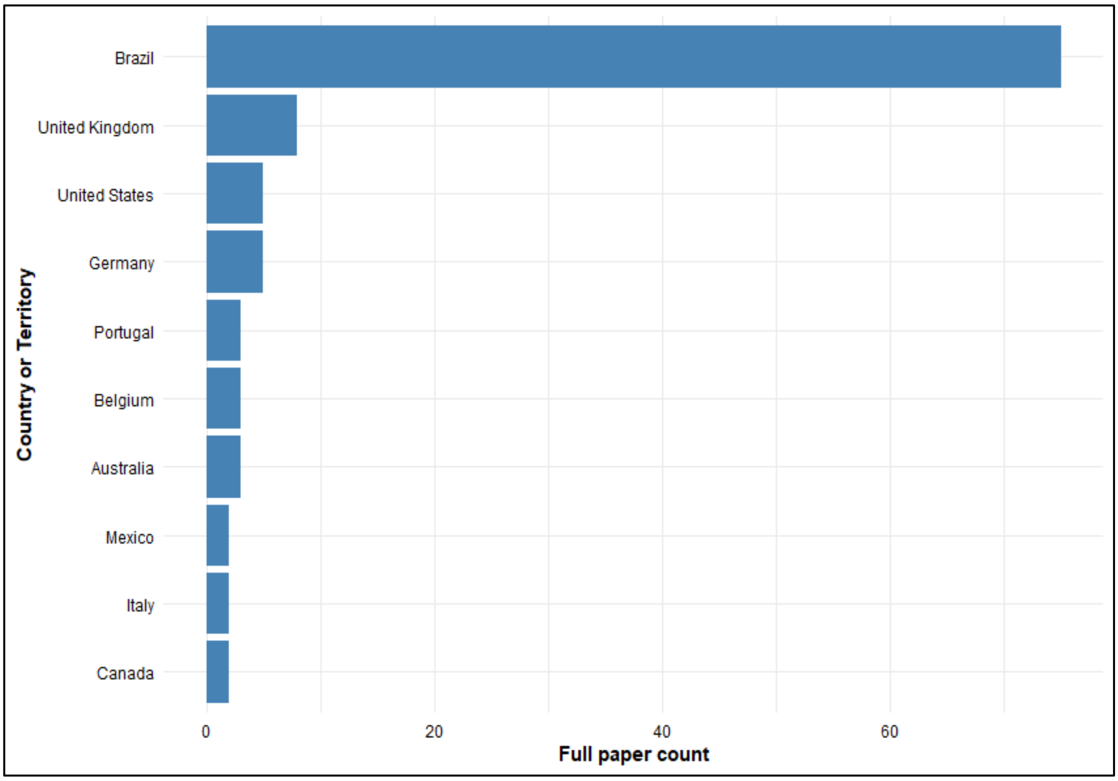

Figure 2: Number of full papers by countries published in Scopus databases related to genetics conservation in Brazilian Rainforest between 1990 and 2020

As shown in Figure 2, the number of papers produced in Brazil also reflected in the number of institutions involved with the BAF studies. As the BAF comprises an extension of the Brazilian territory from north to south (1,110,182 km^2), it was expected that the research would have been promoted by public institutions in several states, as shown in figure 3.

The data also shows that, from a total of 76 organizations involved with BAF studies, 65 produced/published between 1 and 3 papers[1], and a majority of these institutions are Brazilian. Particularly in the field of conservation genetics, the "top 10" institutions conducted the studies are as follows with a count of published papers: University of Sao Paulo – USP (13 papers), Federal University of Rio Grande do Sul – UFRGS (12 papers), State University of Santa Cruz – UESC (11 papers), Federal University of Santa Catarina – UFSC (10 papers), State University of Campinas (9 papers), Federal University of Rio de Janeiro – UFRJ (8 papers), Botanical Garden Research Institute of Rio de Janeiro – JBRJ (6 papers); the State University of Rio de Janeiro – UERJ (5 papers), the State University of São Paulo – UNESP (5 papers), and the Institute of Botany of São Paulo (5 papers) (Figure 3).

Aggregating the documents by sponsor revealed that there were five main sponsors for conservation genetics of the BAF during the period between 1990 and 2020, being the Ministry of Science, Technology and Innovation (MCTI), National Council for Scientific and Technological Development (CNPq), Coordination for the Improvement of Higher Education Personnel (CAPES), The São Paulo Research Foundation (FAPESP) and Carlos Chagas Filho

[1] Available at: https://github.com/britogustavo/BAF-Study/blob/main/scopus_analysis_affiliation_final.csv

Foundation for Supporting Research. These sponsors supported projects in the State of Rio de Janeiro mostly (Table 1). Occasional contributions by different agencies or institutions were also found, sponsoring between one and two documents. The full table with all the sponsors extracted from the data can be found in the additional files. Table 1 reflects the researchers' subordination to the Brazilian government's investment management. This data indicates, as around 90% of Brazilian research is carried out in public universities, that the main vector of this production being the *Stricto sensu* graduate programs (Bueno, 2014).

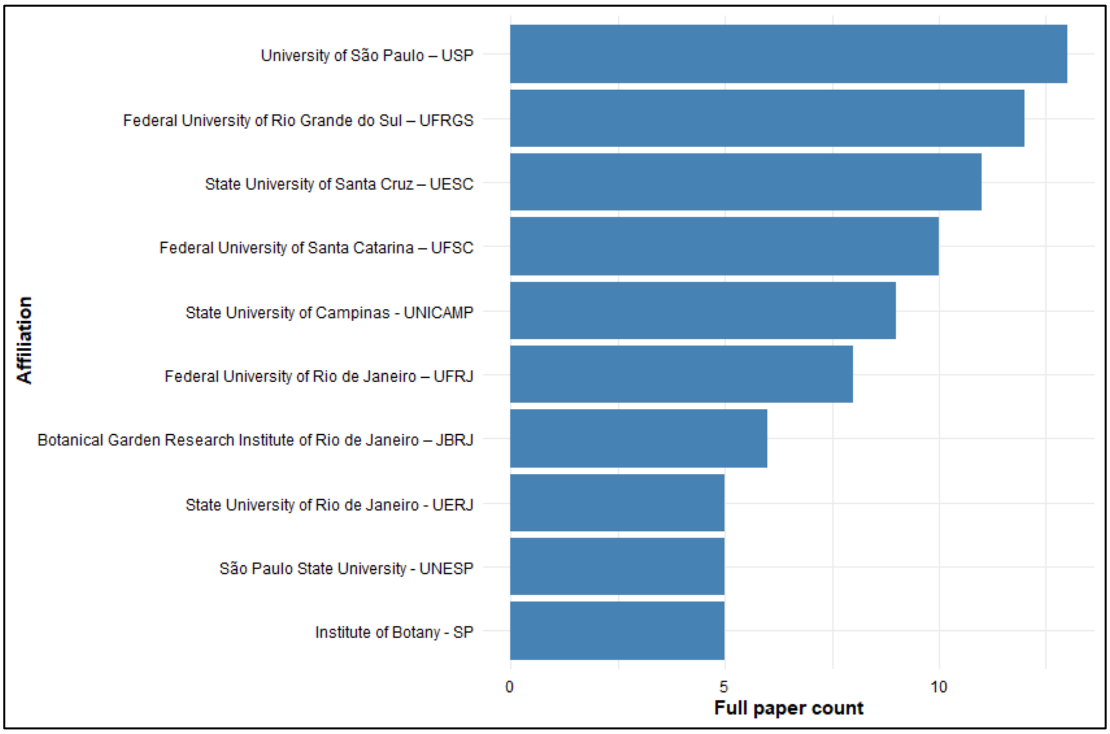

Figure 3: Number of full papers by affiliation published in Scopus database related to genetics conservation in Brazilian Rainforest between 1990 and 2020

Table 1: Main sponsors document count published in Scopus database related with genetics conservation in Brazilian Rainforest between 1990 and2020

Sponsor	*Document count*
Ministry of Science and Technology	33
National Council for Scientific and Technological Development	33
Coordination for the Improvement of Higher Education Personnel	25
The São Paulo Research Foundation	10
Carlos Chagas Filho Foundation for Supporting Research in the State of Rio de Janeiro	7

According to information provided by the Institute for Applied Economic Research (IPEA), while in the United States of America (USA) the 90% of government funding for research is oriented towards the country's development, this is only 30% in Brazil. Currently, in Brazil, the private sector invests less than 0.6% of GDP, while in the US the private sector invests 1.97% of GDP, in Korea 2.6% and in China 1.2%. With these indicators, the trend is the dissolution of most entities that make up the National System of Science, Technology and

Innovation (SNCTI) (Norte, 2020; Vilela, 2020). As the main source of funding for Brazilian research is public, scientists do have many difficulties in conducting their work. In 2021, a decrease in the budget, compared to the base year 2020, of 34% to MCTI, 8% to CNPq, 1% to CAPES and 30% to FAPESP was forecast (Correia, 2020; Escobar, 2021).

Considering sponsored studies of 116 agencies or institutions during the period between 1990 and 2020, the number of authoring researchers was expected to be high. Surprisingly, the analysis of the data collected from Scopus revealed that a total of 9 authors are responsible for most of the papers produced in the referred period (Table 2). In addition, another 151 authors were responsible for authoring between one and three papers on the subject.

Table 2: Document count by authorship published in Scopus database related with genetics conservation in Brazilian Rainforest between 1990 and 2020

Author	*Document count*
Gaiotto, F.A.	8
Bered, F.	6
Palma-Silva, C.	6
Goetze, M.	5
Montagna, T.	5
Nazareno, A.G.	5
Zanella, C.M.	5
Büttow, M.V.	4
dos Reis, M.S.	4

As shown in table 2, Gaiotto, F.A. was the researcher with the largest number of publications focusing in tree population *versus* conservation genetics. Having focus in tree population *versus* conservation genetics, with several contacts abroad (e.g., Florida University, USA), and also with the private sector, it was not a surprise that Gaiotto, F.A. stood out in this review. The data obtained from the Scopus search demonstrate that these authors are recognized as expressive scientists. Not only these authors are involved in research on genetic conservation at BAF, other databases need to be verified and cross-examined.

According to 80 documents retrieved from Scopus, the two main subject areas "Agricultural and Biological Sciences" and "Biochemistry, Genetics and Molecular Biology" were covered by 70% and 50% of the papers, respectively. The subject area "Environmental Science" also showed an expressive coverage by 18.75% of the published papers (Figure 4).

Since most researchers from Brazil involved in this topic are graduates in Agronomic Engineering, Forestry Engineering and Biological Sciences, the distribution of papers was done accordingly. Accordingly, of the total number of articles analyzed, the majority refers to endemic and vulnerable flora species (70%). Studies involving fauna are more laborious at field and need to be processed by the ethics council. Another limitation may be associated with the biome structure itself. This is very fragmented, which directly relates to the survival of these animals, making the sampling process hard work. In contrast, Torres-Florez *et al.* (2018) in an extended analysis (in all Latin America countries) discovered more than a third of the published articles focused on plants, while the rest on animals. These authors studied the period from 1992 to 2013, but the methodology was different. Nevertheless, the main goals were similar to this work.

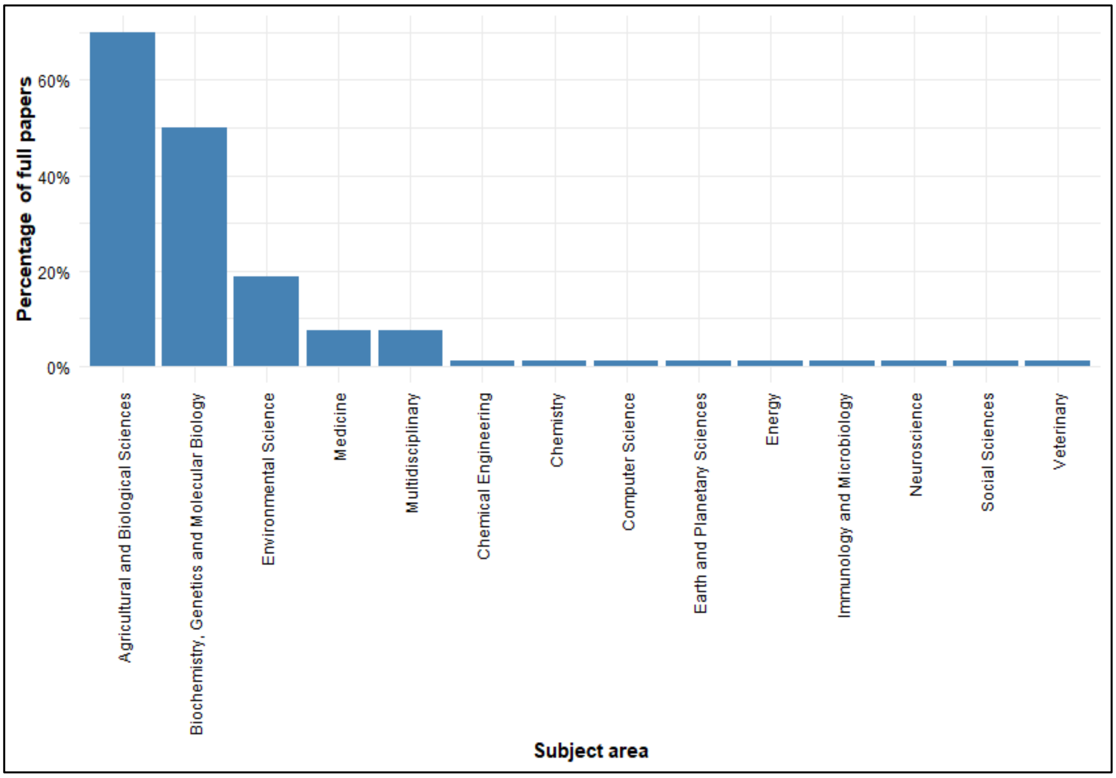

Figure 4: Percentage of full papers by subject area published in Scopus database related with genetics conservation in Brazilian Rainforest between 1990 and 2020

Regarding genetics methodologies, most molecular tools are expensive with limited additional resources in many low-income countries (Harris, 2004; Prasad and Santosh, 2019). Scientists' resort to other approaches in conservation biology, such as quantitative genetics, also makes it possible to estimate genetic variability linking direct management strategies for species in risk (Moran, 2002). Thus, the adoption of molecular markers in Brazil was slow and exclusive to only a few research centers. From the works evaluated here, a significant application of SSR markers and, to a lesser extent, AFLP, isoenzymes, ISSR and RAPD markers were observed. It is understood that the application of SSR is still limited in the conservation genetics in the BAF and other biomes. Although we are in a transition from genetics to conservation genomics (Ouborg *et al.*, 2010), SSR will still be of great use for conservation projects due to their characteristics, such as methodological practicality, low cost, ease of data processing, in addition to great acceptance in international journals (Ferreira, 2006; Hauser *et al.*, 2021).

Despite studies on conservation genetics being relatively new in Brazil and all the difficulties to its application both in field and laboratory scenarios, papers were retrieved emphasizing the importance of molecular markers and genetic studies in context of conservation efforts. Soares *et al.* (2019) made use of SSR markers to study how human interference can lead to losses both in the genetic structure and diversity of populations of *Euterpe edulis*, an endangered palm tree species facing challenges of habitat fragmentation and illegal logging. These authors have demonstrated how reducing illegal activities and reforestation efforts are keys to preserve gene flow. The idea of how habitat preservation/conservation can directly impact the genetic conservation of a species. Mariot *et al.* (2020) demonstrated how even a small number of populations can maintain the genetic diversity of a species if conservation efforts aim to enhance gene flow. The works of Amaral *et al.* (2019) and Santos Júnior *et al.* (2019) both demonstrate how genetic data can be used in conservation and distribution studies in BAF, with the former showing how the use of genetic studies' techniques can produce good results in identifying 12 new amphibian species in BAF. Santos Júnior *et al.* (2019) used genetic data coupled with niche models to study the distribution (both historical and current) of two bumblebee species in BAF, demonstrating how genetic data can be integrated with other studies while becoming important tools to conservation planning and efforts.

As stated earlier, forest types in BAF have complex of typologies, as the montane moist forests are represented from higher altitude wet forests across mountains and plateaus of southern Brazil to Campo Rupestres represented by high altitude shrubby grasslands in southern regions. Works of Hodkinson (2005) and Lawton *et al.* (1987) show that the altitude gradient affects biodiversity (e.g. species richness). However, researches in BAF correlate altitude with levels of genetic patterns. The lack of studies regarding conservation genetics in montane regions may derive from many (or a combination of) factors, such as difficult access to sampling sites, restricted species distribution, and high levels of endemism, thus, making species difficult to observe (de Lima *et al.*, 2020; Eisenlohr *et al.*, 2013, 2015).

4. Conclusion

Though the Scopus platform is a reference in the academic panorama for consulting scientific papers, it was possible to observe some deficient points in the search for journals. This limitation was more present in the 1990s, when Brazilian researchers were more reluctant to publish in English, and confined to national journals. However, as they established partnerships with international institutions, this scenario gradually changed. In this way, the present paper generated a better understanding of the state of the art related to BAF conservation. However, it is necessary to continue such research by covering other databases and considering *ex situ* (BAF) and *in situ* (Brazilian biomes) genetic conservation.

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6. References

Amaral, C.R.L., Chaves, A.C.S., Borges Júnior, V.N.T., Pereira, F., Silva, B.M., Silva, D.A., Amorim, A., Carvalho, E.F. and Rocha, C.F.D. (2019). Correction: Amphibians on the hotspot: Molecular biology and conservation in the South American Atlantic Rainforest. *PLoS ONE*, 15: e0227329. DOI: https://doi.org/10.1371/journal.pone.0227329.

Arroyo-Rodríguez, V., Pineda, E., Escobar, F. and Benítez-Malvido, J. (2009). Value of Small Patches in the Conservation of Plant-Species Diversity in Highly Fragmented Rainforest. *Conservation Biology*, 23: 729–739. DOI: https://doi.org/10.1111/j.1523-1739.2008.01120.x.

Beech, E., Rivers, M., Oldfield, S. and Smith, P.P. (2017). GlobalTreeSearch: The first complete global database of tree species and country distributions. *Journal of Sustainable Forestry*, 36: 454–489. DOI: https://doi.org/10.1080/10549811.2017.1310049.

Brancalion, P., Viani, R., Strassburg, B. and Rodrigues, R. (2012). Finding the money for tropical forest restoration. *Unasylva*, 239: 41–50.

Bueno, A.P.A. (2014). Universidade e os projetos para o país. *Revista Caros Amigos*, 18(70): 23–24.

CESP (1992). *Recuperação de áreas degradadas* [Recovery of degraded areas]. São Paulo: CESP (Série Pesquisa e Desenvolvimento, 059).

Chazdon, R.L., Peres, C.A., Dent, D., Sheil, D., Lugo, A.E., Lamb, D., Stork, N.E. and Miller, S.E. (2009). The Potential for Species Conservation in Tropical Secondary Forests. *Conservation Biology*, 23: 1406–1417. DOI: https://doi.org/10.1111/j.1523-1739.2009.01338.x.

Correia, S. (2020). Ciência perde R$ 454 milhões no orçamento de SP em 2021. [Science loses BRL 454 million in the SP budget in 2021]. O Globo. Available online at: https://oglobo.globo.com/sociedade/ciencia-perde-454-milhoes-no-orcamento-de-sp-em-2021-24800954 [Accessed 05 August 2021].

Correia, A., Paredes, H. and Fonseca, B. (2018). Scientometric analysis of scientific publications in CSCW. *Scientometrics,* 114: 31–89. DOI: https://doi.org/10.1007/s11192-017-2562-0.

Coutinho, R.X., Dávila, E.S., dos Santos, W.M., Rocha, J.B.T., Souza, D.O.G., Folmer, V. and Puntel, R.L.(2012). Brazilian scientific production in science education. *Scientometrics,* 92: 697–710. DOI: https://doi.org/10.1007/s11192-012-0645-5.

de Lima, R.A.F., Oliveira, A.A., Pitta, G.R., Gasper, A.L., Vibrans, A.C., Chave, J., Steege H. and Prado, P.I. (2020). The erosion of biodiversity and biomass in the Atlantic Forest biodiversity hotspot. *Nat Commun,* 11: 6347. DOI: https://doi.org/10.1038/s41467-020-20217-w.

Eisenlohr, P.V., Alves, L.F., Bernacci, L.C., Padgurschi, M.C.G., Torres, R.B., Prata, E.M.B., Santos, F.A.M. dos, Assis, M.A., Ramos, E., Rochelle, A.L.C., Martins, F.R., Campos, M.C.R., Pedroni, F., Sanchez, M., Pereira, L.S., Vieira, S.A., Gomes J.A.M.A., Tamashiro, J.Y, Scaranello, M.A.S., Caron C.J. and Joly, C.A. (2013). Disturbances, elevation, topography and spatial proximity drive vegetation patterns along an altitudinal gradient of a top biodiversity hotspot. *Biodivers Conserv*, 22: 2767–2783. DOI: https://doi.org/10.1007/s10531-013-0553-x.

Eisenlohr, P.V., Oliveira-Filho, A.R. and Prado, J. (2015). The Brazilian Atlantic Forest: new findings, challenges and prospects in a shrinking hotspot. *Biodivers Conserv*, 24: 2129–2133. DOI: https://doi.org/10.1007/s10531-015-0995-4.

Escobar, H. (2021). Orçamento 2021 condena ciência brasileira a "estado vegetativo". [Budget 2021 condemns Brazilian science to a "vegetative state"]. Jornal da USP. Available online at: https://jornal.usp.br/universidade/politicas-cientificas/orcamento-2021-coloca-ciencia-brasileira-em-estado-vegetativo/ [Accessed 05 August 2021].

Ferreira, P.C.G. (2006). Use of microsatellite markers in conservation biology studies. *Floram*, 13(2): 25-36.

Fischer, M.C., Rellstab, C., Leuzinger, M., Roumet, M., Gugerli, F., Shimizu, K.K., Holderegger, R. and Widmer, A. (2017). Estimating genomic diversity and population differentiation – an empirical comparison of microsatellite and SNP variation in

Arabidopsis halleri. *BMC Genomics*, 18: 69. DOI: https://doi.org/10.1186/s12864-016-3459-7.

Francisco, N.A. and Zucatto, L.C. (2018). Estado da arte das produções referente ao financiamento e fomento da pesquisa científica no Brasil: uma análise a partir do ciclo de políticas públicas. [State of the art of productions regarding the funding and promotion of scientific research in Brazil: an analysis from the public policy cycle]. *Práticas de Administração Pública*, 2(1): 41–62. DOI: https://doi.org/10.5902/2526629230604.

Frankham, R., Ballou, J.D., Briscoe, D.A. and McInnes, K.H. (2002). *Introduction to Conservation Genetics*. Cambridge: Cambridge University Press.

Geffen, E., Luikart, G. and Waples, R. (2007). Impacts of modern molecular genetic techniques on conservation biology. U.S. Department of Commercep. 461.

Giam, X. (2017). Global biodiversity loss from tropical deforestation. *Proceedings of the National Academy of Sciences*, 114 (23): 5775–5777. DOI: https://doi.org/10.1073/pnas.1706264114.

Harris, E. (2004). Building scientific capacity in developing countries. *EMBO Rep.*, 5(1): 7-11. DOI: https://doi.org/10.1038/sj.embor.7400058.

Hauser, S., Athrey, G. and Leberg, P. (2021). Waste not, want not: microsatellites remain an economical and informative technology for conservation genetics. *Authorea*, 27. DOI: https://doi.org/10.22541/au.161175207.74315618/v1.

Hodkinson, I.D. (2005). Terrestrial insects along elevation gradients: species and community responses to altitude. *Biological Reviews*, 80: 489-513. DOI: https://doi.org/10.1017/S1464793105006767.

Holderegger, R., Balkenhol, N., Bolliger, J., Engler, J.O., Gugerli, F., Hochkirch, A., Nowak, C., Segelbacher, G., Widmer, A. and Zachos, F.E. (2019). Conservation genetics: Linking science with practice. *Molecular Ecology*, 28(17): 3848–3856. DOI: https://doi.org/10.1111/mec.15202.

ICMBio (Instituto Chico Mendes) (2020). Unidades de conservação [Conservation units]. Available online at: https://www.icmbio.gov.br/portal/unidadesdeconservacao/biomas-brasileiros [Accessed on 12 August 2021].

IPCC (2018). Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. Intergovernmental Panel on Climate Change, Switzerland.

Joly, C.A., Metzger, J.P. and Tabarelli, M. (2014). Experiences from the Brazilian Atlantic Forest: ecological findings and conservation initiatives. *New Phytologisty*, 204(3): 459-473. DOI: https://doi.org/10.1111/nph.12989.

Khan, S., Nabi, G., Ullah, M.W., Yousaf, M., Manan, S., Siddique, R. and Hou, H. (2016). Overview on the Role of Advance Genomics in Conservation Biology of Endangered Species. *International Journal of Genomics*, 2016: 3460416. DOI: https://doi.org/10.1155/2016/3460416.

Lawton, J.H., Macgarvin, M. and Heads, P.A. (1987). Effects of altitude on the abundance and species richness of insects herbivores on bracken. *Journal of Animal Ecology*, 56: 147–160. DOI: https://doi.org/10.2307/4805.

Lima, R.A.F., Oliveira, A.A., Pitta, G.R., Gasper, L., Vibrans, A.C., Chave, J., Steege, H. and Prado, P. (2020). The erosion of biodiversity and biomass in the Atlantic Forest biodiversity hotspot. *Nature Communications,* 11, 6347. DOI: https://doi.org/10.1038/s41467-020-20217-w.

Lima, R.A.F., Mori, D.P., Pitta, G., Melito, M.O., Bello, C., Magnago, LF., Zwiener, V.P., Saraiva, D.D., Marques, M.C.M., Oliveira, A.A. and Prado, P.I. (2015). How much do we know about the endangered Atlantic Forest? Reviewing nearly 70 years of information on tree community surveys. *Biodiversity and Conservation,* 24: 2135–2148. DOI: https://doi.org/10.1007/s10531-015-0953-1.

Mangueira, J.R.S.A., Vieira, L.T.A., Azevedo, T.N., Sabino, A.P., Ferraz, K.M.P.M.B., Rother, D.C. and Rodrigues, R.R. (2021). Plant diversity conservation in highly deforested landscapes of the Brazilian Atlantic Forest. *Perspectives in Ecology and Conservation,* 19(1): 69–80. DOI: https://doi.org/10.1016/j.pecon.2020.12.003.

Mariot, A., Montagna, T. and Reis, M.S. (2020). Genetic diversity and structure of Drimys brasiliensis in southern Brazil: insights for conservation. *Journal of Forest Research,* 31: 1325–1332. DOI: https://doi.org/10.1007/s11676-019-00934-9.

Mingers, J. and Leydesdorff, L. (2015). A Review of Theory and Practice in Scientometrics. *European Journal of Operational Research,* 246(1): 1-19. DOI: https://doi.org/10.1016/j.ejor.2015.04.002.

Moreno, M.R., Nascimento, M.T. and Kurtz, B.C. (2003). Estrutura e composição florística do estrato arbóreo em duas zonas altitudinais na Mata Atlântica de encosta da regiao do Imbé, RJ [Structure and floristic composition of the arboreal stratum in two altitudinal zones in the Atlantic Forest on the slopes of the Imbé region, R]. *Acta Bot Bras*, 17: 371–386.

Moran, P. (2002). Current conservation genetics: building an ecological approach to the synthesis of molecular and quantitative genetic methods. *Ecology of Freshwater Fish*, 11(1): 30-35. DOI: https://doi.org/10.1034/j.1600-0633.2002.110105.x.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., Da Fonseca, G.A. and Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature*, 403: 853–858. DOI: https://doi.org/10.1038/35002501.

Norte, D.B. (2020). Cortes e mais cortes: o que será da ciência e da pesquisa no Brasil? [Cuts and more cuts: what will become of science and research in Brazil?] VC S/A. Available online at: https://vocesa.abril.com.br/carreira/cortes-bolsas-pesquisa-ciencia/ [Accessed 10 August 2021].

Nunes, R., Lima, N. E., Pinto, R. B., de Bem Oliveira, I. and de Campos Telles, M. P. (2020). Caryocaraceae Voigt (Malpighiales): a Synthesis Based on Science Mapping and Systematic Review. *Botanical Review*, 86(3/4): 338-358. DOI: https://doi.org/10.1007/s12229-020-09233-z.

Laurance, W.F. (2009). Conserving the hottest of the hotspots. Biol Conserv, 142: 1137. DOI: https://doi.org/10.1016/j.biocon.2008.10.011.

Oliveira, I., Nunes, R. and Mattiello, L., Barros-Ribeiro, S., Souza, I.P., Coelho, A.S.G. and Collevatti, R. G. (2019). Research and partnership in studies of sugarcane using molecular markers: a scientometric approach. *Scientometrics,* 119: 335–355. DOI: https://doi.org/10.1007/s11192-019-03047-6.

Ouborg, N.J., Pertoldi, C., Loeschcke, V., Bijlsma, R.K. and Hedrick, P.W. (2010). Conservation genetics in transition to conservation genomics, *Trends in Genetics*, 26(4): 177-187. DOI: https://doi.org/10.1016/j.tig.2010.01.001.

Prasad, A.K. and Santosh, P. (2019). Applied Research in Low-Income Countries: Why and How? *Frontiers in Research Metrics and Analytics*, 4. DOI: https://10.3389/frma.2019.00003.

Ribeiro, M.C., Martensen, A.C., Metzer, J.P., Tabarelli, M., Scarano, F. and Fortin, M-J (2011). The Brazilian Atlantic Forest: a shrinking biodiversity hotspot. In: Zachos, F.E., Habel, J.C. (eds), Biodiversity hotspots: distribution and protection of conservation priority areas. Springer, Heidelberg, pp. 405–434. DOI: https://doi.org/10.1007/978-3-642-20992-5_21.

Ruiz, M.A. (2012). Challenges of emerging countries: barriers to get published. *Revista brasileira de hematologia e hemoterapia*, 34(2): 71-2. Doi: https://doi.org/10.5581/1516-8484.20120021.

Santos Júnior, J.E., Silveira, F.A., Oliveira, U., Dias, C.A.R. and Santos, F.R. (2019). Conservation and historical distribution of two bumblebee species from the Atlantic Forest. *Systematics and Biodiversity*, 17: 22–38. DOI: https://doi.org/10.1080/14772000.2018.1530313.

Soares, L.A.S.S., Cazetta, E., Santos, L.R., França, D. de S. and Gaiotto, F.A. (2019). Anthropogenic Disturbances Eroding the Genetic Diversity of a Threatened Palm Tree: A Multiscale Approach. *Frontiers in Genetics* 10: 1090. DOI: https://doi.org/10.3389/fgene.2019.01090.

Turchetto, C., Turchetto-Zolet, A.C., Passaia, G. and Zanella, C.M. (2017). Marcadores genéticos baseados em DNA [DNA-based genetic markers]. In: Turchetto-Zolet, A.C., Turchetto, C., Zanella, C.M. and Passaia, G. (eds.), *Marcadores Moleculares na Era genômica: Metodologias e Aplicações [Molecular Markers in the Genomic Era: Methodologies and Applications].* Ribeirão Preto: Sociedade Brasileira de Genética, pp. 12–20.

Torres-Florez, J., Johnson, W., Nery, M., Eizirik, E. Oliveira-Miranda, M. and Galetti Jr, P. (2018). The coming age of conservation genetics in Latin America: what has been achieved and what needs to be done. *Conservation Genetics*, 19: 1-15. DOI: https://doi.org/10.1007/s10592-017-1006-y.

Viani, R., Mello, F., Euán Chi, I. and Brancalion, P. (2015). A new focus for ecological restoration: management of degraded forest remnants in fragmented landscapes. *GLPNews*, 12: 6–9.

Vilela, R. (2020). A ciência faz muito pelo Brasil, mas quanto o Brasil faz por ela? [Science does a lot for Brazil, but how much does Brazil do for it?] Reconta aí. Available online at: https://recontaai.com.br/a-ciencia-faz-muito-pelo-brasil-quanto-o-brasil-faz-por-ela [Accessed 03 August 2021].

Wainer, J. and Vieira, P. (2013). Avaliação de bolsas de produtividade em pesquisa do CNPq e medidas bibliométricas: correlações para todas as grandes áreas [Evaluation of CNPq research productivity grants and bibliometric measures: correlations for all major areas]. *Perspectivas em Ciência da Informação*, 18(2): 60-78. DOI: https://doi.org/10.1590/S1413-99362013000200005.

Zachos, F.E. and Habel, J.C. (2011). Biodiversity hotspots: distribution and protection of conservation priority areas. Tokyo: Springer Science & Business Media.

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Chapter 19

Mountain Identity and Development Aspirations

By Elena Konstantinidou and Konstantinos Moraitis

Mountain Identity and Development Aspirations

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Abstract

This chapter refers to management issues of mountainous areas, with emphasis on the built environment, highlighting "identity" as a key element for development perspectives and aspirations. Mountain areas are addressed as a system, the identity of which has to be recognized, in terms of protection, promotion, and integrated development. The concept of identity is explored through its reference to the elements that constitute mountain settlements, as well as the conditions of its recognition, protection, and promotion. Further, through the idea of the deliberate "construction" of place-identity and its correlation to the development process, mountain settlements are discussed. References are be made to key concepts related to the issues, such as tradition, tangible and intangible, and the cultural and economic importance of its preservation, considering culture as a key pillar for integrated development. In this context, key issues concerning development aspirations include the component elements of the cultural character and identity of mountainous settlements, its problems, the changes, and the dangers that may threaten them, the relationship between its integrated protection and sustainable development, as well as the problems and strategies of creating and implementing a management plan that ensures its preservation, protection, and invigoration. The article is founded on the research that took place within the framework of the postgraduate program, "Environment and Development of Mountains Regions", annually held at the Metsovion Interdisciplinary Research Center (MIRC) in the Hellenic Mountain Area of Metsovo, Greece.

Keywords

Place identity; Tradition; Mountain settlements; Preservation; Protection; Integrated development

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1. Introduction

This chapter refers to management issues concerning mountainous areas, with emphasis on the built environment, highlighting "identity" as a key element for development perspectives and aspirations. Mountain areas are addressed as a system, the identity of which we ought to recognize, in terms of protection, promotion, and integrated development. The concept of identity will be explored through the reference to the elements that constitute mountain settlements, as well as the conditions of its recognition, protection, and promotion. Also, the subject will be understood through the idea of the deliberate "construction" of identity and its relation to development process. Moreover, reference needs be made to key concepts related to the issues, such as the concept of tradition, tangible and intangible, and the cultural and economic importance of its preservation, considering culture as a key pillar of integrated development. In this context, key issues concerning development aspirations include the component elements of the cultural character and identity of mountainous settlements, the problems of mountain settlements, the changes, and the dangers that threaten them, the relationship between integrated protection and sustainable development, problems and strategies of creating and implementing a management plan ensuring the preservation, protection, and development.

The above tenets are founded on an academic course concerning "Identity and development prospects of mountain areas", a course organized within the framework of the postgraduate program, "Environment and Development of Mountains Regions", organized at the School of Architecture, National Technical University of Athens. The program is the only one that focuses on the study of the mountainous regions of Greece, which nevertheless cover almost 70% of the country's total area. The aim of the course is the study of the specific challenges and opportunities being presented by the mountainous areas. It is based on multidisciplinary education, and it, moreover, offers to the students the opportunity not only to study but to live in the mountain regions. The recognition of the mountain settlements proposed through the course, presented in this paper, is a methodological tool for the students, for field research, exercises, dissertations, and often diploma projects in the context of the postgraduate program.

The program is held annually in the Metsovion Interdisciplinary Research Center (MIRC) in the Hellenic Mountain area of Metsovo, an interdepartmental Laboratory organized by NTUA, in a research center for mountainous environments and the local cultures (Figure 1).

Figure 1: Life in Metsovion Interdisciplinary Research Center (MIRC) (Photos by Elena Konstantinidou)

2. Definitions (Key Concepts)

The basic concepts and definitions are closely correlated to the subject of this paper. Firstly, *Cultural Heritage*, defined by UNESCO in its Draft Medium Term Plan 1990-1995[1], as *"the entire corpus of material signs - either artistic or symbolic - handed on by the past to each culture and, therefore, to the whole of humankind. As a constituent part of the affirmation and enrichment of cultural identities, as a legacy belonging to all humankind, cultural heritage gives each particular place its recognizable features and is the storehouse of human experience... The idea of heritage has now been broadened to include the human and the natural environment, both architectural complexes and archaeological sites, the rural heritage, and the countryside... Furthermore, the preservation of the cultural heritage now covers the non-physical cultural heritage, which includes the signs and symbols passed on by oral transmission, artistic and literary forms of expression, languages, ways of life, myths, beliefs and rituals, value systems and traditional knowledge and know-how".*

The term *landscape* is defined by the European Landscape Convention[2] of the Council of Europe, Florence 2000, as "*the landscape is part of the land, as perceived by local people or visitors, which evolves through time as a result of being acted upon by natural forces and human beings".* Each landscape forms a blend of components and structures: types of territories, social perceptions and ever-changing natural, social and economic forces. Once this identification work has been completed and the landscape quality objectives are set, the landscape can be protected, managed or developed.

Similarly, the concept of *Architectural Heritage* is defined by the European Charter of Architectural Heritage[3], Amsterdam1975, as "*the European architectural heritage consists not only of the most important monuments: it also includes the groups of lesser buildings in old towns and characteristic villages in their natural or manmade settings. ... The architectural heritage is an expression of history and helps us to understand the relevance of the past to contemporary life".*

Another key concept is the concept of *tradition*. The concept of tradition was firstly formed, in correlation to the concept of the folk culture, during the end of the 18th century and afterwards, as a reaction to the centralized European civilization. It was, firstly, the result of a reaction of the German and northern European ethnicities, against the cultural and political pressure exerted upon them by the southern European countries. In contradiction to the accelerated speed of progress of the southern European countries that destroyed primordial values, European romanticism proposed the respect to the age-long existence of the tradition and the folk culture in many ways associated to the 'sublime' nature (Löwy and Sayre, 2001). The anti-historical quality of the previous three referential domains, as presented by the European romanticism, was presented as existing outside the tormented continuous transformation of history.

However, could such a cultural and political condition be possible, especially in the geopolitical context of the European continent? Contemporary theoretical criticism associates the concept of tradition with the formation of the concept of nations (Hobsbawm and Ranger, 1983) and the creation of the neoteric nation states. Social groups claiming to possess a genuine ethnic identity that survived unaltered for centuries may demand a

[1] Draft Medium Term Plan 1990-1995 (UNESCO, 25 C/4, 1989, p.57)
[2] https://www.coe.int/en/web/landscape/the-european-landscape-convention
[3] https://www.icomos.org/en/resources/charters-and-texts/179-articles-en-francais/ressources/charters-and-standards/170-european-charter-of-the-architectural-heritage

differentiated nationality and, thus, the formation of a nation state. In this way, tradition was many times invented, in order to compensate pressures exerted by other ethnic groups.

Nevertheless, even in the territory of the eastern Mediterranean, where historic changes continuously transformed social and cultural contexts, we could not disregard cultural formations, which seem to survive for centuries. The word 'tradition' itself derives from the Latin 'tradere' literally meaning to transmit, to hand over, and to give for safekeeping (Moraitis, 2013).

To the previous stabilized cultural formations, the *identity* of a social group may be closely correlated; and unaltered habits and beliefs seem to defend and conserve the genuine cultural qualities of the social group. However, the identity is also a matter of the ongoing historical transformation; it could be a continuous association to an active historical process. Thus, identity may be regarded as the sum of all the inherent characteristics of a social group and of all the possible tendencies of its future development that have to be recognized, amplified and promoted. It is in the same way that we analyze the identity of a place, recognizing its inherent characteristics and its possible tendencies as well. We may then continue and discuss the subject of the place identity and its promotion, usually described under the place branding and, thus, correlated to the economic development of the place and the local societies, to its touristic appeal and to the expansion of its consummative character.

However, place identity and its promotion, or place branding, appear also to be of central cultural and political importance, as they may strengthen as well the place pride of the inhabitants of a place. The feeling that they live in a place of local interest has to preserve its important qualities, correct its inadequacies and insist on its future opportunities of development.

Figure 2: Kastanitsa, Kynouria, Peloponnese, Greece (Photo by Elena Konstantinidou)

3. Mountainous Settlements: Components of Identity

In Greece, the mountainous landscape is formed by small settlements, large in numbers and variety. They are located over a large geographical area, often isolated from each other due to geomorphological constraints and lack of communication infrastructure. The issue of identity is central in the management of mountainous areas. Mountainous areas are treated as a single system, the identity of which we must recognize, in terms of protection, promotion, and integrated development. The identity of a place may be considered as is a palimpsest of spatial and social phenomena that evolve and transform through time. It consists of tangible and intangible elements, as well as of the wider place formation, physically and culturally considered as the landscape. It is thus established by its *physical, spatial, and human elements*. The physical elements are geographical elements, climate, flora and fauna. They also refer to topography, morphology of the ground, natural relief and orientation.

The creation of settlements has always been correlated to real needs – considered essential and timeless values. We may, for example, refer to sparing, economy, and social data, as well as to a number of additional parameters as to the selection in terms of interconnection with neighbouring settlements, visual communication, views, water sources, quality of topography, safety, climate, sunshine, cultivation or forests for the supply of materials. Settlements are, moreover, located in association with other landmarks or places of importance and significance, a phenomenon rather common in Greece.

The natural landscape, geomorphology, and relief influence the creation and development of the settlements to the maximum extent, and we may comment that traditional ekistics formations are usually located in a way and scale to harmonize with their environment – to become a naturalized, constitutive element of it (e.g., the settlement of Kastanitsa in Peloponnese, see Figure 2). Climate is of great importance for the configuration of the complexes, their general formal outline, as well as for the location of the buildings, and free open spaces. The construction materials are related to natural materials, while constructions take advantage of the environmental characteristics (organized according to bioclimatic principles). The mountain settlements are located in natural environments with abundance and diversity. The free development of nature, the creation of rich ecosystems, the natural environment exhibits large-scale diversity, high steep mountains, ravines, rivers, abundant springs, and rich/varied vegetation.

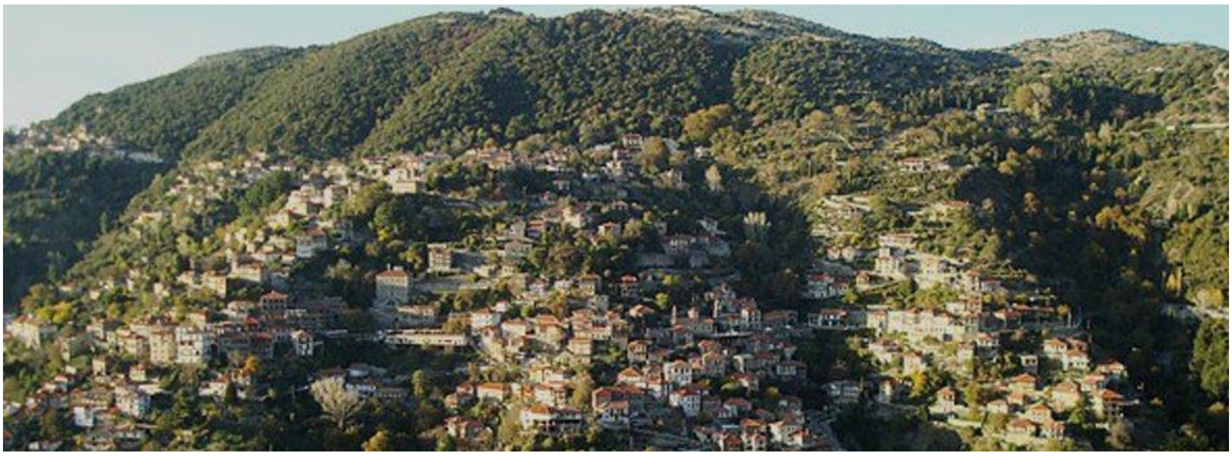

Figure 3: Lagadia, Arcadia, Peloponnese, Greece (Photo by Elena Konstantinidou)

Although, the way we perceive space is not only visual. The identity of a place is associated with aesthetic qualities, visual, acoustic, olfactory, tactile (Stefanou, 2000). Qualities concerning the satisfaction of the human senses contribute significantly to the determination of the character of a place. The colour, scents, tastes, sounds, etc. establish a place and contribute, in a way, to the diachronic link between the present and the past. Human data relates to social activities, historical, economic, demographic characteristics and its traces in the field. Human elements also present dynamics of a site as defined in relation to the population composition, social structures, economic and productive activities, and cultural elements (history, mythology, customs, religious traditions, etc.).

Furthermore, the spiritual and cultural elements, the "Genius Loci" of a place, form part of its identity (Norberg-Schulz, 1979), which is perceived by the process of collective memory (such as reason and myth, narratives, literature, cinema, painting, photography, etc.). Even the name of a place often contains and expresses the history, the tradition, and the spatial peculiarities. Let us refer, for example, to the village of Lagadia in Peloponnese (Figure 3). The morphological configuration of the land on which they were built probably gave the name of the settlement (Lagadi means gorge, ravine, or torrent). The historical identity of a place is composed of the grid of the monuments, landmarks, archaeological sites, sites associated with historical events, which are, therefore, closely tied to the collective memory of its inhabitants.

However, apart from the tangible cultural heritage, we may also find out important intangible references, for example, in the case of Metsovo (Figure 4), with Vlach origins, scholars, national benefactors, creators of local art and crafts, and the production of livestock products and household appliances. All of them constitute elements of the identity of the place.

Figure 4: Metsovo, Epirus, Greece (Photo by Elena Konstantinidou)

Another important element of identity has to do with the professional activities of the inhabitants, which are often preserved through the centuries, as in the case of the settlement of Stemnitsa in the Peloponnese (Figures 5, 6). There, since the post-Byzantine years, metallurgy flourished, mainly silversmithing and goldsmithing, which still survives till today thanks to the craftsmen silversmiths, who continue to work and manufacture products of local tradition, but mainly thanks to the operation of the Technical Vocational School of Silver and Goldsmithing.

The identity of *built environments* concerns the typological, morphological, and structural elements of the sites (Konstantinidou, 2011). Each settlement forms a "composition" of buildings and free spaces. Key components of the spatial elements refer, among others, to the relationship of natural and built environments, the structure and organization of urban space, road and path network, squares and Free Spaces, reference points, as well as the features of buildings and public space. The form and function of the urban fabric are very important, as is the street grid and open space. In general, in the mountainous settlements of Greece, the public space, streets, squares, and gathering places, are all in complete interdependence with the natural element.

Buildings constitute a fundamental factor in the physiognomy of a place, especially houses that are the most prevalent type of buildings composing the settlements. Elements as scale, volume, proportion, size, shape, material, constitute an important part of the identity of a place. It is, therefore, important to recognize their structure, form, and construction. The components of the identity of a settlement, as suggested above through the identification procedure, avail the tools to design and define the parameters for the protection strategy and sustainable development.

Figures 5 & 6: School of Silver Craftmanship, Stemnitsa, Arcadia, Peloponnese, Greece (Photos adapted from http://iek-stemn.ark.sch.gr/)

Figure 7: Vathia, Mani, Peloponnese, Greece (Photo by Elena Konstantinidou)

4. Changes/Problems/Dangers

Various problems and dangers threaten mountain settlements. The problem underlies the *phenomenon of abandonment* related to social causes, natural disasters, or emergencies, and also the geomorphological causes (e.g., the settlement of Vathia in Mani, see Figure 7). In Greece, the abandonment of mountain settlements (during the period 1950s to 1970s) is associated with the mass movement of their inhabitants to cities, resulting in the desertification of mountainous areas. The majority of abandoned mountain settlements remained "untouched" by interventions and alterations; there is thus a fertile ground through a suitable design for its strengthening or even reuse. Regarding *"alive"* settlements, in the effort to coordinate with contemporary needs, threats and problems are identified, some of which are environmental problems, natural disasters, and hyper-tourism. These problems are usually related to the alteration of the "image" and "contour" of the place, contemporary expansions, new constructions and additions, which are incompatible with the existing built environment. They also refer to a shift in the relation of built and non-built, natural and structured, due to inadequate building regulations, and also alterations of historic buildings as well as the form and function of public space.

Furthermore, problems are related to a lack of financial resources, a lack of will and incentives, and generally the socio-economic changes that often lead to the relocation of residents and the economically active population; thus, the loss of the traditional cultural expressions and characteristics of the local and topical way of life occurs.

Moreover, *changes* and *problems* occur in the intangible elements that constitute the cultural heritage of the place: customs and traditions, traditional techniques and cultural practices, functions acquired over time, activities of the inhabitants facing risks of extinction, alteration, or degradation due to socio-economic changes. Thus, there is often abandonment of settlements by permanent residents, as a consequence of immigration of the economically active population and young people, through the introduction of new intensive uses with catastrophic requirements for the scale of the place, occupation of public space, and alteration of its form and operation, and due to excessive increase in land prices. All the above problems and threats may be addressed through legislative and administrative measures resulting from planning and development strategies, as well as through incentives and tools for the activation of the residents.

5. Protection and Development Planning and Aspirations

The concepts of *Protection and Development* evolved through important international documents, Charters, Declarations, and Recommendations. Specifically for historical settlements, including several mountainous settlements, the declarations from international organizations (as Icomos, Unesco, Council of Europe) highlight the values, threats, and the process of planning for their protection.[4] International texts (see Box 1) highlight the trend that is gradually being imposed to address the problems concerning protection of cultural heritage, which combines the actions of preservation and protection of cultural property with sustainable development. The concept of "*Protection*" nowadays is identified with the concept of "*Active Development*", aiming to integrate mountainous settlements into the current reality and also ensuring viability in the future.

The *planning of protection and development* presupposes the management of the changes taking place in the settlements, while contemporary approaches accept today's reality for change and the need for its management. The methodology of a sustainable design process should be based on a deep understanding of the identity of the cultural context, its characteristics, mutations, and also its problems.

Box 1: Basic Principles Texts on the subject of the Protection and Management of Cultural Heritage

1964 - The Venice Charter
1972 - World Heritage Convention (Convention Concerning the Protection of the World Cultural and Natural Heritage, Paris)
1975 - European Charter of the Architectural Heritage, COUNCIL OF EUROPE
1975 - The Declaration of Amsterdam
1976 - Nairobi Charter (Recommendation concerning the Safeguarding and Contemporary Role of Historic Areas, Nairobi)

[4] Particular reference is made to Nairobi Recommendation, 1976, Charter of Historic Cities - map of Washington in 1987, Vienna Memorandum in 2005, and VALETTA Principles, Malta 2011

1987 - The Washington Charter (Charter on the Conservation of Historic Towns and Urban Areas), ICOMOS 1994 - The Nara Document on Authenticity, Japan 1998 - The New Charter of Athens (the principles of ECTP for the planning of cities) 2000 - European Landscape Convention, Florence, COUNCIL OF EUROPE 2005 - Vienna Memorandum (on "World Heritage and Contemporary Architecture – Managing the Historic Urban Landscape", UNESCO) 2005 - Faro Convention (Convention on the Value of Cultural Heritage for Society), Council of Europe 2011 - The Valletta Principles (for the Safeguarding and Management of Historical Cities, Towns and Urban Areas, ICOMOS) 2011 - Recommendation on the Historic Urban Landscape, Paris, UNESCO

An essential condition is the development of a *Protection Plan*, based on an Urban Plan with a comprehensive exploration and inquiry of cultural, technical, social, and economic values. The Protection Plan must cover all the tangible and intangible elements, establishing a proposal of Promotion, combined with a Management Plan, which is monitored. The respect and promotion of all values and the historicity of the place should be ensured while maintaining the overall image of the site and its relationship to the natural and built environment. It should also protect the structure, form, and function of the traditional urban fabric in its entirety, maintain the important historical buildings and elements in the wider environment, and protect the functional character of a settlement and its socio-economic identity. It is also important to consider and protect the cultural diversity and multiculturalism of the place.

An integrated protection plan (or an integrated renewal program) should include several measures: administrative measures to resolve operational, traffic, and other problems, while social measures to complement the social and cultural equipment, to enhance the functioning of housing, and maintain the quality of life of residents (Maistrou, 2012). Spatial projects also require the revival of abandoned neighborhoods, upgrading, and rehabilitation of significant parts of the public space, improvement of infrastructure networks, ensuring the amenities of contemporary life, and highlighting the particular physiognomy of the place. Further, important are the legislative measures for the integration of contemporary structures and the protection of the settlement and its individual characteristics.

The strategy of management should aim at preserving the cultural heritage of the place, strengthening traditional occupations, and evaluating the introduction of foreign standards. Providing the inhabitants with the comforts of contemporary life and attracting investments that do not destroy the environment are crucial measures.

6. Conclusions

The settlements of the mountainous areas are associated to several important natural and cultural values: the mountainous landscape's quality aesthetics, historic and mnemonic references, traditional cultural formations, economic possibilities, and quality of human life. The importance of these settlements depends not only on its material status but also on the immaterial and intangible values associated with its history or traditions. In addition, it may be considered as par excellence formations for the application of sustainability strategies, as it usually incorporate many environmentally friendly features and bioclimatic elements.

It is, therefore, necessary to recognize the identity and understand the value system of mountain settlements - as total, natural-environmental, structural and man-made qualities - to formulate proposals for its protection and integrated development. The settlements should continue to live and develop as living organisms, utilizing their cultural potential, which can bring the necessary resources for its development. In particular, the advantage of these settlements is its cultural characteristics, which can be a driver for economic development and (possibly) special forms of tourism. Natural resources (natural environment, forests, arable land, landscape), cultural resources (e.g., churches, historic buildings, traditional cobbled streets, etc.), social environment (human scale, quality of life, cultural associations, etc.) are of paramount value. Moreover, the intangible heritage (local festivals, religious festivals, music events, traditional local products, arts, etc.) can be the necessary resources for their complete and sustainable development.

In addition, it is pointed out that the future of the mountainous settlements can be based on its function as a network (nature-loving, mountaineering, cultural, architectural, folk tradition, religious, sports, gastronomic, highlighting the primary sector).

7. References

Hobsbawm, E. and Ranger, O. (1983). *The Invention of Tradition*. Cambridge: Cambridge University Press. DOI: https://doi.org/10.1017/CBO9781107295636.

Löwy, M. and Sayre, R. (2001). *Romanticism against the Tide of Modernity*. Durham, North Carolina: Duke University Press. Available online at: https://www.dukeupress.edu/romanticism-against-the-tide-of-modernity [accessed on 13 January 2023]

Maistrou, E. (2012). Historic Cities and Settlements Integrated Protection and Sustainable Development. *Sustainable Development, Culture, Traditions Journal*, 1-B: 79-85. Available online at: https://sdct-journal.com/index.php/2015-10-18-22-23-19/2012-volume-1-b [accessed on 13 January 2023]

Moraitis, K. (2013). Tradition - Landscape – History: The Island of Syros as an example of multiple cultural correlations. *Sustainable Development, Culture, Traditions Journal*, 1: 100-113. DOI: https://doi.org/10.26341/issn.2241-4002-2013-1b-2.

Norberg-Schulz, C. (1979). *Genius Loci: Towards a Phenomenology of Architecture*. Milano: Rizzoli International Publications.

Stefanou, J. (2000). *The physiognomy of the Hellenic city* (in Greek: *Η φυσιογνωμία της ελληνικής πόλης*). Athens: Urban Design Laboratory of NTUA, Hellenic Ministry of Environment, Spatial Planning and Public Works. Available online at: https://search.lib.auth.gr/Record/867922 [accessed on 13 January 2023]

UNESCO (1998). Unesco General Conference: Draft Medium Term Plan 1990-1995 (25 C/4). Available online at: http://specialcollections.nust.na:8080/greenstone3/library/sites/localsite/collect/unesco/index/assoc/HASHac50.dir/Third_medium-term_plan_1990-1995.pdf;jsessionid=C13C5452542BDDE7666CD9068A9EF477 [accessed on 13 January 2023].

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Professor Dr. Konstantinos Moraitis is a qualified architect (National Technical University of Athens 1978). He has 43 years of *professional experience,* focusing on architectural, urban and landscape design and construction. He may present 33 projects, awarded in National and International architectural competitions. Among them 10 FIRST PRIZE distinctions, 2 of them in international competitions. He is Ph.D. in Architecture and Landscape Architecture, School of Architecture NTUA, under the subject: "Landscape – Allocating place through Civilization: Exposition and theoretical correlation of the most significant modern approaches concerning landscape". He was involved in the following didactic activities:

- 1982-1987: Scientific Assistant (School of Architecture NTUA)
- 1987-1994: Lecturer (School of Architecture NTUA)
- 1994–2007: Assistant Professor (School of Architecture NTUA)
- 2007-2011: Associate Professor (School of Architecture NTUA)
- 2011-2020: Professor (School of Architecture NTUA) Since 2021 Emeritus Professor (School of Architecture NTUA).

At the *undergraduate level,* he taught courses on architectural design, urban design and landscape design. He was the first to introduce, in the curriculum of the School of

Architecture NTUA, lessons dedicated to landscape design (for the first time in 2004). He is also didactic responsible or participates in interdepartmental *postgraduate programs* of NTUA:

- Responsible for the postgraduate seminar of "History and Theory of Landscape Design" (1996-till now).
- Responsible for the postgraduate seminar "Built Environment and Development, of the postgraduate program Environment and Development - 1st stream" (2018-2020).
- Participation to the postgraduate seminar "Built Environment and Development, of the postgraduate program Environment and Development - 1st stream" (2020-till now).
- Participation to the postgraduate program "Environment and Development - 2nd stream, Environment and Development of Mountain Regions", held annually in the Metsovion Interdisciplinary Research Centre (MIRC) in Metsovo, Greece (2016-till now).
- Participation to the Erasmus Plus joint master "Architecture, Landscape, Archaeology", organized by Sapienza University of Rome, National Technical University of Athens, University of Coimbra and University of Naples (2019-till now).
- Didactic responsible for Ph.D. theses (12 theses successfully finished till now).
- Visiting professor in foreign universities (Sapienza University of Rome, Bezalel Academy of Arts and Design Jerusalem, Frederick University of Nicosia etc.)

His research *interests* are concentrated on the area of Theory and Methodology of Architectural Design, Architectural Design, Theory and Design of the Landscape, Philosophy of Culture, and Philosophy of Aesthetics. His *research* experience includes participation in 28 programs and projects; among them the programs concerning the:

- "Touring promotion of places of archaeological importance: Organization of physical itineraries in correlation to digital guidance" (2020-2022, responsible for the research team).
- "Revolutionary Palimpsests: Historic and geographical research, concerning the nodal historical territories of the 1821 Hellenic Revolution" (2020-2021, participation to the research team).
- "Research on the historic region of Souli: Promotion, conservation and development of its cultural landscape" (2020-2021, participation to the research as an architectural design, landscape design and place branding contributor).
- "Ottomans and the Hellenic landscape: Landscape apperception in the territory of Greece, during the period of the ottoman governance, and its influence on architectural and landscape design" (2020-2021, responsible for the research team).

He has also participated and organized, as part of scientific and organization committees, many national and international *seminars, workshops, scientific meetings,* and *conferences.* Furthermore:

- Participation, as lecturer, in 36 *scientific seminars* in Greece and abroad.
- Participation, with presentation of lectures, in 145 *conferences* in Greece and abroad.

Chapter 20

Psychological Discourse in Building the Environmental Consciousness in Special Context of Carpathian Mountains

By Olena Khrushch and Yuliya Karpiuk

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Psychological Discourse in Building the Environmental Consciousness in Special Context of Carpathian Mountains

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Abstract
This chapter provides a theoretical analysis of environmental consciousness in terms of its defining features, structural dimensions and types. More specifically, it explores the correlation between the anthropocentric/ecocentric perspective and sustainable household practices and interactions with the natural world especially in Carpathian Mountains. Another focus is the underlying dimensions of environmental consciousness such as environmental sensitivity, sustainable consumption, environmental concern and commitment to act pro-environmentally. Ecological crisis is examined through the lens of spirituality, value orientations, attitudes, worldviews and environmental consciousness. Among the other issues addressed are effective environmental literacy programs through school-family partnership and the driving forces of pro-environmental behavior as exhibited by the population in Carpathian Mountains.

Keywords
Environmental consciousness; Environmental education; Environmental culture; Spirituality; Morality; Values

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1. Introduction

The current ubiquity and magnitude of social and economic challenges, such as proliferation of conflicts, increasing hostility and anti-social behavior, rapid globalization, environmental degradation and the impending ecological catastrophe, have added new urgency to research that will help raise environmental consciousness and shift value orientations towards sustainable consumption (Beck, 2009; Kiselov, 1990; Liuri, 1997; Morris, 2002; O'Sullivan and Taylor, 2004; White, 2009). Ecology used to be a sub-field of biology, which focused on exploring interactions among living beings and non-living objects in a particular territory, such as a mountain. Today, however, ecology encompasses all aspects of the human-nature relationship. Being global in scope, environmental issues have not only gained prominent relevance in biology, medicine, sociology, pedagogy, psychology, political science and economics but also in a comprehensive and interdisciplinary perspective. For instance, Vernadsky (1967) examines a number of theoretical issues in ecology with consideration of social and planetary evolution. Most ecological problems are attributed to populations living in extreme climatic and geographical conditions. Hence, it is important to explore the effect of such conditions on an individual's health, livelihood and overall well-being. No less important is the need to examine the magnitude of human impact on such natural environments, especially mountain ecosystems, and suggest ways of minimizing it.

The late 20th and early 21st century saw significant degradation of natural resources in mountains with the resultant need to search for new ones. The globalization of environmental issues stems from the negative effects of anthropogenic activity on the natural systems. More specifically, any type of livelihood and commercial activity, if conducted in fragile mountain ecosystems, disrupts the ecological equilibrium constructed by nature, thereby, increasing the risk of another anthropogenic catastrophe. There is a significant body of research attributing ecological crisis to self-centered consciousness and a crisis of spirituality. Therefore, this chapter intends to examine the psychological aspects of environmental consciousness, which underlie a propensity for sustainable consumption.

2. Methodology

This chapter provides a theoretical analysis of publications embodying environmental psychology with a focus on environmental consciousness and conservation regarded as worldviews and behavior patterns that optimize the positive outcomes of the human-nature relationship while minimizing its negative impacts. The literature analyzed in this study were published in the last 50 years and retrieved from libraries and other databases in print or digital form. The authors first examined the interacting effects among 10 types of environmental attitudes and 4 forms of environmental consciousness, as well as their impact on livelihoods of mountain people. Next, they outlined the underpinnings of effective environmental education based on shaping the cognitive domain of environmental consciousness, especially confining the Carpathian area. This is followed by a comprehensive summary of ideas about building adequate environmental consciousness, with a particular emphasis on home and school influences. Finally discussed are the environmental attitudes and value orientations of children living in high-altitude areas of Ukrainian Carpathians, as well as ways of motivating them to regard nature as valuable and worthy of protection. In terms of research methodology, this chapter relies on the prior studies conducted and published by Darenskyi (2006), Deriabo and Yasvin (1996) and Losev (2010), who provided a comprehensive description of approaches to exploring environmental consciousness. This research employs systematic and personal approaches. More specifically, the personal approach takes into account an individual's relationship with nature. Thus, the authors identified character traits and personal qualities in Carpathian inhabitants who had different types of environmental consciousness about mountains. The systematic approach was used to explore the structure of environmental consciousness, the development of its dimensions and formation mechanisms.

3. Results and Discussion

3.1 Environmental consciousness

There is widespread recognition among sociologists and experts dealing with the human-nature relationship that human activity in natural settings is controlled by environmental consciousness (Darenskyi, 2006, p.29). While processing information, environmental consciousness assesses human activity and predicts its consequences for the natural world, thereby, optimizing the human-nature relationship. Serving as a mediator between human and nature, environmental consciousness shapes judgments about the natural environment through self-reflection and analysis of technological transformations, and social and cultural contexts (Losev, 2010, p.11).

It should be noted in this regard that the perception and regulation of human behaviour depends on an individual's psychological make-up, which accounts for the rich variety of attributes characterizing the environmental consciousness. If viewed as a form of perceiving and reflecting the ecological dimension of life from a social perspective, environmental consciousness can be defined as a "multidimensional conceptual domain for organizing the human-nature relationship". Thus, environmental consciousness serves as both a form and a means of representing the content that encompasses the strong connections between human and nature.

From the perspective of psychology, the dual nature of consciousness manifests itself as activity and reflection. Unlike psyche, consciousness is composed of conceptual and semantic content reflected in mental models (Rubinshtein, 2000, p.39). Having socio-historical roots, the semantic dimension of consciousness is a social construct, which manifests itself in interactions with the surrounding world and society represented by collective consciousness. Therefore, the link between the material, particularly natural, world and consciousness is mediated by its social essence.

Vygotsky (1982) emphasizes the importance of regarding consciousness as a precondition for behavior. Consciousness serves as an inherently human, higher-order mental representation, which enables the cognition, reflection and awareness of the surrounding world (e.g. mountain landscapes). The manifestations of consciousness include knowledge of the self; the external and internal world; as well as evaluative, theoretical and practical attitudes to surrounding reality. More specifically, attitudes to nature play a mediating role in human interactions with natural objects, the ecological system and the surrounding milieu.

The scope of environmental consciousness is currently a matter of ongoing debate. Some studies (Girusov, 1983; Kochergin *et al.*, 1987) treat environmental consciousness as a set of views, theories, conceptions and social emotions, which reflect interactions between society and the natural environment of the mountain ecosystems. Other studies (Deriabo and Yasvin, 1996) define it as a complex system, which builds, stabilizes or alters the human-nature relationship associated with the satisfaction of human basic needs.

Shagun (1994) views environmental consciousness as an aspect of psyche connected with knowledge and ideas about values, behavioral and emotional convictions associated with environmental conservation in mountains. At the same time, environmental values constitute the moral dimension of consciousness, which is responsible for selecting relevant activities and taking decisions. In turn, the most stable values build an individual's value orientations, which then mark the direction and essence of their activity. In addition, value orientations determine an individual's general vision of the world and themselves, serve as landmarks in life, motivate opinions and behaviour. An individual shapes his/her relationships with nature by relying on the experience of previous generations as well as on his/her own perceptions. Consequently, attitudes, value orientations and worldviews underlie human interactions with natural objects. This is the basis for identifying the intersection of individual and collective consciousness, which affects personal opinions, views and preferred solutions to problems arising from interaction with the environment. The dynamics of such interaction manifests itself as certain actions, acts, behaviour and personal ideas about the connections between humans and mountain ecosystems.

Deriabo and Yasvin (1996, p.6) view environmental consciousness as a system of attitudes. The researchers define environmental consciousness as a set of individual and collective ideas about the interconnections in the human-nature system, as well as in nature itself, about well-formed attitudes to nature, corresponding strategies and interaction techniques.

Lihachev (1993) defines environmental consciousness as a system of safeguarding aspirations, and the system is based on the principle of sustainability in the human-nature interactions. Additionally, the ecological dimension includes a system of knowledge, skills and abilities, which are responsible for sustainable domestic activities. It stems from the need to preserve natural resources on a countrywide scale. Such a need belongs to the realm of personal characteristics that motivate behaviour; in addition, they impact an individual's moral, political and ideological views, value orientations, industriousness, and creativity – all being in line with social expectations.

Zverev *et al.* (1994) and Suravegina (1999), *inter alia*, stress that environmental consciousness includes knowledge of environmental laws, determinants of contradictions inside the human-nature relationship system, with contradictions indicating the discrepancies between social laws and those of nature.

3.2 Types of environmental consciousness

Environmental consciousness has undergone continuous change, with its every stage marked by special interactions between human and nature. This research has identified two main types of environmental consciousness: the anthropocentric and the ecocentric. More specifically, "western" environmental consciousness is anthropocentric". In other words, its underlying feature is human exceptionalism, which is perceived as freedom from the need to comply with objective ecological norms. Summarizing the typological features of anthropocentric environmental consciousness, Deriabo and Yasvin (1996) note that it regards human life as inherently valuable in contrast to non-human living beings; the latter being perceived in terms of benefits from them. In this view, humans are the only beings who have intrinsic value and, therefore, the right to dominate over the natural world, which only exists for their own benefit. The pragmatic imperative views nature only in relation to what it can provide for humanity. Ethical norms and rules hardly extend to the human-nature relationship. Sustainability is motivated exclusively by pragmatic considerations. For instance, environmental stewardship is regarded as important only when it comes to preserving natural resources for future generations.

The New Environmental Paradigm values the environment for its own sake. According to Deriabo and Yasvin (1996) and Simonova (1999), this type of environmental consciousness is focused on ecological relevance, which preserves balance between pragmatic and non-pragmatic human activity within the boundaries of ecological systems. It is based on a comprehensive awareness of imminent global catastrophe and the development of ecological crisis. In addition, it contains a moral dimension, which is responsible for selecting purposeful activities. Decision-taking is based on the ecological imperative and of its desirability.

3.3 Groups of environmental consciousness

In modern psychology, environmental consciousness is traditionally divided into four groups. Medvedev and Aldasheva (2001) define *collective environmental consciousness* as shared views on attitudes to nature determined by the level of awareness, as well as ideas about the unity of an individual, humanity and the environment. Collective environmental consciousness includes general interpretations of the human-nature relationship, which is characteristic of a certain social structure (professional group or population, ethos or humanity as a whole). It is responsible for a systemic assessment of the human-nature relationship, its organizational goals and impacts on natural objects and phenomena. Another feature is general acceptance and commitment to all norms and laws pertaining to the human-nature relationship.

At the same time, *individual environmental consciousness* represents an individual's concrete experience with nature, and its outcomes. It encompasses a system of knowledge about the natural world that an individual acquires through studies and socialization, while building awareness of the existing social dimensions of environmental consciousness and ecological behaviour. An important aspect is the assimilation of new experience by taking into account an individual's personal psychological characteristics. In the Carpathian mounts, such individual characteristics are visible and prominent. In this connection, mass media serve as an important tool for shaping a society's consciousness. At the same time, in modern society individual environmental consciousness is faced with a growing number of changes caused by anthropogenic influence, which poses a real threat to human wellbeing. Thus, consciousness is characterized by its openness to information, which allows for a possibility of understanding the causes of change and estimate their extent and possible negative consequences. Medvedev and Aldasheva (2001) identify *routine environmental consciousness* as a system of views shaped on the basis of immediate contacts with natural objects, as well as controversial data obtained from various sources. Another characteristic feature refers to shaping views from individual experience under the pressure from the surroundings without any link with scientific substantiation of the data or purposeful environmental education. War imposed by Russia on Ukraine has triggered this last feature of environmental consciousness among the citizens of Ukraine.

Scientifically substantiated environmental consciousness is shaped through scientific inquiry, which uses objective relationships inside natural systems, plus interactions between human and nature, nature and society. Furthermore, it takes into account urgent societal interests. Scientifically substantiated environmental consciousness results from a critical analysis of ecological consequences as well as the significance of predicted changes for an individual, a social group, or society as a whole. Scientifically substantiated environmental consciousness is closely connected with scientific knowledge about natural objects and their interrelations. They enable an individual to estimate their importance, the possibilities and ways of using them in order to satisfy human needs and interests, as well as predict the outcomes of the preferred type of interaction with a particular object in the environment, both for an individual and the object itself.

3.4 Forms of environmental consciousness

Researchers identify four major forms of environmental consciousness. *The consciousness of negation* is marked by disregard for information about the nature and content of ecological links that have no direct bearing to a particular individual or social group with a mature collective environmental consciousness. In this perspective, there is personal detachment from certain questions or issues. The phenomenon of negation can be observed in conditions of very slow changes in the environment. There is a prevailing orientation towards the current moment and current events. In consequence, individuals possessing this form of environmental consciousness tend to perceive ecological problems as political, economic or nationalistic. This breeds indifference to nature; disregard for existing and potential problems; light-mindedness about environmental bans and restrictions.

Hyperbolized environmental consciousness is marked by unrealistic or inadequate assessment of ecological problems, a tendency towards fatalism and catastrophism. At the same time, this perspective on environmental consciousness fails to differentiate between what refers directly to a particular individual and what does not… As a result, threatening situations are perceived with exaggeration, whereas favourable changes are assessed inadequately or slightly pessimistically. Hyperbolized environmental consciousness tends to be burdened with frustration arising from underestimated capabilities to control a situation. Consequently, ecological behaviour is marked by reluctance to search for active creative solutions, as well as automatic and stereotyped actions and disbelief in their success. Furthermore, there is an atrophied capacity for prediction or an inclination towards pessimistic vision, which leads to passivity in performing predefined algorithms (Deriabo and Yasvin, 1996, pp. 49-66).

Hyperbolization is based on information obtained through direct interaction with nature and through the mass media. Hyperbolized environmental consciousness is steady. Yet, if there is a contradiction between the original information, the predictions inferred from it and further events, this form of consciousness can be replaced with that of negation.

Self-centered environmental consciousness stems from the human-nature relationship and human-society interaction, which comply with existing regulations and moral restrictions. At the same time, in resolving problematic ecological issues, subjective interest assumes priority. This form of ecological behaviour pursues individual self-centered objectives closely connected with satisfying material needs. It is noteworthy that an individual can be aware or know of the possible unfavourable consequences of their own ecological behaviour in the present or future. However, individuals with self-centred environmental consciousness are prone to justify their choice of illegal methods and ways to achieve personal goals. Developing collective ecological self-centered consciousness is associated with the predominance of the interests of a particular group over those of a whole society, and individual interests over those of a social group. This process leads to decreased resilience and the emergence of contradictions between an individual's worldview, their aspirations, decisions and actions. If self-centred consciousness spreads to individuals of a higher rank, it has a direct effect on political decision-taking concerning the human-nature relationship. Self-centred consciousness underlies pragmatic inclinations aimed at conquering the world and using natural resources in order to obtain short-lived benefit. Its characteristics include narrow-mindedness, prevailing false ideas about "man being the master of nature"; and when an individual's omnipotence and exceptionalism are confirmed in practice, they resort to barbaric devastation of nature.

Rapid capitalization, desire to become rich "at any cost" and "by any means" lead to the dominance of behaviour directed at transformation and depletion over the ability to enjoy natural beauty (Deriabo and Yasvin, 1996, p. 59). Destruction is the most disgusting form of interaction with nature; it stems from self-centred environmental consciousness. A practical manifestation of self-centred environmental consciousness is statistics on deforestation that reflect daily transportation of timber in hundreds of train cars from immature Carpathian forests, destruction of berry fields and rare animal species. Another instance of self-centred environmental consciousness is profit-motivated mismanagement. More specifically, river-bank slips are caused by extensive removal of gravel and sand and the resulting meander of mountainous rivers and torrents.

The current pervasiveness of pragmatism and instrumentalism has a significant impact on the human-nature interaction. Specifically, human desire for wellbeing knows no bounds; unrestrained overconsumption and excessive comfort will inevitably lead to psycho-physiological and moral degradation (Rohozha, 2006, p. 84). This breeds avarice and pathological consumerism, thus turning a person into a predator devoid of common sense or morality, let alone spirituality. The complexity of developing personality and environmental consciousness is that, in modern society, the rich and poor divide is widening. Extreme social polarization and lack of middle-class households inhibit the natural development of a personality, especially in high-altitude areas of Carpathians. Having become rich through ruthless exploitation of mountains (deforestation, aggregate resources, etc.), the so-called "new Ukrainians" go unpunished for destroying the nature of the Carpathians. Particularly harmful is the path to enrichment through environmentally unfriendly behaviour rooted in self-centred environmental consciousness. A fear of industrial poverty and a strong disbelief in the possibility of human existence without natural resources, which are being exhausted, are catching people off guard and leaving them dazed in the face of the consequences of their own actions, thus shaping self-indulgent exploitation of the natural world.

Ukrainians tend to be selfish, which is why their interaction with nature can be driven by personal benefits. This self-centredness and disregard for others reflect lack of development, culture and manners. Distorted perceptions of human needs and lack of common-sense manifest themselves in hunting endangered animals, fishing during the spawn, water pollution, outdated manufacturing practices – all causing air pollution, massive use of environmentally hazardous substances, absence of safe waste disposal technologies and so on. Such activities are detrimental to both ecosystems and humans themselves. Thus, mere sufferings caused by deteriorating health by air and water pollution, harmful substances in food urges an individual to think about environmental sustainability and placing restrictions on their interaction with nature. It should be noted that self-centred environmental consciousness and its characteristic behaviour leads to environmental degradation.

Therefore, the mass media are becoming increasingly fixated on “the crisis of civilization”, “the death of humanity and all life on the Earth”, “catastrophic consequences”, “effects of globalization”. As a result, society has become subconsciously aware of pervasive tension, anxiety and unrest. At the same time, the awareness that the danger is coming from self-centered ecological behaviour is the driving force for finding out about the actual causes of crises, catastrophes, or any other cataclysms, which reflect a crisis of spirituality in the ecological, economic, financial and anthropological dimensions. Konnov (2006, p. 67) notes in this matter that activism has external limits: a person must not exceed the measure set by the Creator or count exclusively on themselves; nature cannot be transformed without the mediation of the Spirit.

Scientific and technological progress, in the context of declining morality and distorted perceptions of the good and the evil, causes number of difficulties in the development of personality, building environmental consciousness and relationship with nature. Nature is not only an object of human impact but also a living reflection of a human being in nature and a reflection of nature in the living being themselves. This indivisible whole can be grasped only by an individual possessing a highly developed self-awareness and spirituality (Dobronosova, 2006, p. 91). Grasping the essence and sense of nature in a human and the sense of a human in nature means pointing the development of the human being themselves in the right direction. For this reason, we believe that highly developed spirituality promotes a more environmentally conscious behaviour and helps move beyond the boundaries of human selfishness. Most philosophers believe that a person is more interested in preserving life on the Earth. Thus, it is only a person who is capable of preventing a global ecological catastrophe. For this reason, scientists are convinced that a person has a remarkable role to play in promoting the significance of nature with its resources. We partly agree with this point. More specifically, we believe that only a developed person, who possesses a strong sense of self-awareness, profound knowledge of the natural world and a willingness to assume responsibility for it, is capable of sustaining the environment and its natural ecosystems. These are characteristics of adequate environmental consciousness.

Adequate environmental consciousness is a scientifically substantiated consciousness, which considers the natural environment as a higher intellect marked by spiritual grandeur. Nature is regarded as spiritual refuge for a person to get away from the hustle and bustle of everyday life, thus focusing on the philosophical problems of the origins of the universe. Adequate environmental consciousness urges sustainability, thereby, minimizing the likelihood of environmental damage from rapid economic growth. Adequate environmental consciousness is marked by activism and constructivism in looking for solutions to urgent problems. Constructive solutions are based on compromise, which prohibits from setting certain goals in the course of scientific and technological progress. The first activities to be limited or prohibited are the ones provoking environmental damage, thus exceeding the benefit gained from them. The decision-taking process and its outcome are affected by emotionally sensual and aesthetic factors. In addition, there is a strong interconnection between individual and collective adequate environmental consciousness. Therefore, the current ecological situation requires unity in viewing ecological issues, solutions and joint coordinated actions, especially when the mountain areas are in core of the considerations.

3.5 Types of environmental attitude

Yasvin (2000), in his monograph on the psychology of the human-nature relationship, describes ten types of environmental attitudes identified on the basis of differences between objective and subjective perceptions of nature. The author considers *objective pragmatic attitude* to nature as perceived through the prism of material benefits as a source of resources and as a tool for achieving goals. This type of attitude is found in individuals with self-centred environmental consciousness. *Subjective pragmatic attitude* can be observed in individuals with subjective perception of natural objects as agents and partners. Human activity is motivated by pragmatism and is inherent in self-centred environmental consciousness.

Objective aesthetic attitude is characteristic of people with perceptive sensual and aesthetic perceptions of the environment. *Subjective aesthetic attitude* is based on the aesthetic experience of contacting natural objects serving as a sort of subjects. Therefore, individuals with this type of environmental attitude are capable of giving an emotional response to nature, having feelings for it, interacting with it on a par. Both types of attitudes are found in individuals with adequate environmental consciousness.

Objective cognitive attitude is marked by a characteristic dominance of the cognitive dimension of environmental consciousness and view. Individuals displaying this type of environmental attitude perceive nature as an object of examination from a rational perspective. *Subjective cognitive attitude* entails exploring nature with complete awareness of its intrinsic value, self-sufficiency and uniqueness; recognizing its unalienable right to existence and the possibility of an equal interaction on the basis of socially acceptable norms and rules.

The defining feature of *objective practical attitude* is intensity and practical ecological views. In this case, nature is perceived as an object and instrument for satisfying individual needs without any attempts to establish a harmonious relationship with the natural environment. A person's practical steps are directed at the natural object *per se*; in other words, it is based on partnership. A person is sensitive towards the features of a natural object, tending to interpret them from a subjective perspective and reacting to them. It is noteworthy that the relationship with the environment is based on reflection and gets adjusted in line with nature's "interests".

Objective safeguarding attitude to nature is marked by the dominance of the behavioural dimension of environmental consciousness and a highly intense objective perception of nature. This type of attitude stems from perceiving nature as belonging to the whole humanity, including future generations in whose interests it is necessary to safeguard natural objects. It should be noted that the above-mentioned type of attitude to nature is regarded as "conscious", "responsible" "rational", and is declared for purposes of environmental education. It is characteristic of environmental activists who promote sustainable environmental movement, as well as for school teachers (Yasvin, 2000).

The abovementioned types of attitudes to nature were identified on the basis of their reflection in certain ideas, opinions, worldviews and value orientations. However, environmental consciousness encompasses not only attitudes to nature but also to an individual's activities in a natural environment, connections between an individual and society and so on. It is necessary to consider these factors while fostering adequate environmental consciousness in children and adults.

3.6 Psychological aspects of building environmental consciousness

The personality of an environmentally conscious individual manifests itself in behavioural norms and rules, as well as environmental attitudes. The ability to identify and analyse environmental problems, assess their urgency and suggest environmental solutions are the features of a well-formed adequate environmental consciousness (Zverev *et al.*, 1994). Because of the structural features of environmental consciousness, it can be inferred that its formation is a long and complex process, which depends on a great number of factors. Except for "adequate environmental consciousness" described in the literature, its other forms must not be discussed in schools because their nature contradicts the goal of environmental education, which is preparing young people for resolving ecological problems and adopting pro-environmental behaviour. Therefore, shaping adequate environmental consciousness is the main goal of environmental education.

Building environmental consciousness in particular contexts of Carpathian Mountains requires a profound understanding of the danger of global ecological catastrophe and local ecological crises. Achieving this goal is possible only through systematic, step-by-step education at all stages of secondary school. Environmental education must focus on shaping a safeguarding attitude to nature. Ecological competence is a cognitive constituent of environmental consciousness, which reflects a body of knowledge about the natural world, the principles and models of interacting with it. It is shaped during the formal education through a special system of educational activities or through self-education as an independently organized activity.

Losev (2010, p.11) is of the opinion that environmental consciousness is built by socio-cultural factors, which urge an individual to act according to their goals; such factors cannot be normal (they do not possess features of crisis situations) since an absence of a problem cannot lead to a new understanding, a new attitude to nature. It follows from this explanation that social and individual experiences arising from ecological crisis motivate an individual to search for a new understanding of the natural world under the emergent socio-cultural conditions. Therefore, socio-cultural circumstances reflect a crisis between society and nature; and new social and personal experiences lead an individual to the development of a new environmental consciousness capable of building a new relationship between nature and society, preventing crisis, reducing tension, searching for environmental solutions. Therefore, the development of the cognitive dimension of environmental consciousness relates to worldviews, which shape attitudes to nature and foster environmental consciousness.

Furthermore, the development of environmental consciousness depends on the cognitive (knowledge and constructive ecological reasoning) and emotive (emotional experiences and feelings associated with environmental interaction) aspects of consciousness, which determine the perception and mental reflection of this part of an individual's life. There are two types of ecological consciousness shaped under the influence of mental processes. One type is marked by automatic involvement of scientific knowledge of ecology and personal ecological experience by analyzing situations, identifying their interconnections, comparing primary information with newly acquired ecological knowledge, predictions, judgments, analytical forecasts and models, and, finally, new environmental behaviour patterns. The other type is characterized by emotional judgment, which arises from personal experiences, assumptions and judgments based on "trusted sources" of environmental knowledge and personal intuitions about ecologically salient events, sources of information, environmental resolutions made by governmental bodies and officials (Chuikova, 2012a, 2012b; Chuikova and Chuikov 2014a, 2014b).

Therefore, the selection of information in the course of building the cognitive aspects of environmental consciousness must be based on a historical analysis of natural and social detrimental factors, which lead to a shortage of food, territory, energy or any other vital resource, because they are representative of the effects on the development of human population and human-nature relations, and they stimulate interest in finding ways of building a harmonious ecological relationship. In addition, it is necessary to conduct an analysis of social factors, which provoke environmental consumerism blurring humane attitudes to nature. The development of critical ecological reasoning and adequate environmental judgments must be based on analyzing academic publications and scientific popular literature, social aspects of using ecological resources, environmental legislation, mass media reports (Chuikova, 2014).

Environmental education is intended to build adequate environmental consciousness on the basis of knowledge and skills acquired in the course of environmental education. Specifically, it is important to develop the ability to analyse one's own impact on natural resources and choose environmentally sustainable strategies. Hence, adequate environmental consciousness manifests itself in a pro-environmental lifestyle. Additional determinants of adequate environmental consciousness include the well-formedness of self-organization, self-control, self-restraint and self-motivation.

To prevent the aggravation of dangerous ecological situations in mountains, it is necessary to learn to treat nature on a par with humans. There is interdependence between adequate environmental consciousness and environmental perception, environmental stewardship. Thus, attitudes and value orientations are the major constituents of environmental consciousness, which determine attitudes to environmental issues. In building adequate environmental consciousness in cotext of mountains, the key factor is a move away from anthropocentric to ecocentric environmental consciousness. Building environmental consciousness is linked to socialization. Social well-being and environmental value orientations are interdependent. Therefore, environmental education must embrace all social institutions – from family through school to society as a whole. Dominant value orientations determine decision-taking and behavioural patterns (Chuikova, 2013).

A child's environmental consciousness takes its roots in the family and continues in primary school under the guidance of teachers, with whom the child spends most of the day. Yet, a child's exposure to the natural world can have profound effects. Perception is associated with the emotional experience of the significance of the human-nature interaction, comparison of one's own ideas with societal ecological norms, followed by the development of one's own views. Building adequate environmental consciousness is facilitated by observing ecological attitudes in the child's family circle. During a lifetime, an individual will accumulate environmental knowledge from schools, the mass media, family members and peer friends, outdoor activities, other professional and personal experiences.

3.7 The environmental education of children living in mountainous areas

This research shows that the impact of high-altitude environments on the mental development of primary school children is reflected in spirituality and local traditions associated with the human-nature relationship. Thus, the human-nature relationship is traditionally viewed from two perspectives: the first one focuses on the links between an individual's psychophysiological development and his/her geographical and living conditions; the other one explores the effect of mental maturity and national mentality on environmental behaviour. While the first perspective is traditionally believed to have greater explanatory power, we will contemplate all the above-mentioned factors as a single coherent whole. Therefore, personal growth and mental development can be the key to the challenges of the natural environment of mountains.

The analysis of data shows that there is a significant body of literature exploring the impact of a child's family and school, peers and adults, as well as the mass media on their ecological conscience. However, the interdependence between the geographical conditions, particularly those in mountainous areas, and household activities, traditions, mode of life is scantily studied in Ukrainian national academia. According to Gumilov (2001), differences in the human-nature relationship stem from different geographical living conditions; therefore, the essence of an individual's environmental consciousness is shaped by their experiences with nature. Hrushevsky (2012) demonstrates that the culture and mentality of Ukrainians are inextricably connected with their natural living conditions. Exploring the spiritual life and household activities of Ukrainians, Kostomarov (1921) identifies their culture-specific characteristics such as individualism, tolerance, unity of religious faith and the church, high spiritual development, and respect for a woman in society. Chyzhevsky (1992) emphasizes the importance of the natural environment for the development of Ukrainians. More specifically, the author regards landscape as the main contributing factor to the Ukrainian psychic make-up; Ukrainians are described as emotional and sentimental, sensitive and lyrical, individualistic and striving for freedom, which can sometimes lead to self-isolation, proneness to conflict, and restlessness. Gachev (1999, pp.47-48) explores how an individual's living conditions (terrain, climatic conditions, weather patterns, flora and fauna) determine their choice of subsistence mode (foraging, horticulture, pastoralism, agriculture) and shape their worldview. A person saturates the surrounding natural environment, uses it to satisfy his/her needs for subsistence and, at the same time, the natural environment saturates the person, his/her household, soul, body and mind. Kulchytsky (1993) notes that vast forest areas associated with mystery and danger develop a tendency towards caution, suspiciousness, patience, apprehension, fear and adaptability. According to Rybchyn (1996, pp.21-23), forest dwellers tend to be romantic and to live in harmony with nature, which is vividly reflected in their folklore, patterns on their craft objects, colours and sounds reminiscent of nature. Khrushch (1994, 2008) describes the Carpathians as emotional, impulsive, dynamic, cheerful and passionate, which can be attributed to the geographic diversity of a high-altitude area with its blooming vegetation and the vibrant interplay of light and shadow.

The character of a primary school child living in a high-altitude area is shaped under the influence of landscape and climate, including the associated risks: squalls, wild rivers, landslides, atmospheric instability, long winter and short summer, hypoxia, hypothermia and so on. The impact of such conditions on a child's character is unavoidable. This might explain the reasons for the commonly held opinion that mountain dwellers are proud of, brave, resilient, independent, courageous, inventive, and so on. Similar descriptions can be found in folklore, fiction, research papers in ethnology, history, ethnopsychology; however, they tend to be unsubstantiated and lack generalizability (Khrushch, 2008, p.174).

The negative traits commonly attributed to mountain dwellers include "intolerance, disregard for authority, grudge bordering on revengefulness, pointless persistence bordering on stubbornness, covert envy, obsessive fear of being deprived of their land, irritability, psychological instability, neglect of familial values, suspiciousness of strangers and so on"

(Khrushch, 2007-2008a, p.174-175). In our opinion, it depends on livelihood, mode of life, cultural and historical traditions.

If a person is capable of grasping the essence and significance of the natural world, he/she also understand their dependence on it and try to live in harmony. The possibility of a harmonious co-existence between human and nature depends on intellectual, moral, aesthetic, spiritual maturity. Narrow-mindedness, ignorance, false beliefs in human exceptionalism and omnipotence lead to barbaric, ruthless destruction of nature. Thus, a crisis of spirituality gives rise to environmental crisis because most of the problems we face are inside of us. This is the reason why human has the key role in the human-nature relationship.

School age is the most sensitive period of shaping the perception of a human as exceptionally important, perfect and unique due to having consciousness. Yet, a human continues to depend on climate, flora and fauna, landscapes, atmospheric phenomena and so on. Natural disasters expose a person's limited power and the importance to safeguard the environment.

We are strongly convinced that the changes happening in life, including those in the human-nature relationship system, depend on a person's level of development, orientation (towards the good or evil, improvement or destruction, augmentation or wastage), morality, spirituality and environmental consciousness (Khrushch, 2013, p.5).

Only a highly conscious and cultured person is capable of combining, on the one hand, the feeling of great awe for the nature of mountains, the desire to preserve them for future generations and, on the other hand, the need to use their resources for improving human life. Spiritual development (which is based on faith, sympathy for others, concern for the consequences of own actions), enables a person to control their desires and make rational choices, thus protecting themselves from being enslaved by comfort at the cost of dominance over nature by using novel technologies.

Human and nature are closely intertwined, with the former being an important part of nature. At the same time, conscious as human is, they do not always display sufficient development and culture. The interdependence between cultural, moral, spiritual development and environmental protection has been discussed by many thinkers. To illustrate, the Austrian scientist Lorenz (1974) describes the "deadly sins" of a civilized person: overpopulation, devastation of the environment, man's race against himself, the breaking with tradition, emotional entropy, indoctrinability, genetic decay and nuclear weapons. In this regard, worthy of special mention is Pope John Paul II's opinion that "the seriousness of the ecological issue lays bare the depth of man's moral crisis" (John Paul II, 1990). Rohozha (2006) wrote about the issue[1] thuswise:

> "Ecological crisis is a systemic crisis of values, a crisis of our cultural existence ... [abridged] therefore, it is necessary that we activate our ability ... [abridged] to resolve the ecological crisis through overcoming the crisis of spirituality, a crisis of cultural exploration of the world." (Rohozha, 2006, p.123)

The spirituality of school age children is shaped through work: while working together with adults, children acquire an understanding of the importance of labor in fighting poverty, create a sense of rightful possession of forests, valleys, cultivated by their ancestors. While morality and spirituality based on industriousness, care and thrift.

[1] *Криза довкілля - це системна криза цінностей, криза нашого культурного існування... тому потрібно активізувати нашу здатність... вирішення кризи екологічної через подолання кризи духовної, кризи культурного освоєння світу.*

Lomatsky (1960) writes that during the times of Dovbush[2] there was no place for poverty in the Carpathian Mountains. Dovbush himself considered poverty to be a sin committed due to laziness. *Hutsuls*[3], with their keen sense of dignity and industriousness, believe that a healthy, able-bodied person must not be poor; this might only happen to the frail, lonely or elderly.

Studying the development of the relationship between nature and children inhabiting high-altitude areas entails exploring their mental processes, worldviews, social perceptions, reactions, sensory images, verbal and non-verbal communication, reasoning skills and so on. In addition, it is necessary to measure the depth and stability of mental processes, memory, consciousness and self-awareness. Another dimension worthy of investigation includes self-esteem, respect for spiritual and material heritage, a commitment to preserve it and deter environmental destruction in Carpathians.

4. Conclusion

Considering the theoretical analysis of environmental consciousness in context of Carpathian Mountains, it is important to fully grasp the close bond between human and nature. Attitude to natural resources is indicative of environmental culture and consciousness.

Environmental consciousness is an integrative construct that encompasses knowledge, values and behaviour patterns, which manifest themselves in environmental stewardship and consumption. An individual's higher-order environmental consciousness is consistent with ecological wisdom; an individual is guided by them in their ways of living and domestic activities. Adequate environmental consciousness underlies pro-environmental behavior of mountainous people.

The underlying dimension of adequate environmental consciousness includes environmental education programs involving a combination of educational approaches that foster value orientations and worldviews aimed at environmental stewardship, capacity to logically process environmental issues, develop strategies of achieving sustainable ways of living though self-restrained consumerism.

A child's environmental consciousness is largely shaped by their adult community, as well by hands-on experiences with nature, a sense of connectedness to nature. Such sensorial engagement creates values. Effective environmental education must enhance a child's hands-on experience by involving child-parent transmission of knowledge, skills and commitments that lead to environmental stewardship in different circumstances and settings.

Building adequate environmental consciousness about mountains must teach parents and educators the fundamentals of understanding the intrinsic value of nature, with all its challenges such as squalls, blizzards, fast-flowing mountain torrents, deep canyons, sharp changes in weather conditions in order to ensure that children acquire true perceptions of the power of nature and the importance of environmental resilience in highlands. Building attitudes of concern for the environment in Carpathian Mountains will boost children's intention to safeguard nature in all its diversity, thereby protecting it from mismanagement and mindless devastation.

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[2] The leader of the resistance group based in the Carpathian Mountains and composed of Ukrainian peasants who rebelled against serfdom in the 18th century. They robbed the rich and distributed their property among the poor.
[3] An ethnic group of Ukrainian pastoral highlanders inhabiting the South-Eastern part of the Carpathian Mountains.

5. References

Beck, U. (2009). *World Risk Society*. Cambridge: Polity Press.

Chuikova, L. (2012a). Ekologicheskoe informatsionnoe prostranstvo i ego vliianie na ekologicheskoe soznanie [Ecological Informational Space and Its Impact on Environmental Consciousness]. *Astrahanskii vestnik ekologicheskogo obrazovaniia* [*Astrahan Bulletin of Ecological Education*]. 2(20): 15-40.

Chuikova, L. (2012b). O kliuchevyh poniatiiah, sviazannyh s ekologicheskim obrazovaniem, ekologicheskim vospitaniem i ekologicheskim informatsionnym prostranstvom kak faktorom, aktivno vliiaushchim na formirovaniie tipa ekologicheskogo soznaniia [On the Key Notions Associated with Ecological Education, Ecological Attitude and Ecological Informational Space as a Driving Force of Building Environmental Consciousness]. *Astrahanskii vestnik ekologicheskogo obrazovaniia* [*Astrahan Bulletin of Ecological Education*], 4 (22):122-129.

Chuikova, L. (2013). *Ekologicheskoe soznanie: sotsialno-pedagogicheskie aspekty, determiniruiushchie ego formirovanie: monografiia [Environmental Consciousness: Socio-Pedagogical Determinants of Its Development: A Monograph]*. Astrahan: Izd-vo Nizhnevolzhskogo Ekotsentra.

Chuikova, L. and Chuikov, Y. (2014a). Ekologicheskaia pedadogoka kak oblast issledovaniia i primeneniia [Environmental Pedagogy as a Field for Research and Application]. *Gumanitarnye issledovaniia* [*Humanitarian Studies*], 1(49): 111-118.

Chuikova, L. and Chuikov, Y. (2014b). Ekologicheskaia pedadogoka: soderzhaniie ekologicheskoi informatsii v kontseptsii formirovaniia adekvatnogo ekologicheskogo soznaniia [Environmental Pedagogy: the Content of Ecological Information within the Conception of Building Adequate Environmental Consciousness]. *Gumanitarnye issledovaniia* [*Humanitarian Studies*], 1(49): 118-125.

Chyzhevsky, D. (1992). *Narysy z istorii filosofii na Ukraini* [*Essays on the History of Philosophy in Ukraine*]. Kyiv: Orii, pp.15-19.

Darenskyi, V. (2006). "Dialog" liudyna-pryroda yak ekzystentsiinyi fenomen [The Human-Nature "Dialogue" as an Existential Phenomenon]. In: Tolstoukhov, A. et al. (Eds.), *Filosofiia Pryrody* [*The Philosophy of Nature*]. Kyiv: PARAPAN, p.29.

Deriabo, S. and Yasvin, V. (1996). *Ekologicheskaya pedagogika i psikhologiia* [*Environmental Pedagogy and Psychology*]. Rostov n/D: Feniks.

Dobronosova, Y. (2006). Tilesnist yak osnova rozuminnia yednosti pryrody ta liudyny [Corporeality as a Foundation for Grasping the Unity between Nature and Human]. In: Tolstoukhov, A. et al. (Eds.), *Filosofiia Pryrody* [*The Philosophy of Nature*]. Kyiv: PARAPAN, p.91.

Gachev, G. (1999). *Natsionalnye obrazy mira. Evraziia – kosmos kochevnika, zemledeltsa i gortsa* [*National Worldviews. Eurasia – a Cosmos of the Nomad, the Farmer and the Highlander*]. Moskva: Institut DI-DIK.

Girusov, E. (1983*). Ekologicheskoe soznanie kak usloviie optimizatsii vzaimodeistviia obshchetva i prorody* [*Environmental Consciousness as a Determinant for Optimizing the Interaction between Society and Nature*]. Moskva: Progres, pp.108-118.

John Paul II (1990). *XXIII World Day for Peace 1990, Peace with God the Creator, Peace with All of Creation.* [online] Vatican.va. Available at: http://www.vatican.va/content/john-paul-ii/en/messages/peace/documents/hf_jp-ii_mes_19891208_xxiii-world-day-for-peace.html [Accessed 8 May 2021].

Hrushevsky, M. (2012). Na horakh [In the Mountains]. In: Sokhan P. et al. (Eds.), *Tvory: u 50 t. T.13* [*Essays: in 50 volumes. Vol.13*]. Lviv: Svit, pp.196–199.

Gumilov, L.N. (2001). *Etnogenez i biosfera Zemli* [*Ethnogenesis and the Earth's Biosphere*]. SPb.: Krystall.

Khrushch, O. (1994). Vyvchennia etnopsykholohichnykh osoblyvostei kharakteru hutsuliv [Studying the Character of Hutsuls from an Ethnopsychological Perspective]. *Etnichna psykholohiia* [*Ethnic Psychology*]. Ivano-Frankivsk, p.45.

Khrushch, O. (2008). Vyvchaemo psykholohiiu horian [Studying the Psychology of Highlanders]. *Hirska shkola ukrainskykh Karpat* [*The Mountain School in the Ukrainian Carpathians*], 2-3:174.

Khrushch, O. (2008a). Vyvchaemo psykholohiiu horian [Studying the Psychology of Highlanders]. *Hirska shkola ukrainskykh Karpat* [*The Mountain School in the Ukrainian Carpathians*], 2-3: 174-175.

Khrushch, V. (2013). Hory yak osoblyve seredovyshche rozvytku osobystosti [Mountains as a Special Environment for the Development of Personality]. *Hirska shkola ukrainskykh Karpat* [*The Mountain School in the Ukrainian Carpathians*], 8-9: 3-8.

Kiselov, N. (1990). *Mirovozzrenie i ekologiia* [*Worlview and Ecology*]. Kyiv: Nauk. dumka.

Kochergin, A., Markov, Y. and Vasilev N. (1987*). Ekologicheskoe znanie i soznanie: osobennosti formirovaniia* [*Ecological Knowledge and Consciousness: Development Specifics*]. Novosibirsk: Nauka.

Konnov, O.F. (2006). Vzaemovidnosyny liudyny z pryrodoiu yak ontolohichna problema [The Human-Nature Relationship as an Ontological Problem]. In: Tolstoukhov, A. et al. (Eds.), *Filosofiia Pryrody* [*The Philosophy of Nature*]. Kyiv: PARAPAN, p.67.

Kostomarov, M. (1921). *Knyhy bytiia ukrainskoho narodu* [*Books of the Genesis of the Ukrainian People*]. Lviv-Kyiv.

Kulchytsky, O. (1993). Rysy kharakterolohii ukrainskoho narodu [The Characterology of the Ukrainian People]. *Entsyklopediia Ukrainoznavstva* [*The Encyclopedia of Ukrainian Studies*]. Vol.2. Lviv, p.708.

Lihachev, B.T. (1993). Ekologiia lichnosti [The Ecology of Personalty]. *Pedagogika* [*Pedagogy*], 2: 19–23.

Liuri, D. (1997). *Razvitie resursopolzovaniia i ekologicheskie krizisy, ili zachem nam nuzhny ekologichaskie krizisy?* [*The Development of Natural Resource Use and Ecological Crises, or Why Do We Need Ecological Crises?*]. Moskva: Delta.

Lomatsky, M. (1960). "*Verkhovyno, svitku ty nash". Narysy z Hutsulshchyny* ["*Verkhovyna, you are our world". Essays from the Hutsul Region*]. New York: Hoverlia.

Lorenz, K. (1974). *Civilized Man's Eight Deadly Sins. Translated by Marjorie Kerr Wilson*. New York: Harcourt Brace Jovanovich.

Losev, V. (2010). Osnovnye kulturno–ideologicheskie determinanty "ekologicheskogo soznaniia" [Major Cultural and Ideological Determinants of "Environmental Consciousness"]. PhD Dissertation, Saratov.

Medvedev, V. and Aldasheva, A. (2001). *Ekologicheskoe soznanie: Uchebnoe posobie* [*Environmental Consciousness: A Study Manual*]. Moskva: Logos.

Morris, M. (2002). Ecological consciousness and curriculum. *Journal of Curriculum Studies,* 34(5): 571-587. DOI: 10.1080/00220270110108187

O'Sullivan, E. and Taylor, M. (2004). *Learning Toward an Ecological Consciousness: Selected Transformative Practices*. London: Palgrave Macmillan Ltd.

Rohozha, M. (2006). Pryroda yak etnosna tsinnist [Nature as an Ethnic Value]. In: Tolstoukhov, A. et al. (Eds.), *Filosofiia Pryrody* [*The Philosophy of Nature*]. Kyiv: PARAPAN, p.84.

Rohozha, M. (2006). Pryroda yak problema kultury [Nature as a Cultural Issue]. In: Tolstoukhov, A. et al. (Eds.), *Filosofiia Pryrody* [*The Philosophy of Nature*]. Kyiv: PARAPAN, p.123.

Rubinshtein, S. (2000). *Osnovy obshchei psihologii* [*Foundations of General Psychology*]. SPb.: Piter.

Rybchyn, I. (1996). *Heopsykhichni reaktsii i vdacha ukraintsia* [*Geo-psychic Reactions and Ukrainian Character*]. München: Dniprova Khvylia.

Shagun, G., Pavlov, V. and Ryzhenkov, P. (1994). Issledovaniie ekologicheskogo soznaniia detei i podrostkov [An Exploration of Environmental Consciousness in Adolescents and Children]. *Psikhologicheskii zhurnal* [*Psychological Journal*], 15 (1).

Simonova, T. (1999). Sotsialnaia ekologiia v sisteme ekologicheskogo obrazovaniia studentov [Social Ecology in the System of Environmental Education of Students]. *Materialy yubilienoi nauchno-prakticheskoi konferentsii "Problemy Severo-Zapada: ekologiia i obrazovaniie"* [*Proceedings of the Jubilee Research to Practice Conference "North-West Issies: Ecology and Education"*]. Saint Petersburgh, pp. 41-42.

Suravegina, I. (1990). Ekologicheskoe obrazovanie v shkole [Ecological Education in School]. *Sovetskaia Pedagogika* [*Soviet Pedagogy*], 12: 47–49.

Vernadsky, V. (1967). *Biosfera* [*The Biosphere*]. Moskva: Mysl.

Vygotsky, L. (1982). *Sobranie sochinenii: V 6-ti t. T.1.* [*A Collection of Essays: In 6 volumes. Vol.1]*. Moskva: Pedagogika.

White, P. (2009). *A phenomenological exploration of ecological consciousness development*. PhD Dissertation, Sydney.

Yasvin, V. (2000). *Psihologiia otnosheniia k prirode: monografiia* [*The Psychology of Treating Nature:* A Monograph]. Moskva: Smysl.

Zverev, I. et al. (1994). *Ekologicheskoe obrazovaniie v shkole. Kontseptsiia [Ecological Education in School. A Conception]*. Moskva: Moskovskii tsentr mezhnatsionalnogo i sravnitelnogo obrazovaniia.

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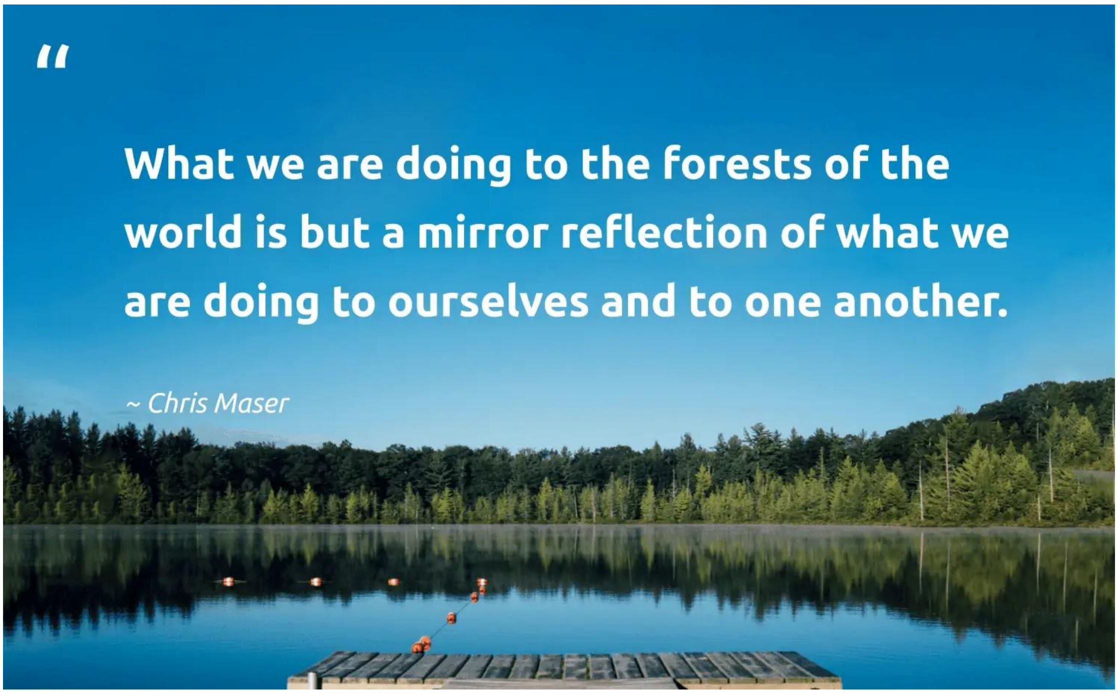
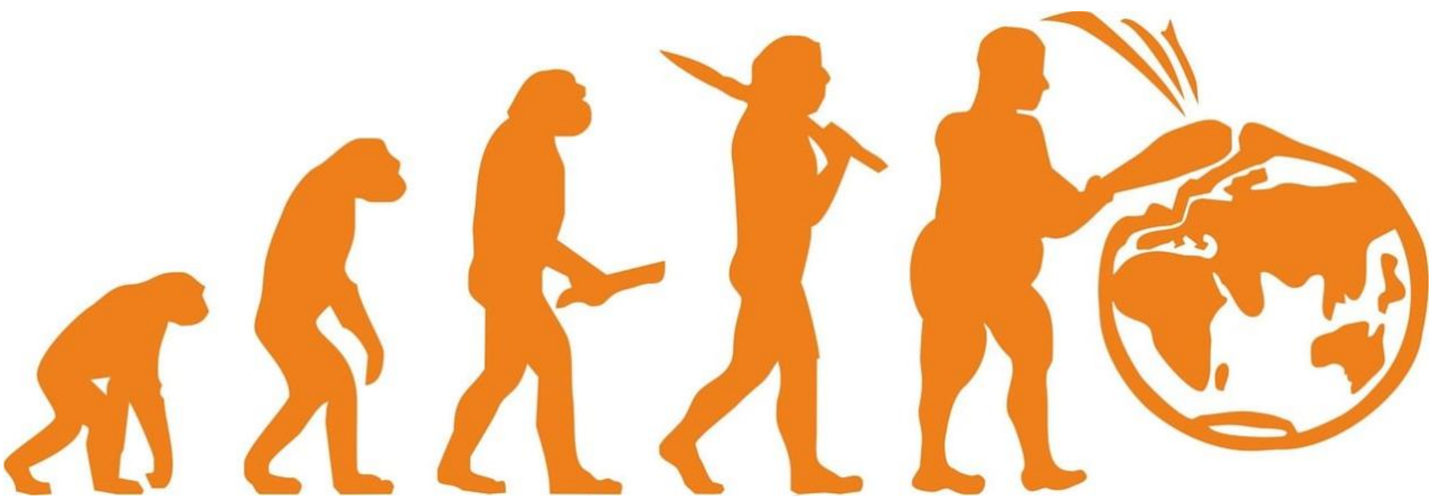

"
What we are doing to the forests of the world is but a mirror reflection of what we are doing to ourselves and to one another.
~ Chris Maser

Chapter 21

Collective Ecological Consciousness from the Prism of Psychological Indicators

By Olena Khrushch, Oksana Fedyk and Yuliya Karpiuk



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Collective Ecological Consciousness from the Prism of Psychological Indicators

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Abstract

This chapter presents the results of a theoretical analysis of the concept of collective ecological consciousness from the standpoint of psychological indicators. It also displays fundamental differences between ecological and individual consciousness in mountain contexts. Furthermore, the chapter depicts the correlation between environmental culture, which arises in the process of socialization, and the power of environmental intents aimed at protecting the environment. During the integration into society, an individual learns a universal system of beliefs, values, customs, traditions, norms, and rules that are followed by dominant public. They also evolve relationships with the world and nature surrounding them. In particular, in a society with a high level of development of collective ecological consciousness, young people from an early age employ effective strategies for the conservation and restoration of natural resources in highlands. Thus, the authors draw attention to the crisis of morality and spirituality, which are the main reason for developing a selfish type of collective ecological consciousness. The authors give examples of environmental education concepts and training to lay the theoretical foundation for developing effective programs to improve environmental culture in the younger generation.

Keywords

Collective ecological consciousness; Ecological psychology; Socialization; Environmental culture; Environmental education; Valuable Orientations; Spirituality

Citation

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1. Introduction

The relationship between humans and nature has always attracted the attention of researchers in various fields of science. However, recently, the relationship between humans and nature also affects human economic activity, and the environmental problem is becoming more acute and threatening as it spreads from local-regional-national–global scales (Miroshkin *et al.*, 2019). The individuals, who carry out actions based on a deeper understanding of the laws of nature, taking into account the many areas of interaction in natural ecosystems and awareness of our belonging to the environment, have stake in the process of the salvation of the planet (Andy, 2009; Mueller, 2009). Thus, we can conclude that the ecological and moral tenets of human interaction with nature have moved from many environmental issues. One such issue is a shift from demand and other negative impacts of human activities on wildlife to find ways to prevent negative consequences of the anthropogenic impacts on building conscious and purposeful relationships with it (Ingalsbee, 2016; Kronlid and Öhman, 2012).

The integration of the said strategy of relations with nature into everyday life is an example of development of ecological culture and moral and ecological consciousness at individual and collective levels, which depends on a person's beliefs, worldviews, and values. Thus, environmental education and increased level of collective ecological consciousness and culture are becoming increasingly important, as we approach large-scale environmental problems. However, unfortunately, the transition to a market economy, which is closely interrelated with the forced course of capitalization processes, increases the wealth, while rejecting fundamental moral principles and norms. At the same time, they often develop behaviors aimed at transformation, activity, and extermination, which prevail over the ability to enjoy natural beauty. Therefore, we can conclude that the crisis of morality deepens the current environmental crisis. The type of the relationship with nature is closely interrelated with the learned moral principles and the level of development of the moral consciousness of each individual and society. That is why the question of ecology is the need for this research connecting to moral education and socialization processes, taking into account all the psychological aspects of these intricate processes.

Humanity cannot survive without an ecological consciousness, that is, from its essence. Therefore, we must permeate this consciousness in all directions including the industry, technology, production. The science should have its transformation for catering the life of present and future generations. Ecological consciousness is the basis for understanding the need for environmental protection and awareness about the lack of a holistic position in interacting the environment. At the same time, ecological consciousness provides an understanding and awareness about personal responsibility of a particular person to preserve certain species of animals and plants and all life on Earth. Given that it is formed based on collective ecological consciousness, it is crucial to understand the principles and ways of greening the society's worldview.

2. Methodology

This chapter presents a theoretical analysis of scientific papers and publications that highlight current issues of environmental psychology in special context of mountain ecosystems.. In particular, the authors explored the essence of collective ecological consciousness, which is considered common to a particular social structure of views on environmental issues, strategies for building relationships with nature, and its conservation, . The latter relies on knowledge of natural ecosystems and unique ideas about unity, the population of the planet, and the environment as a whole. The authors first explored the relationships between collective ecological consciousness, environmental culture, environmental intentions, and individual behavior. Therefore, the predominance of a pragmatic approach and its effects on the use of natural resources are described.

Additionally, spiritual and moral aspects of the formation of the behavior are represented. Finally, identified are the key ways to raise ecological consciousness and culture through systematic environmental education and training among young people's using socialization process as a tool. In conducting this study, the focus was on the principle of systematicity in describing the psychological phenomenon studied along with the factors of its formation. The scientific paradigm of the doctrine of the noosphere and accumulated psychological knowledge of consciousness were also taken into account.

3. Results and Discussion

3.1 The concept of ecological consciousness

Before understanding the essence of the concept of collective ecological consciousness and the methods of its formation, it is pertinent to reveal the meaning of the concept of consciousness as a category of psychological science. Thus, consciousness is the unity of all mental processes, states, and properties of human as a person. It is one of the most challenging ways to reflect objective reality spiritually. Consciousness is an integrative formation that combines all the forms of knowledge and human experience known to science and the attitude to what it reflects. It follows that consciousness is a specific form of human life and the product of its interaction with objective reality.

It is worth noting that philosophers, psychologists, and sociologists have studied the phenomenon of consciousness for many centuries. In particular, Descart (1984) defined consciousness as a completely independent entity, in other words, a mental substance, the nature of which finds its expression in the process of thinking. On the other hand, Leibniz (1989) argued that human consciousness is a holistic system, the elements of which are constantly interacting with each other and closely interconnected. In this case, apperception (the process of perception) is its core.

Wundt (1927) defines consciousness as "inner experience". It is only the "immediately real" phenomena constituting this experience, and nothing behind or beyond it. That is the object of psychology, as opposed to the physiological or psychophysical investigation (Kim, 2016).

Analyzing the meaning of the concept of consciousness, Taylor (1982) noted, "we know from our own experience what consciousness is: it is the understanding of ourselves and the world around us that is the basis of our existence. Beyond this, however, we know almost nothing about the nature of consciousness, and there is a reason for this: consciousness cannot be seen, felt, touched" (Taylor, 1982, p. 167).

At the same time, in modern psychology, we can distinguish three main approaches to study the phenomenon of consciousness. Primarily, these approaches include the 'biological naturalism approach' (Revonsuo, 2001), the 'global workspace theory' (Baars, 1988), and the 'introspective physicalism approach' (Jack and Shallice, 2001). Moreover, recent theoretical models, for example, introspective physicalism, proposed by Jack and Shallice (2001), have stressed the strong relationship between executive function and conscious awareness. In other words, it is aware of its representation and performs intentional self-monitoring and evaluation, otherwise known as introspection. Conscious contents provide the nervous system with coherent global information (Baars, 1983).

Abstract concepts as consciousness, including our currently expressible beliefs, intentions, meanings, knowledge, and expectations, need attention (Baars, 1988). In reality, every task people engage in involves all three elements: conscious experience, access, and control. Ultimately, the role of consciousness cannot be understood if we do not explore all three. However, one can make the case that conscious qualitative experience is fundamental to understanding other aspects and uses of consciousness (Baars, 1988).

Consciousness enables comprehension of novel information, and conscious information enables many types of learning using various brain mechanisms (Baars, 2002). Within a single cognitive cycle, consciousness functions to filter the attention paid to the agent's internal model of its world and to select contents to be learned (Baars and Franklin, 2007). In addition, conscious goals and perception of results enable voluntary control (Baars, 2002). The psychological dictionary interprets consciousness as a high level of mental reflection, which is unique to human and is empirically manifested in a set of sensory and mental images. As 'attitude to the world with knowledge', consciousness is defined in other psychological dictionaries. According to Skripnik (2012), 'consciousness' is the highest form of the most general property of matter - reflection. This concept consists of generalized, evaluative, and purposeful reflection of reality in its constructive and creative transformation, advanced numerical modeling of actions, the anticipation of their consequences, and rational regulation and self-control of human activity (Skripnik, 2012).

One of the modern scientists, Furman (2017), emphasizes that adequate methodological tools and instruments for comprehensive knowledge of such an incredibly complex phenomenon as consciousness have not yet been created. The researcher insists that consciousness is a multifunctional being that generates meanings and values. According to the scientist, consciousness is the actualization of cognitive, sensory, intentional, intuitive, and other psycho forms (personal experiences, thoughts, knowledge). Therefore, they all enable reflection in acts of self-awareness and self-conceptualization (Furman, 2017). The latter is a practical approach forming ecological consciousness in future generations. Thus, two main aspects of consciousness can be identified. In particular, they include the processes that take place in consciousness. These include attention, memory, emotions, and more. At the same time, the other side of consciousness is represented by its content. The latter is the basis for 'conscious life' and the formation of attitudes toward the world. Universality and objectivity are the main properties of consciousness (Plyaskovskiy, 1991). Suppose the universality of consciousness is the awareness of the reflected and the detection of personal activity. In that case, the objectivity of consciousness reflects only particular objects, aspects, and properties used in practical human activities (Plyaskovskiy, 1991).

Accordingly, analysis of approaches interpreting the concept of consciousness showed that most authors note four main psychological components in its structure. These elements include knowledge, differences between subject and object, goal setting as a component of activity, and attitude to self, world, and other people. Based on the above definitions of consciousness, in modern scientific and methodological space, many psychologists, philosophers and sociologists consider this phenomenon a higher form of reflection of reality, which is inherent in society and is associated with worldview and human thinking, self-control and anticipation of the results of their behavior and activities.

At the same time, various forms of consciousness have been formed in the scientific space, such as scientific, ecological, professional, philosophical, religious, pedagogical, moral, aesthetic, legal, political, etc. There is also a modern form of ecological consciousness (Plyaskovskiy, 1991; Skripnik, 2012). Each form of social consciousness has its specific ways and objects of reflection and a special kind of knowledge.

In particular, ecological consciousness is a form of social consciousness at the formation stage. Ecological consciousness covers the whole set of ideas, theories, views, and motivations that reflect the ecological side of social life. It also includes the actual practice of relations between man and his environment, society, and nature, including a set of regulatory principles and norms of behavior aimed at achieving the optimal state of the system 'society-nature' (Skripnik, 2012).

Ecological consciousness is understood as a higher level of mental reflection of the natural and artificial environment, one's inner world, reflection on the place and role of human in the biological world, and the regulation of this reflection (Skrebets, 1998). Skrebets (1998) states: "Consciousness, like thinking, can be determined by the content and direction of the dominant attitude of human (or people) to reality. In this understanding of the essence of ecological orientation concerning the ecological content of the mental reflection of reality, we can talk about ecological consciousness". Dobryden (2004) proposes the following definition of ecological consciousness: "Ecological consciousness is a type of social consciousness, which is a worldview system of views, ideas, theories and emotions that determine the practical and creative activities of human in the formation of socio-ecological relations, and vice versa". Levochkina (2003) emphasizes that ecological consciousness is a higher level of mental reflection of different types of the surrounding world, especially the natural, artificial, and social environment and one's inner world. The researcher also attaches great importance to reflection, through which awareness of the place and role of human in the ecological world. Skladanovska (2006) emphasizes: "The term ecological consciousness should mean not just the attitude to nature and a set of ideas about the relationships within the system 'man-nature', but the higher level of development of human consciousness and self-consciousness, its worldview aspect largely corresponds to the concept of 'environmental' and is characterized by awareness of life as an excellent value for any creature, a willingness to grind before life piously. According to the scientist, such a worldview fills the deep essence of every human action and reveals its moral aspect, which is familiar with the vector of evolution. She notes that the focus of eco-consciousness is the creative power of human thought.

Fenchak's (2005) works present an integrative approach to the definition of ecological consciousness. The scientist sees the notion as a manifestation of the highest form of reflection of the actual ecological situation, responsible for a holistic view of environmental problems, awareness of human unity and environment, a sense of responsibility, a healthy lifestyle, and active environmental activities. Mainly, a person's attitude to the world around him determines the aspects mentioned above (Fenchak, 2005).

Based on the analysis of scientific works by Nabochuk (2013), we can conclude that the ecological consciousness of the individual means a high level of individual reflection of the surrounding reality. This environment ensures harmonious coexistence and interaction of man and nature.

Shedlovska (2013) understands ecological consciousness as a complex of specific knowledge (particularly the one which lies within the plane of human ↔ society ↔ nature), emotions, and evaluations. All of these reflect the specific way of treating the nature, creating the appropriate emotional background, testifying a certain level of environmental concern and instructions on the actions taking place in a particular field of values determineing each of the components above and manifests itself in these components. The essential cognitive component is knowledge because it includes the totality of ideas and concepts of individuals about the environment, the interrelation of humans and nature, and the results of these relations. The effective component is formed by personal subjective evaluation of the individual and by emotion that arises as a result of the system of relations ''human – environment'. Active component shows readiness for action, which has a tremendous significance for society. Strictly ecological behaviour is that index, the most noticeable results, carrying the benefit or harm, especially when there is an interaction between human and surroundings. Therefore, ecological sets produce this component as the readiness for a particular behaviour, readiness to support or not specific actions in a 'human-environment' system. Besides, those sets can reflect the support or lack of social-ecological offers. Thus, we may consider cognitive, affective, and active components the structural elements of ecological consciousness, each highly influenced by the values field within which an individual exists. It means that ecological consciousness contains specific knowledge relevant to the correlation in the system 'human – environment', the assessment of its values, and specific settings to actions within this system (Shedlovska, 2013). According to the researcher, the proposed definition does not go beyond the classical triad in the interpretation of consciousness through the cognitive component (mental reflection of the natural, social, artificial, and internal environment), emotional (attitude to the environment), and connotative components (behavioral – self-reflection and self-regulation of the environment, strategies, and technologies of interaction with it).

Puk (2018) defines ecological consciousness as "an empathic and abiding, connecting-presence with natural processes. Ecological consciousness aims to find a sustainable niche for human beings in the Earth's natural order and preserve ecological integrity" (Puk, 2018, p. 118). Ecological consciousness fills our whole being and guides us in our daily decision-making (Puk, 2018). Morris (2002) says that an ecological consciousness thrusts humankind back into the world and down into the earth, and the focus shifts from human-centered to earth-centered (Morris, 2002, p. 580). According to Thomashow (1996), it is a high level of ecological understanding and awareness, and the sense of self as part of a larger system (Thomashow, 1996, p.19).

In general, Lysianska and Bielousova (2020) distinguish between regulatory, cognitive, structural, and integrative approaches to define the essence and content of the concept of 'ecological consciousness'. Thus, ecological consciousness is the same consciousness, one of its forms. However, a particular specificity and direction characterize it. The differences are due to the uniqueness of the natural world and the constructive, creative components involved in its transformation.

Ecological consciousness is an integrative construct encompassing knowledge, values and behavior patterns manifesting in environmental stewardship and consumption. An individual's higher-order ecological consciousness is consistent with ecological wisdom; they guide an individual in their ways of living and domestic activities. Adequate ecological consciousness underlies pro-environmental behavior (Khrushch and Karpiuk, 2021). Considering the theories of consciousness described above, we conclude that increasing the level of environmental education leads to an automatic transition to a new model of environmentally sound behavior through changes in the type and forms of attitudes toward the environment.

3.2 The concept of collective ecological consciousness

Skrebets (1998) believes that grouping ecological consciousness is an integral part of the dialectical sum of individual perceptions of the environmental characteristic of a particular social group. At the same time, group ecological consciousness can act as a carrier of mass phenomena about the environment. In particular, the scientist explains the meaning of the concept of 'mass phenomena' of ecological consciousness. Thus, he interprets them as "homogeneous assessments, overlapping guidelines, accepted stereotypes, and internally inspired images of environmental disasters associated with people's mental experiences at the same time" (Skrebets, 1998, p. 44).

According to Skrebets (1998), public ecological consciousness is a set of priority feelings and opinions of various social groups on current and possible future environmental problems. In particular, the structure of public ecological consciousness includes generalized judgments, ideas, and stereotypes that reflect the attitude of large social groups or society as a whole to the phenomena and problems of ecology. Skrebets (1998) emphasizes the essential fact that "ecological mood in ecological, social consciousness is not only the most massive socio-psychological phenomenon but also one of the most influential forces that unite and motivates people to certain activities: production, domestic, cultural, educational, creative or destructive" (Skrebets, 1998, p. 44).

De Chardin (1965) stated: "We cannot wait passively upon the statistical play of events to decide which road the world will take tomorrow. We must positively and ardently take a hand in the game. If it is true, as I suggest, that salvation lies in the direction of an Earth organically in-folded upon itself, it is then surely evident that through a reciprocal mechanism of action and reaction, the vision and provision of this ultimate end, this outcome of History and Life, may be made to play an essential part in the building of the future, if only by creating the atmosphere, the psychic field of attraction, without which it will be impossible for humanity to continue to converge upon itself" (de Chardin, 1965, p. 256). The scientist pointed out that humanity must be considered a collective subject and a holistic organism endowed with a single mind. He interpreted history as the self-development of a single spiritual source. He further described this process as an evolution caused by the inner spiritual energy that gives rise to matter and its various forms and involves certain stages: survival, life, thought, and survival. The researcher calls the organized community of animate and inanimate biosphere. The origin of thought within the biosphere consolidates all forms of being in the noosphere. Then, the noosphere develops to perfect unity (integrity). The transition to it (perfection) is the 'point of Omega'. After that, the tendencies to isolation and disintegration will be overcome, and humanity will become the only intelligent organism in absolute harmony with the world (de Chardin, 1959: 407–417). In his analysis of the evolution of human and society, Krutov (2014) sees the bright future of humankind in the pursuit of just and peaceful coexistence on our long-suffering Earth and the boundless energy of love, goodness, joy, and happiness.

Moreover, a remarkable influence on the state of reality has a collective (not individual) consciousness. The strength and effectiveness depend on the critical number of participants who interact with each other. These participants are not only people but also other living beings (plants and animals), united in a community that creates a single information and energy field - the consciousness of the living, able to connect with the consciousness of the planet - the Earth's noosphere (Krutov, 2014, pp. 367 - 368).

Therefore, based on the analysis of approaches to collective ecological consciousness, we conclude that it is considered an integrative entity. The mentioned entity includes a set of views on building relationships with nature due to its level of knowledge, patterns, and ideas about the unity of the individual, humanity, and the environment. At the same time, the collective ecological consciousness determines the general interpretation of the forms and content of different types of interaction between human and nature, which is inherent in a particular social structure. Consequently, this type of ecological consciousness is characterized by the system of effective human activity for the environment. Furthermore, it analyzes the goals of interaction with the environment, strategies for organizing and implementing the impact on individual objects of nature, and ecosystem goals. Also, the collective ecological consciousness is the basis for the general acceptance and observance of all norms and rules governing the relationship between human and nature.

3.3 The structure of collective ecological consciousness

Levochkina (2004) identifies cognitive, emotional, and cognitive components in the structure of ecological consciousness. In particular, the cognitive component covers all ideas and beliefs about the natural, social, artificial, and internal environment. He is also responsible for the mental reflection of the surrounding reality. In this case, the emotional component forms a confident attitude to this environment through emotions and feelings that arise from contact with him. Finally, the cognitive component is responsible for self-reflection and self-regulation in the environment. Therefore, we can conclude that the behavioral component is responsible for the specific features of interaction with nature.

Dobryden (2004) refers to the structure of ecological consciousness of various types of environmental activities in each sphere of human existence. Skladanovska (2006) believes that ecological consciousness integrates seven components. In particular, it identifies the cognitive component, which covers the entire system of knowledge and ideas about the environment, evolution, development, role, and place of human in the universe, and its relationship with the ecosystem and the universe as a whole. The forecasting component provides the ability to predict the possible consequences of applying a strategy of environmental behavior in the long run. The creative component performs the function of imaginary and figurative modeling of probable developments in the ecological system and on Earth. In particular, it provides an opportunity to create a shared vision of the results and consequences of purposeful actions of each individual and human society. The integrative component is the foundation for understanding the need for the harmonious coexistence of human with nature. Therefore, it is due to this structural component of the collective ecological consciousness, a system of norms, principles, and rules of interaction with the world, economic activity, and use of natural resources based on knowledge of the laws of the biosphere and noosphere. The reflective component contributes to the ability to form assessments of individual and collective actions and the commonality of thoughts and feelings about the results of human activity in natural ecosystems. The moral component is the basis for forming collective and individual responsibility for everything that happens on Earth with human's participation, with his tacit consent, support, or lack of opposition (Skladanovska, 2006). The communicative component provides the ability to transfer accumulated human knowledge about nature in the process of interpersonal communication, learning, and education. The problem of self-education and upbringing in the youth is at the intersection of the reflective ability of ecological consciousness. Additionally, the presence of corresponding character traits and personality traits would catalyze the development of ecological consciousness and its formation at the collective level (Skladanovska, 2006).

3.4 Types of collective ecological consciousness

Shedlovska (2011) identifies five types of ecological consciousness: *conscious-activity, conscious-selfish, conscious-detached, limited-activity* and *limited-selfish*. In particular, individuals and social structures with deep environmental knowledge and well-developed skills and abilities used in everyday life and professional activities have a conscious-activity type of ecological consciousness. In this case, the relationship between human and nature is subject-subject. Thus, this type of ecological consciousness can be found in the teams of scientific and educational institutions and environmental organizations. At the same time, Shedlovska (2011) notes that this type of consciousness includes two subtypes: *active* (activity becomes the meaning of professional and daily life) and *passive* (activity not as a life credo, but depending on circumstances, specific events, such as the storms or floods, etc.).

Individuals and social structures with a piece of sufficient environmental knowledge, skills, and abilities but who do not use them in real life or professional activities are characterized by a consciously *selfish ecological consciousness*. In this case, the relationship with nature is subject-object. There are individuals and commercial entities that have a sufficient level of ecological awareness, yet they do not implement their knowledge in their real life or professional activities. This type of environmental consciousness is called consciously egoistical; consequently, such relations with the environment are subject-objective by nature. That is, the environment is treated solely as an object of consumer activities of an individual. At the same time, individuals with such a type of environmental consciousness clearly understand the consequences of their actions. They adhere to the behavioral strategy of an active consumer and use the natural resources solely for their own benefit. Nevertheless, the bearers of this type of ecological consciousness are aware of the consequences of their actions. However, they continue to follow a behavioral strategy of active consumption and use of natural objects only in cases of self-interest.

Among the representatives of the consciously detached type, a passive position on environmental issues is widespread. At the same time, they have a good set of environmental skills and knowledge. However, individuals and social structures with a consciously detached ecological consciousness consciously avoid active actions aimed at protecting the environment due to a lack of desire or motivation, despite the available opportunities. Therefore, the relationship with nature is object-object.

Limited activity type of ecological consciousness is characteristic of residents and social groups in rural areas. It is characterized by the lack of a sufficient level of environmental knowledge. At the same time, rural residents, based on their own experience and intuitive approach, tend to conduct their activities taking into account the interests of nature. However, this ecological consciousness can be divided into active and passive representatives. At the same time, the relationship with nature is subject-subject.

The bright example of a limited-selfish type of ecological consciousness is when the interests of its bearers dictate their actions. However, unfortunately, the bearers do not know the harmfulness of their actions and skills that would help them not to do so. Relationships with nature have a typical subject-object nature, where nature is the object of achieving human goals and meeting the needs of society, i.e., the natural environment is exclusively the object of activity of each individual and society as a whole.

Summarizing the above, given the realities of modern Ukrainian society, we can identify three main types of collective ecological consciousness: altruistic or conscious-activity and limited-activity types of ecological consciousness (nature of the subject-subject relationship), neutral or consciously detached type object-object relations) and pragmatic or consciously selfish ecological consciousness (the nature of subject-object relations). Thus, we have tried to describe the main types of collective ecological consciousness ordinarily existing in Ukrainian society. At the same time, the key criterion in determining them was the presence of a set of knowledge, skills, and abilities that, in one way or another, relate to human interaction with nature.

Thus, a society with a high level of development of collective ecological consciousness evaluates information coming from the outside and inside world, considering the available knowledge and awareness of itself among all the diversity of environmental objects. Moreover, the society mentioned above preserves the existing system of attitudes towards other people and the environment. Such action serves as a basis for managing the behavior of each of its members. The development of the individual ecological consciousness of each person occurs amid the process of socialization, i.e., the entry of the individual into society and building a relationship with other people and their environment, which ensure the formation of this type of consciousness. The described process requires compliance with social norms and rules, meeting the needs in acceptable and legal ways, fulfilling commitments, and discipline, which should be manifested in behavior, expressions, and following traditions and customs dictated by collective ecological consciousness.

Palamarchuk (2003) notes that a system of ideas about the world (according to which the highest value is the harmonious development of human and nature) aims to interact with nature to meet the needs of human and nature. Consequently, the ecological imperative should determine the nature of the interaction: it is correct and permissible that it does not destroy the ecological balance; ethical norms and rules should apply equally to the interaction between people and the natural world. Thus, it characterizes the high level of development of collective ecological consciousness, which ensures the harmonious interaction of society with nature aimed at preserving and restoring its wealth.

3.5 Psychological features of the formation of collective ecological consciousness

The formation of collective ecological consciousness is influenced by the level of ecological culture, which is characteristic of a specific society. Simultaneously, ecological culture should be considered a systemic concept, the most critical and integral component of universal culture, reflecting the development level of individual and collective ecological consciousness. In particular, it covers the system of intellectual, moral, ethical, patriotic, legal, and aesthetic values of human and society as a whole, which contribute to the conservation of natural resources, environmental security, and sustainable social, economic, and cultural development of all humanity and each individual.

In 'Environmental Values in American Culture', three sets of values that influence the rise of environmentalism in American society are identified. They include:

1. religious and spiritual values based on religious teaching and spiritual beliefs;
2. anthropocentric values or human-centered views focused on human benefits (aestheticism, included) and goals;
3. bio-centric values emphasizing rights and ethics of nature (Kempton, Boster and Hartley, 1996)

Benton and Benton (2004) argue that forming a system of environmental values is closely linked to mastering human activity's socio-cultural and economic context. Thus, the problems of ethics of relations with nature reveal their content not in special thematic sections or subjects but in discussing the moral aspects of various types of human life. At the same time, the critical role belongs to the ability to reflexively perceive the consequences of their behavior and any interaction with nature.

It should also be noted that a society with a high level of development of ecological culture subordinates all types of its activities to the requirements of rational use of natural resources, cares about improving the environment, and takes measures to prevent its destruction and pollution. At the same time, the dissemination of actual scientific facts, the formation of appropriate value orientations, and mastering practical skills and abilities to apply constructive strategies of interaction with the environment is a solid basis for the formation of a model of caring for nature.

Another critical factor in developing ecological consciousness and forming environmental culture is environmental responsibility. The psychological nature of environmental views and beliefs that influence the formation of personal and collective responsibility includes three main components. The intellectual aspect encompasses a set of environmental knowledge and intellectual skills that are associated with the process of forming a worldview. Also, this component includes methods of finding causal relationships between certain phenomena and processes. The personal aspect includes motivation, a system of attitudes and assessments, confidence in their ability to make a significant contribution to implementing a system of measures to prevent environmental catastrophe, and internal needs that necessitate environmental protection. Thus, the inner readiness to protect nature is determined by the individual's desires, intentions, and needs in implementing its position through actions and activities to protect the environment. In particular, the worldview, beliefs, ideals, and public interests, which simultaneously act as motives for activity in learning, education, and socialization, are filled with environmental content.

Thus, the level of development of collective ecological consciousness is closely interrelated with the level of development of the spiritual sphere of each individual and the system of concepts, 'values - attitudes – activities', which are realized in the process of education. Additionally, during the environmental training, the emphasis is on intelligence and operation of the system of concepts 'consciousness - thinking - knowledge – activity'.

In particular, ecological consciousness is a set of theoretical knowledge about environmental problems and ways to solve them combined with some experience of changing the adverse effects of human activities on nature. The ecology of the world begins with the ecology of the soul. External events and human's inner world are closely intertwined and follow each other. In the conditions of increasing the intensity of production, accelerating the processes of movement, and increasing the anthropogenic impact on the environment, it is vital to launch global processes that will affect the ecology of the human soul.

Sand (2009) wrote that nature is beautiful; every time it breathes feelings, love, youth, and beauty live in its imperishability. However, today, the state of nature raises the question: "How to change people's minds and direct their activities in a constructive direction to solve the global environmental problem?" It is necessary to form a new worldview, a new system of values and philosophy, a new way of life, and a program of concrete actions to prevent a new environmental crisis. The philosophical basis, in this case, may be ecological philosophy, i.e., the philosophy of the harmonious relationship of human with ecological systems. Therefore, in the system 'society - man - technology - natural environment', it is necessary to find a way to harmonize the relationship between nature and human. The ecological approach must penetrate science in order for science's ecological and humanistic orientation to resolve the traditional contradiction between 'anthropocentrism' and 'cosmo-naturalism'. Moreover, the critical role here can be played by social ecology, which contributes to forming a new type of environmental thinking.

Vernadsky (2001) emphasized that in the gradual destruction of the Earth's biosphere, it is necessary to change human activities to resolve the contradictions between society and nature. The latter should be based on new principles because they provide for reaching a reasonable compromise between society's social and economic needs and the ability of the biosphere to meet them without compromising its normal functioning. Thus, environmental success and modern human's social and economic efficiency depend on a critical review of all areas of human activity and areas of knowledge and spiritual culture that shape the individual's worldview.

Wicks (2011) pointed out that most people pursuing pragmatic goals treat the world as an object of consumption from the subject's position, i.e., the leading actor in communication between human and the world. Nevertheless, in moments of admiration for the beauty of nature and enjoying the sight of waterfalls, rainbows, or delicate flowers, a person can forget and enter into a new type of relationship with the world, namely the object-object relationship. Further, a person seems to dissolve in the object he/she is contemplating. Any object of nature can use it. Such 'dissolution' is a beautiful moment of awakening the state of genius within the individual, characterized by loss of connection with time and space, merging with the environment, and correlation with particular fragments of life.

It is worth noting that thinkers have pointed to the close relationship between the spiritual and natural spheres of human existence. According to philosophers, from antiquity to the postmodern period, the universe is harmonious and strives for balance in everything. Therefore, it is essential to define the priority boundaries for human activity in which society will unite spiritual values and worldviews. In particular, one such idea may be the concept of the noosphere, described by Vernadsky (2001). The scientist considers ecology as a global problem of the present and describes the forecasted ways of its decision. According to him, the noosphere is the geographical envelope of the globe. The leading role is played by the transformation processes of matter, energy, and information associated with the activities of '*Homo sapiens*'. Throughout the history of humankind, lots of opportunities have arisen for using the natural environment and its resources to meet the needs of society. However, the current environmental situation indicates the need to change the nature of the relationship with nature.

Specifically, Marcuse (1991) emphasizes the need to give up everything superfluous to preserve ecological balance. The author argues a repressive attitude toward the individual in a large society because the 'consumer society' forms a unique culture and a particular opinion. On the one hand, an individual has rich creative potential. On the other hand, society seeks to put the 'soul' in the framework of empty 'forms'. According to the scientist, the latter is a conflict between the individual's energy and the pressure of social conventions and institutions, growing every day. Marcuse (1991) proposed a way to overcome or mitigate this conflict, which, on the one hand, is to develop creative imagination as a way to improve society, and, on the other, to form a global worldview that will reduce consumption to maintain ecological balance. The scientist notes that mass production, consumption, and mass culture have prevailed over traditional forms of consciousness, which form a conscious attitude of human to nature. Marcuse (1979) considers this topic in his essay and writes that nature is becoming a lever of control over human in the modern world. Commercialized, polluted, and militarized nature is an extension of the hand of society, as well as its power. Hence, the essay's author emphasizes the need for the liberation of nature, i.e., the revival of the vital forces of nature and sensual aesthetic qualities that are far from a life lost in endless competition. Instead, it is used for domination and becomes a matter devoid of value (Marcuse, 1979, p. 109). Marcuse (1979) also wrote that air and water pollution, noise, and industrial and commercial attacks on the open space meant the physical enslavement of *Homo sapiens*, and the connection between human liberation and the liberation of nature is becoming apparent today (Marcuse, 1979, p. 110).

Global, regional, and local environmental problems are one of the main threats to civilization and the causes of social turbulence in modern society. In particular, due to scientific and technological progress, people are increasingly interfering in natural processes. As a result, we are witnessing new cases of disruption of the dynamic balance and systemic nature of the organization of ecosystems. Environmental changes are almost close to the thermonuclear threat, which may soon lead to the extinction of *Homo sapiens* from our planet. Therefore, considering the circumstances described above, special ecological knowledge and competencies, the level of development of ecological culture not only of each individual but also of the society as a whole begins to play an increasing role. In our opinion, teachers and educators can significantly influence the environmental situation and eradicate the need for young people to benefit immediately. The environmental situation should alter at the cost of unwise and barbaric exploitation of natural resources and form knowledge, competencies, and unconscious beliefs. All necessary efforts can serve as a solid basis for choosing a caring attitude towards nature, understanding their role in the ecosystem, and responsibility for saving life on the planet.

Thus, there is an urgent need to identify a component of ecological consciousness that will provide the most effective transition from learning environmental knowledge to the practical use of environmentally sound behavioral strategies in everyday life. In particular, it is worth mentioning that such components of ecological consciousness as ecological knowledge, attitude to the world of nature (ecological attitude), ecological beliefs, and ecological intention play a unique role in forming ecological behavior. Likewise, the value of environmental education and upbringing in the context of solving the problem of environmental protection is that they have a direct and indirect impact on the formation of ecological consciousness, as well as its structural components: environmental knowledge, environmental beliefs, and environmental attitudes. Moreover, sometimes they develop into behavioral habits that are closely interrelated with environmental protection issues, species diversity, and ensuring the sustainable development of natural ecosystems.

Environmental intent is critical in forming collective and individual environmental behavior. In addition, it is a conscious desire to complete the environmental action by the selected program of interaction with the environment, which aims to achieve the projected result. Thus, ecological intention is an integrated personal formation, the structure of which is the unity of four components: cognitive, affective-evaluative, value and target, and behavioral. Precisely, the cognitive component is represented by environmental knowledge. It is the result of the process of cognition by the individual of the expected environmental activities through the acquisition of social experience while learning in the family and educational space. At the same time, it ensures their reflection in the ecological consciousness of human through ideas, concepts, judgments, hypotheses, theories, principles, laws, and patterns passed down from generation to generation. The affective-assessment component includes ecological self-assessment, a positive attitude to natural subjects, and a system of reflective connections with everyday ecological activity based on the ability to imaginatively reflect their feelings about natural objects and actions in the natural environment. Finally, the value and target components provide an opportunity to determine the priority of environmental intentions of the individual and their nature and are closely related to personal readiness and propensity for future activities in the area of residence or activity. Noticeably, it directs the activities of the individual in a particular direction. The latter contributes to achieving goals in interaction with nature and is the basis of the particular activity within ecosystems.

The behavioral component is responsible for the processes of actualization of environmental goals and self-regulation of environmental activities. It supports the conscious desire to complete the environmental action following the developed program to achieve the expected environmental result.

During the formation of ecological intention in the structure of ecological consciousness of the individual, in psychological and pedagogical practices, it is necessary to consider the internal determinants of the development of ecological consciousness. The cognitive function is the primary motive for studying the environment, as well as environmental knowledge, values, and attitudes to the environment. The cognitive function is likewise vital for competence, communicative function, rehabilitation, evaluation, self-awareness, psychophysiological and psychotherapeutic, environmental self-control, self-realization, environmental planning, programming, forecasting, and implementation of environmental intent. Also, it should be noted that the formation and development of ecological intentions of the individual in the current environmental situation have not yet become the subject of a sufficiently complete study in psychological science. Therefore, the introduction of psychological and pedagogical support in educational practice, which contributes to environmental intentions, will help individuals develop the most flexible and adaptive strategies for environmental activities, considering current environmental conditions and life.

In considering psychological features of the formation of collective ecological consciousness, it is expedient to mention the mechanisms that regulate the behavior of representatives of a specific social group. Subsequently, they are described in the Theory of Planned Behavior and the Theory of Value-Belief Norm.

3.6 Theory of Planned Behavior (TPB)

"The theory of reasoned action (TRA) along with its subsequent developed version of the theory of planned behavior (TPB), as articulated by Ajzen (1991), is based on the perceived behavioral control component to account for behavior without a person's volitional control and norms" (Ajzen and Fishbein, 1980; Ajzen and Madden, 1986). "The proponents of this theory argued that subjective norms refer to the strength of normative beliefs and the motivation to comply with these beliefs and social and moral values. As observed earlier, the theory of planned behavior extends the theory of reasoned action (TRA) by its addition of influences on behavior beyond people's control. TPB theorists believe that two assumptions have to be made to assess these influences by employing the perception of one's control:

1) the predicted behavior must be at least partially beyond volitional control;
2) the perception of control must reflect actual control upon behavior with some accuracy (Kalafatis, Pollard and Tsogas, 1999).

Theory of Value-Belief Norm (VBN): The premise of value-belief-norm theory (VBN) is that pro-social attitudes and personal moral norms are significant predictors of pro-environmental behavior (Stern *et al.*, 1999). The theory above suggests that people who undertake environmental action have at least some altruistic or moral reason for doing so or have been affected by self-serving interests (Aliagha *et al.*, 2013).

Vargo (2006) argues that at the present stage of the formation of Ukrainian statehood, it is advisable to use a kind of Ukrainian mentality to form an ecological society, as it focuses on connection with nature. Similarly, the ecological society remains the future society, which may be the result of the merger of Western European science and rationalism and the inherent traditional worldview of an attentive attitude to nature (Vargo, 2006). He also considers increasing the level of development of ecological consciousness as a critical condition for transforming Ukrainian society into an environmental one. Thus, Vargo (2006) emphasizes that one of the directions of development of society should be the formation of worldviews and social relations designed to overcome the modern alienation between human and nature. Besides, the author points to the need for changes in society's political, economic, and social life to its greening. Changing worldview plays a vital role in this process. Finally, this scientist characterizes the new imperative of collective ecological consciousness: to take care of the search for ecological balance and its preservation. Thus, the collective ecological consciousness can be considered an indicator of a high level of society's development, which considers the interests of nature at the level of their own. According to Vargo (2006), the ecological society, which has the highest level of development of ecological consciousness, considers human and nature in the light of new values, namely the equal development of humanity and nature.

Thus, the leading role in forming individual and collective ecological consciousness and public environmental culture belongs to education and upbringing. After all, the individual manages the multinational corporation and produces harmful products to nature and human, antibiotics, growth promoters, takes measures to cover up the oil spill in the sea bays, and damages the landscape by dumping a used ticket. Therefore, with significant theoretical and practical potential, training and education can significantly impact human's inner world and personal characteristics and prevent even the slightest harm to the environment.

3.7 Methods of formation of collective ecological consciousness

It should be borne in mind that the collective ecological consciousness is characterized by the gradual formation and the phasing of this process. The most crucial conceptual idea on which the environmental education program should be based is the principle of integrity as a characteristic of the individual, which is achieved through personal development and socialization. Therefore, the individual is an active, active subject who can transform the world and himself and take personal responsibility for the results of their actions. The factor of recognizing the value of ecological orientation in the system 'human – nature' is decisive in the process of self-determination and self-development of the individual and identification of oneself as a citizen of the state. Among the main concepts that should be used in the preparation of the program to increase the level of ecological consciousness and culture, we can highlight the system-activity approach to the organization of the educational process, the strategic approach to personality formation, and the personality-oriented approach. Sukhomlinsky (2004) also said that education should be subordinated to the main thing: "… education of humanity, i.e., humane attitude to nature, society, other people and yourself".

In addition to environmental laws and a social tool that maintains a sufficient level of environmental culture and fosters environmental values, citizens' assemblies, foundations, and committees on ecology and environmental protection play an important role. Thus, environmental unions and organizations should become a leading force in environmental education for the population, especially the younger generation. Of course, all citizens must abide by the provisions of the Constitution and laws and take care of the environment. However, one study of the relevant laws is not enough to form ecological consciousness and ecological culture in young people. It is necessary to hold events dedicated to ecological culture in educational institutions to intensify propaganda and agitation to raise its level. At the same time, it should be borne in mind that the formation of ecological culture in school and university students is influenced by family, educational institutions, society, and the environment. To the previous list, we can also add a variety of life situations and other factors that directly or indirectly affect the development and formation of young people. Nevertheless, environmental education is considered an essential component of public education and the process of socialization in general.

Tolstoukhov (2007) writes in his environmental encyclopedia that 'environmental education is a process of forming a humane, responsible, caring attitude of human to nature as a unique value, affirmation in the views, beliefs, moral attitudes of the principles of rational nature management, readiness for the environmental activities'.

It is important to note that the environment, work, and human relations have always been considered a means of environmental education. Travel, excursions, walks, a study of works of art dedicated to nature, and work on research sites are traditional activities in this direction. During excursions, hikes, and work on the research site, teachers draw young people's attention to the richness of nature and various environmental problems and explain the need for care for the environment.

Studying educational subjects such as science, botany, biology, geography, and the basics of ecology is an effective means of environmental education in the learning process. In addition, the young generation develops knowledge about the unity of the individual, society, and nature, the place and essence of the ecosystem in human life and society, a sense of responsibility for the planet's future, and awareness of the need to care for the environment and nature.

Together with, the formation of ecological culture of students of higher education is carried out by studying the humanities and natural sciences. The contribution of the first disciplines is closely interrelated with the assimilation of the ideas of the unity of humanity and the biosphere, the relationship between the historical development of human civilization and changes in the natural environment, and moral and aesthetic attitudes to nature. It is expedient to generalize students' ideas about today's global problems around the idea of optimizing the interaction between nature and society. A unique integration role belongs to environmental courses, which form a holistic view of environmental issues based on the content of other disciplines. The priority of environmental education is the organization of interdisciplinary seminars, discussions, and business games that will help students systematize their knowledge and integrate it into their lives. Kemp (2015), Oakeshott (1972), and Walker (2017) argue that the following methods need to be used: 1) non-simulation (problem lectures and seminars, thematic discussions and round tables, brainstorming, etc.), and 2) simulation (analysis specific situations or case studies, role-playing, business games, etc.).

Caravan (2013) singles out conversation and preparation of abstracts and reports as the most common environmental education methods. That is right, and the scientist notes the essential role of environmental education methods in developing skills to search and organize information. However, according to the researcher, to increase ecological consciousness in students, it is more appropriate to use forms and methods of work to develop motivational-value and behavioral components of ecological consciousness and behavior, including research and problem-solving. Equally, students must find answers to them during the lesson, analyzing and summarizing the information obtained. Also, Caravan (2013) talks about such interactive methods as brainstorming, case studies, critical discussion, group discussion, role-play, simulations, seminars, and group projects as a source of information. With the latter carriers of environmental norms and requirements, the students themselves act, and environmental norms and requirements are perceived as their own choices and decisions, which is a much stronger incentive to comply than external coercion. Among the methods of extracurricular activities are conferences, seminars, quizzes, group work, and elective classes. The reason is that such forms of work provide an opportunity to go beyond the curriculum, supplement the knowledge, skills, and experience of students and provide choice and decision making, analysis, and assessment, contributing to the formation of environmentally sound behavior (Caravan, 2013).

Thus, the acquisition of environmental knowledge, raising the level of environmental culture, compliance with laws and regulations on environmental protection and nature management, and instilling a love of nature must move from environmental education and socialization of the individual to the needs and qualities of each individual. Simultaneously, educational institutions play an essential role in forming the described qualities, knowledge, and skills in young people. This fact must be considered in forming an ecological society because the younger generation and future professionals will serve Motherland's prosperity, fight for cleanliness, and organize cities and villages, improving the people's economic and cultural life. The young generation may soon become the nucleus of a new collective economical consciousness that promotes environmental protection and the wise use of natural resources. Therefore, it is appropriate to emphasize the importance of environmental education, training, and preparation of future thought leaders and lay the groundwork for adopting new innovative views on ways and means to eliminate the adverse effects of human activities from the authorities of modern environmental thought.

4. Conclusions

Thus, environmental competence becomes one of the essential characteristics of the society of the future, as damage to nature is caused not only intentionally but also due to ignorance. According to the Ecological Encyclopedic Dictionary, ecological consciousness provides a deep understanding of the inseparable connection of each person with nature, the dependence on the welfare of society, and the integrity of the natural environment from anthropogenic changes beyond the use of adaptive abilities as a species.

It should be noted that solving the problem of greening consciousness and forming ecological culture is one of the critical psychological and pedagogical tasks: developing ecological thinking, shaping an ecological worldview, and creating a sense of ecological responsibility for each individual in socialization.

Therefore, we consider ecological education and raising the level of development of ecological culture as a constant process of deepening knowledge about the environment, forming an attitude to nature as a value, and the ability to work to protect the environment actively. In particular, environmental education covers the training and development of personality, which are aimed at forming a holistic worldview, values, responsible attitude to nature, and strong beliefs in the need to protect it.

5. References

Ajzen, E.I. and Fishbein, M. (1980). *Understanding Attitudes and Predicting Social Behavior*. Englewood Cliffs, NJ: Preentice Hall.

Ajzen, E.I. and Madden, T.J. (1986). Prediction of Goal-Directed Behaviour: Attitude, Intentions, and Perceived Behavioural Control. *Journal of Experimental Social Psychology*, 22(5): 453-474. DOI: https://doi.org/10.1016/0022-1031(86)90045-4.

Ajzen, I. (1991). The Theory of Planned Behavior. *Organisational Behavior and Human Decision Processes*, 50(2): 179 – 211.

Aliagha, G.U., Hashim, M., Sanni, A.O. and Ali, K.N. (2013). Review of Green Building Demand Factors for Malaysia. *Journal of Energy Technologies and Policy*, 3(11): 471-478. Available online at: https://core.ac.uk/download/pdf/234667798.pdf [accessed 13 May 2022].

Andy, S. (2009). Paradoxes of increased individuation and public awareness of environmental issues. *Environmental Politics*, 18(4): 467-485, DOI: https://doi.org/10.1080/09644010903007344.

Baars, B. (1983). Conscious contents provide the nervous system with coherent, global information. In: (Davidson, R.J. *et al.* (eds), *Consciousness and Self-Regulation* (vol. 3). Baltimore, USA: Plenum Press.

Baars, B. (1988). *A cognitive theory of consciousness* [Kindle edition, 2012]. New York, NY: Cambridge University Press.

Baars, B. (2002). The conscious access hypothesis: origins and recent evidence. Trends in Cognitive Sciences, 6(1): 47–52. Available online at: https://www.psychologytoday.com/files/attachments/47898/baars-2002-the-conscious-access-hypothesis-origins-and-recent-evidence2.pdf [accessed on 22 April 2022].

Baars, B. and Franklin, S. (2007). An architectural model of conscious and unconscious brain functions: global workspace theory and IDA. Neural Networks, 20(9): 955–961. DOI: https://doi.org/10.1016/j.neunet.2007.09.013.

Benton, R. and Benton, C.S. (2004). Why Teach Environmental Ethics? Because We Already Do. *World Views: Environment, Culture, Religion*, 8(2/3): 227-242. DOI: http://dx.doi.org/10.1163/1568535042690790.

Boyko, A.M., Bardinova, V.D., Demyanenko, N.M. and others (2004). Personalii v istorii natsionalnoi pedahohiky. 22 vydatnykh ukrainskykh pedahohy [*Personalities in the history of national pedagogy. 22 outstanding Ukrainian teachers*] (2004) Kyiv: VD «Professional», 576 p.

Caravan, Y. (2013). Formuvannia ekolohichnoi svidomosti studentiv [*Formation of ecological consciousness of students*]. Proceedings of the International scientific-practical Internet conference «Problems and prospects of science development at the beginning of the third millennium in the CIS countries» [Electronic resource]. Available online at: http://oldconf.neasmo.org.ua/node/2721 [accessed on 11 March 2022]

De Chardin, P.T. (1959). The Phenomenon of Man. New York: Harper & Row, 552 p.

De Chardin, P.T. (1965). The Future of Man, translation by N. Denny. New York: Harper & Row Publishers, 256 p.

De Chardin, P.T. (1966). The Vision of the Past, translated by J.M. Cohen. New York: Harper & Row Publishers, 229 p.

Descart, R. (1984). *The Philosophical Writings of Descartes*, volume 2. Cambridge: Cambridge University Press, 450 p.

Dobryden, O. (2004). Ekotsentrychna svidomist i vira yak chynnyky optymizatsii sotsialno-ekolohichnykh vidnosyn [*Ecocentric consciousness and faith as factors of optimization of social and ecological relations*]. *Grani*, 1: 91–95.

Fenchak, L. (2005). Metodologichniy aspekt formuvannya ekologIchnoyi kulturi studentiv-agrarnikiv [*Methodological aspect of formation of ecological culture of agricultural students*]. *Novi tehnologiyi navchannya: nauk. metod. Zb*, 41: 158–164 [*In Ukrainian*].

Furman, A. (2017). Svidomist yak peredumova psihologichnogo piznannya i profesiynogo metodologuvannya [*Consciousness as a prerequisite for psychological knowledge and professional methodology*]. *Science and Education*, 3: 5–10. DOI: https://doi.org/10.24195/2414-4665-2017-3-1.

Ingalsbee, T. (2016). Earth First! Activism: Ecological Postmodern Praxis in Radical Environmentalist Identities. *Sociological Perspectives*, 39(2): 263-276. DOI: https://doi.org/10.2307/1389312.

Jack, A. and Shallice, T. (2001). Introspective physicalism as an approach to the science of consciousness. *Cognition*, 79(1-2): 161–196. DOI: https://doi.org/10.1016/S0010-0277(00)00128-1.

Kalafatis, P., Pollard, M. and Tsogas, H. (1999). Green marketing and Ajzen's theory of planned behavior: A cross-market examination. *Consumer Marketing*, 16: 441- 460.

Kemp, P. (2015). The animal: My partner. In: Peter Kemp Sune Frolund (eds.), *Nature in education*. Zurich: LIT Verlag, pp. 215–226.

Kempton, W., Boster, J. S. and Hartley, J. A. (1996). *Environmental Values in American Culture*. Massachusetts: MIT Press, 320 p.

Khrushch, O. and Karpiuk, Y. (2021). Psychological Aspects of Building Environmental Consciousness. *Grassroots Journal of Natural Resources*, 4(2): 120-135. DOI: https://doi.org/10.33002/nr2581.6853.040209.

Kim, A., (2016). Wilhelm Maximilian Wundt. The Stanford Encyclopedia of Philosophy. Available online at: https://plato.stanford.edu/archives/fall2016/entries/wilhelm-wundt/ [accessed on 23 April 2022].

Kronlid, D.O. and Öhman, J. (2012). An environmental ethical conceptualframework for research onsustainability and environmentaleducation. *Environmental Education Research*, 19(1): 21-44. DOI: https://doi.org/10.1080/13504622.2012.687043.

Krutov, V. (2014). Vozvrashchenye k sebe. Osnovi razvytyia soznanyia y upravlenyia mishlenyem [*Return to yourself. Fundamentals of the development of consciousness and management of thinking*]. Kyiv: Genesis, 400 p.

Leibniz, W. (1989). Philosophical Essays. 1st edition. Indianapolis: Hackett Publishing Company, 384 p.

Levochkina, A. (2003). Ekolohichna psykholohiia: navch. posib [*Environmental psychology: textbook. Way*]. Florida: Millennium, 120 p.

Levochkina, A. (2004). Osnovy ekolohichnoi psykholohii: navch. posib [*Fundamentals of environmental psychology: textbook. way]*. Kyiv: MAUP, 136 p.

Lysianska, T. and Bielousova, N. (2020). The concept of «environmental consciousness» in the modern psychological space. *Psychological Journal*, 6(7): 114-123. DOI: https://doi.org/10.31108/1.2020.6.7.9.

Marcuse, H. (1979). Ecology and the Critique of Modern Society. *Capitalism, Nature, Socialism*, 3(3): 29-37.

Marcuse, H. (1991). One-dimensional Man: Studies in Ideology of Advanced Industrial Society. New York: Routledge, 261 p.

Miroshkin, D.V., Grinenko, A.V., Tkhugo, M.M., Mizonova, O.V., Kochetkov, I.G., Kazakova, S.N. and Miloradova, N.G. (2019). Psychology of Ecological Consciousness. Ekoloji, 28(107): 593-599. Available online at: http://ekolojidergisi.com/download/psychology-of-ecological-consciousness-5679.pdf [Accessed on 21 June 2022]

Morris, M. (2002). Ecological consciousness and curriculum. *Journal of Curriculum Studies*, 34(5): 571-587.

Mueller, M.P. (2009). Educational Reflections on the "Ecological Crisis": EcoJustice, Environmentalism, and Sustainability. *Science & Education,* 18: 1031–1056. DOI: https://doi.org/10.1007/s11191-008-9179-x.

Nabochuk, O. (2013). Rozvitok ekologichnoyi svidomosti osobistosti: aktualnist problemi [*Development of the ecological consciousness of the individual: the urgency of the problem*]. Zbirnik naukovih prats Kam'yanets-Podilskogo natsionalnogo universitetu imeni Ivana OglEnka, Institutu psihologiyi imeni G.S. Kostyuka NAPN UkraYini "Problemi suchasnoyi psihologiyi". Kam'yanets-Podilskiy: Aksioma Publication, Vol. 20: 449–463. [*In Ukrainian*]. Available online at: http://v-khsac.in.ua/index.php/2227-6246/article/viewFile/159769/159011 [accessed on 15 March 2022].

Oakeshott, M. (1972). Education: The engagement and its frustration. In: R.F. Dearden, Paul H. Hirst and R.S. Peters (eds.), *Education and the development of reason*. London: Routledge. pp. 19–49.

Palamarchuk, O. (2003). Ekolohichna svidomist: protses vynyknennia ta dynamika rozvytku [*Ecological consciousness: process of formation and dynamics of development*] / O. M. Palamarchuk. [Elektronnyi resurs]. Available online at: https://ecopsy.com.ua/data/zbirki/2003_01/sb01_49.pdf [accessed on 30 March 2022].

Plyaskovskiy, B. (1991). Dialektika rozvitku ekologichnoyi svidomosti [*Dialectics of development of ecological consciousness*]. Filosofski problemi suchasnogo prirodoznavstva. Ekologiya, kultura i sotsialna praktika, vol. 77: 71–78 [*In Ukrainian*].

Puk, T. (2018). Healing the ecological self: Stop peeing in the drinking water. Unpublished manuscript, Faculty of Education, Lakehead University, Thunder Bay, ON, Canada.

Revonsuo, A. (2001). Can functional brain imaging discover consciousness in the brain? *Journal of Consciousness Studies*, 8: 3-23.

Sand, J. (2009). Frantsuzskye krilatie virazhenyia [*French winged expressions*]. Kharkiv: Folio, 254 p.

Shedlovska, M. (2011). Oznachennia ta typy ekolohichnoi svidomosti [*Definitions and types of ecological consciousness*] *Ukrainian Society*, 2: 95-100.

Shedlovska, M. (2013). The conceptual model for environmental consciousness measurement (According to the empirical sociological data). *Economics & Sociology*, 6(1): 78.

Skladanovska (2006). MG Liudyna i svit: Vstup do ekolohichnoi psykholohii (*Man and the world: Introduction to environmental psychology)*. (2006) navch. posib. Skladanovska [etc.]; Nat. horn. un-t. D.: Nat. horn. un-tu,. 144 p.

Skrebets, V. (1998). Ekologicheskaya psihologiya: ucheb. posobie [*Environmental Psychology: textbook manual*]. Kyiv, Vid-vo Mizhregionalnoyi akademiyi upravlinnya personalom, 142 p. [*In Ukrainian*]. Available online at: https://www.twirpx.com/file/221249/ [accessed 11 May 2022]

Skripnik, S. (2012). Ekologichna svidomist, ekologichna kultura v sotsialniy ekologiyi [Ecological consciousness, ecological culture in social ecology]. *Naukovi zapiski. Seriya: pedagogichni nauki*,109: 139–144. [In Ukrainian]. Available online at: http://irbis-nbuv.gov.ua/cgi-bin/opac/search.exe?C21COM=5F2012%2Epdf [accessed 11 May 2022].

Stern, C., Thomas, D., Abel, T., Guagnano, A. and Kalof, L. (1999). A value-belief-norm theory of support for social movements: The case of environmentalism. *Human Ecology Review*, 6: 81 – 97.

Sukhomlinsky, V. (2004). Personalii v istorii natsionalnoi pedahohiky. 22 vydatnykh ukrainskykh pedahohy [Personalities in the history of national pedagogy. 22 outstanding Ukrainian teachers]. Kyiv: VD «Professional», p.576.

Taylor, D. (1982). *Mind*.New York: Simon and Schuster, 239 p.

Thomashow, M. (1996). *Ecological identity: Becoming a reflective environmentalist*. Massachusetts: MIT Press.

Tolstoukhov, A. V. (ed.) (2007). Ecological encyclopedia: volume 1 LLC «Center for Environmental Education and Information», 432 p.

Vargo, O. (2006). Ekolohichna svidomist yak umova stanovlennia ekolohichnoho suspilstva [*Ecological consciousness as a condition of formation of ecological society*]. Dissertation Cand. Philosopher Sciences: 09.00.03, Kharkiv University of the Air Force, Kharkiv, Ukraine.

Vernadsky, V. (2001). *Biosphere and noosphere*. Moscow: Biosfera [*Biosphere*], pp. 159-177. [*In Russian*]

Walker, C. (2017). Tomorrow's Leaders and Today's Agents of Change? Children, Sustainability Education and Environmental Governance. *Child Sociology*, 31: 72–83. DOI: https://doi.org/10.1111/chso.12192.

Wicks, R.L. (2011). Schopenhauer's The World as Will and Representation: A Reader's Guide. London: Bloomsbury Publishing.

Wundt, W. (1927). Wilhelm Wundts Werke. Ein Verzeichnis seiner sämtlichen Schriften [Wilhelm Wundt's Works: An index of all his writings]. München: C.H. Beck.

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Chapter 22

United Nations Mountain Agenda, the Mountain Partnership and Related Regional Mechanisms

By Rosalaura Romeo

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United Nations Mountain Agenda, the Mountain Partnership and Related Regional Mechanisms

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Abstract

Mountains cover almost a third of the Earth's land surface and are home to 15 percent of the global population, many of whom are among the poorest in the world. Since the Earth Summit in Rio de Janeiro in 1992 and the adoption of Agenda 21's Chapter 13, "Managing Fragile Ecosystems: Sustainable Mountain Development", global action to promote sustainable mountain development has been supported by the United Nations (UN) and national and international stakeholders. The Mountain Partnership is the UN alliance dedicated to sustainable mountain development. It promotes advocacy and knowledge sharing in support of national policies and international cooperation to sustainably manage mountain landscapes and empower mountain people. Regional level initiatives for transboundary cooperation exist for some of the major mountain ranges, such as the Alps, the Andes, the Carpathians and the Himalayas. Accelerated international and national actions to reduce the vulnerabilities of mountain people and to respond to the impacts of climate change in mountains are needed.

Keywords

Mountains; sustainable development; biodiversity; climate change

Citation

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1. Why do mountains matter?

Mountains are found on all continents, covering more than a quarter of the earth's land surface (Romeo *et al.*, 2020). Mountains play essential ecological roles for the planet and provide important ecosystem services to billions of people living downstream, such as stabilizing slopes, regulating climate, regulating hydrological cycles, and supporting livelihoods (Baral *et al.*, 2017). Mountains and their peoples are under pressure from climate change, hunger, poverty, and migration. Isolation, marginalization and lack of access to services make mountain peoples – especially those living in rural areas – among the poorest, most malnourished and vulnerable to hunger in the world. Because of their globally recognized ecological, social and cultural importance, and due to the transboundary nature of many ranges, mountains are specifically part of and mentioned in the global sustainable development agenda.

Sustainable mountain development is multifaceted and aims at enhancing the capacity of institutions to promote sustainable growth in mountains, managing mountain landscapes, ensure the provision of ecosystem services, empowering mountain communities, boosting mountain economies, and improving food security and nutrition.

Box 1. Key statistics on mountains and mountain peoples

- Mountains cover about 27 percent of the earth's land area and are home to 1.1 billion people (15 percent of the world's population) (Romeo *et al.*, 2020).
- Ninety percent of mountain people live in developing countries (Romeo *et al.*, 2020).
- Mountains host about half of the world's biodiversity hotspots and 30 percent of all Key Biodiversity Areas, as well as vital genetic resources for locally adapted crops and livestock (Romeo *et al.*, 2021A).
- Mountain ecosystems provide important ecosystem services to billions of people living downstream, such as stabilizing slopes, regulating climate, regulating hydrological cycles, and supporting livelihoods (Baral *et al.*, 2017).
- Mountains are of paramount importance as water towers, both for mountain people and for around 2 billion people living in connected lowland areas (Immerzeel *et al.*, 2020).
- Two-thirds of irrigated agriculture globally depend on runoff contributions from mountains (Adler *et al.*, 2022).
- In 2018, 39 percent of the global mountain area was covered in forests[1].
- In 2019, mountain tourism was estimated to represent between 9% and 16% of total international tourist arrivals (between 195 and 375 million international arrivals) (FAO and WTO, 2023).
- Since 2000, vulnerability to food insecurity has constantly increased in rural mountain areas of developing countries, where a great majority lives below the poverty line and more than 1 in 2 rural people faces food insecurity (±350 million) (Romeo *et al.*, 2020).
- Approximately 516 million rural people are estimated to live in mountain areas affected by past natural hazards (Romeo *et al.*, 2020).

[1] International Year of Sustainable Mountain Development 2022 communication plan https://www.fao.org/fileadmin/templates/mountain_partnership/doc/Communication_plan_IYM-2022.pdf

- 311 million people – approximately half of the mountain population in the developing countries – live in areas exposed to progressive land degradation, 178 million of whom are considered vulnerable to food (Romeo *et al.*, 2020).
- An estimated 212 million rural people in mountains lived in areas affected by conflicts between 2000 and 2018. Out of those, 128 million people were vulnerable to food insecurity (Romeo *et al.*, 2020).
- 85 million rural mountain people live more than one hour's travel distance from the closest market (Romeo *et al.*, 2020).

2. Milestones in the global mountain agenda

The global mountain agenda dates back to the landmark United Nations Conference on Environment and Development, also known as the "Earth Summit", which was held in Rio de Janeiro, Brazil in 1992. At the Rio Earth Summit, an entire chapter of the plan of action "Agenda 21" adopted by the Summit, was dedicated to mountains: chapter 13, "Managing Fragile Ecosystems: Sustainable Mountain Development". Agenda 21 represented the most comprehensive plan of action for governments, major groups and organizations of the United Nations to address the impacts of human activities on the environment developed until then. Chapter 13 included key objectives for sustainable mountain development, such as raising awareness of the importance of mountains at global, regional and local levels, protecting mountain natural resources, protecting the livelihoods of local communities and Indigenous People, and promoting international cooperation for mountains. At regional level, the Alpine Convention, an international treaty to address transboundary cooperation in the Alps, was signed in 1991 and entered into effect in 1995. The Alpine Convention[2] entails the guiding principles towards a sustainable life in the Alps, now and in the future. The Convention is the legal basis for safeguarding the sensitive Alpine ecosystems, the regional cultural identities, heritage and traditions in the Alps. At the same time, it is a living instrument, which allows the signatories to deal jointly with pressing and cross-cutting issues.

Another milestone was the International Year of Mountains 2002 (IYM 2002). Its main outcome was the launch of the International Partnership for Sustainable Development of Mountain Regions, commonly referred to as the Mountain Partnership. The Food and Agriculture Organization of the United Nations (FAO) – which was already the task manager for chapter 13 and the lead United Nations agency to coordinate observance of the IYM 2002 – was designated as the host organization for the Mountain Partnership Secretariat.

In 2004, the United Nations Convention on Biological Diversity (CBD), adopted a Programme of Work on Mountain Biological Diversity[3] with the overall purpose to significantly reduce the loss of mountain biodiversity by 2010 at global, regional and national levels. The CBD decision emphasized the importance of mountain biodiversity for livelihoods, and recognized the value of traditional and sustainable land use practices of indigenous and local communities in preserving mountain biodiversity. The programme of work focused on the high concentration of biodiversity hotspots in mountain regions; the cultural diversity of mountain peoples, and particularly the key role of indigenous and local

[2] https://www.alpconv.org/en/home/convention/framework-convention/
[3] https://www.cbd.int/doc/decisions/cop-07/cop-07-dec-27-en.pdf

communities in the conservation and management of mountain biodiversity; the fragility of mountain ecosystems and their vulnerability to land-use change and climate change (such as the retreat of glaciers and increased areas of desertification); and upland-lowland interactions, and the relevance of upland ecosystems for the management of food, water and soil resources (CBD, 2004).

Largely, as a result of Mountain Partnership members' active collaboration and engagement during the run-up to, and negotiations for the Third International Conference on Sustainable Development (Rio+20), three paragraphs on mountains were included in the outcome document "The Future We Want". In September 2015, the United Nations adopted the 2030 Agenda for Sustainable Mountain Development[4]. Three mountain-related targets were included under two of the 17 Sustainable Development Goals (SDGs), recognizing the importance of pursuing sustainable mountain development for a more sustainable future:

- Target 6.6: Protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes;
- Target 15.1: Ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements; and
- Target 15.4: Ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development (UN, 2015).

In 2017, members of the Mountain Partnership agreed on a Framework for Action to ensure that sustainable mountain development is integrated into the 2030 Agenda and in the implementation of the Paris Agreement. The Framework for Action calls upon governments and major groups to support concrete actions, put in place long-lasting processes, and establish policies to strengthen the resilience of mountain peoples and environments.

The United Nations General Assembly declared 2022 as the International Year of Sustainable Mountain Development. The resolution[5] notes that "despite the progress made in promoting the sustainable development of mountain regions and the conservation of mountain ecosystems, including their biodiversity, the prevalence of poverty, food insecurity, social exclusion, environmental degradation and exposure to the risk of disasters is still increasing, particularly in developing countries, and access to safe and affordable drinking water and basic sanitation as well as to sustainable modern energy services continues to be limited". The International Year also marked the twentieth anniversary since the proclamation by the United Nations General Assembly of the IYM 2002 and the establishment of the Mountain Partnership. The main outcome of the IYM 2022 was the declaration of 2023-2027 as Five Years of Action for the Development of Mountain Regions[6].

3. The Mountain Partnership: A multistakeholder global alliance

The Mountain Partnership is the only United Nations global alliance specifically dedicated to sustainable mountain development. In its over 20 years of existence, the

[4] https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf

[5] https://undocs.org/A/RES/76/129

[6] For more information: https://www.fao.org/mountain-partnership/five-years-action/en/

Partnership has evolved so to maintain its relevance in a changing international context and to adapt to its growing membership. It brings together governments and civil society organizations that are dedicated to protecting mountain environments around the world, under a multi-stakeholder governance structure. The Partnership currently has 522 members, including 66 governments, 21 intergovernmental organizations, 423 major group organizations and 12 subnational authorities (member count as of 22 November 2023)..

Box 2. Timeline of the mountain agenda's key milestones

1992: Earth Summit - Chapter 13 of Agenda 21 adopted
1995: Alpine Convention entry into force
2002: International Year of Mountains
2004: CBD Programme of Work on Mountain Biological Diversity adopted
2006: Carpathian Convention entry into force
2012: Rio+20 - The Future We Want adopted
2014: Andean Initiative founded
2015: 2030 Agenda and SDGs adopted
2017: Mountain Partnership Framework for Action launched
2022: International Year of Sustainable Mountain Development
2023-2027: Five Years of Action for the Development of Mountain Regions

The work of the Mountain Partnership is organized along four pillars: advocacy, capacity development, knowledge sharing and communications, and joint action[7]. One of the Mountain Partnership's main advocacy activities is facilitating the annual observance of International Mountain Day globally on 11 December. The Mountain Partnership Secretariat at FAO, the coordinating agency for this United Nations Day, supports Mountain Partnership members and non-members with communication campaigns including the dissemination of key facts and messages, infographics, social media cards, videos and a photo contest. International Mountain Day provides the opportunity to raise awareness about the importance of mountains to life and to highlight various mountain-related issues such as mountains as a source of freshwater, mountain tourism, disaster risk management, food security, mountain cultures, and others.

Another significant advocacy activity led by the Mountain Partnership is the production of the triennial United Nations Secretary-General report on sustainable mountain development. The report describes the status and progress made in promoting sustainable mountain development at the national and international levels. Focusing on various themes, it provides an overall analysis of the challenges and includes recommendations on how to more effectively achieve sustainable development in mountain regions. The report forms the basis of a resolution[8] that is adopted every three years by the United Nations General Assembly. The report has been compiled periodically since 2001 by the Mountain Partnership Secretariat and FAO in collaboration with governments, other United Nations agencies and non-governmental organizations.

[7] For more information, please refer to the Mountain Partnership website: https://www.fao.org/mountain-partnership/our-work/en/
[8] For more information, please refer to the Mountain Partnership website: https://www.fao.org/mountain-partnership/our-work/advocacy/un-secretary-generals-report-on-mountains/en/

4. The international policy landscape on sustainable mountain development

Mountain policy is generally realized through non-legally binding instruments. At the international level, there are many soft-law instruments but few legally binding instruments. Most legal instruments related to mountains are thus national legislation, many having a sectorial approach.

The Alpine Convention[9] is a treaty under international law between Austria, France, Germany, Italy, Liechtenstein, Monaco, Slovenia, Switzerland and the European Union. It strives for an integrated sustainable development of the Alps, a very densely populated mountain region with more than 13 million inhabitants.

Another regional instrument is the Carpathian Convention[10] having seven parties, including the Czechia, Hungary, Poland, Romania, Serbia, Slovakia and Ukraine. The Convention provides the framework for cooperation and multisectoral policy coordination, a platform for joint strategies for sustainable development, and a forum for dialogue between all stakeholders involved.

The idea of an Andean Initiative[11] was officially launched in Argentina in September 2007 with a declaration and an Andean Action Plan[12]. Through the Mountain Partnership Secretariat, FAO supported the process though a dedicated project. In 2014, Argentina, Bolivia (Plurinational State of), Chile, Colombia, Ecuador, Peru and Venezuela (Bolivarian Republic of) formalized this regional mechanism with the aim to support the sustainable development of the Andes, strengthening of national institutions, and well-being of mountain peoples.

A study by the FAO Legal Office in 2002 found that only a few countries had specific mountain legislation: Spain (Ley de Montes of 1957, abrogated replaced by Law 43/2003[13]); Italy (Law of 03/12/1971)[14]; France (Law of 17/01/1985)[15]; Greece (Law 1892/1990)[16]; Georgia (Constitution of 1995 + Law of 08/06/ 1999[17]); Switzerland (Law of 21/03/1997)[18]; Ukraine (Law of 1995); and Russian Federation – Republic of Ossetia-Alania (Law of 30/12/1998)[19] (FAO, 2002). The situation has changed little in the last 20 years, owing also to the challenges represented by legislative integration to adopt a law concerning a specific territory, as this has to build – among other things – on legal and institutional clarity, funding, new authorities, and interaction with other sectorial laws.

5. Conclusion

Sustainable mountain development means sustainably managing mountain landscapes and empowering mountain communities for better environment and better lives.

[9] For more information, please refer to the Alpine Convention website: https://www.alpconv.org/en/home/
[10] For more information, please refer to the Carpathian Convention website: http://www.carpathianconvention.org/
[11] For more information, please refer to the Andean Initiative website: https://iam-andes.org/?lang=en
[12] For more information, read the Tucuman Declaration: https://iam-andes.org/wp-content/uploads/2021/10/2007-Declaracion-de-Tucuman.pdf, Timeline and info here: https://iam-andes.org/infografia/
[13] https://www.global-regulation.com/translation/spain/1449749/law-43-2003%252c-of-21-november%252c-montes.html
[14] https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:legge:1971-12-03;1102!vig=
[15] https://www.legifrance.gouv.fr/loda/id/JORFTEXT000000317293/
[16] https://www.e-nomothesia.gr/kat-dasos-thera/n-1892-1990.html
[17] https://matsne.gov.ge/ka/document/view/19210?publication=16
[18] https://www.fao.org/3/Y3549E/y3549e14.htm
[19] https://base.garant.ru/31902883/

In the 30 years since the adoption of the mountain chapter of Agenda 21 at the Earth Summit in 1992, the role of mountains for sustainable development has received constant global attention. A multitude of governments, researchers, academics, and non-governmental organizations contribute to keeping the importance of mountain ecosystems and the needs of mountain communities in the spotlight of the international development agenda. Many of these stakeholders convene under the umbrella of the Mountain Partnership to strengthen international cooperation and strengthen their voices and efforts.

The declaration of the Five Years of Action for the Development of Mountain Regions 2023-2027 provides an opportunity to mobilize political commitment and investments for mountains. The quinquennium will enhance the international community's awareness of issues affecting mountain countries and give new impetus to efforts aimed at addressing their challenges. On the path to achieving the goals of the 2030 Agenda for Sustainable Development, reducing the vulnerability of mountain people should be a priority. Policies are needed to address the root causes of their vulnerability, including inequitable gender dynamics and marginalization. The high fragility of mountains to the impacts of climate change cannot be underestimated. Accelerated global and national level actions and transformational approaches are needed to reduce greenhouse gas emissions and support adaptation in mountains.

6. References

Adler, C., P. Wester, I. Bhatt, C. Huggel, G.E. Insarov, M.D. Morecroft, V. Muccione, and A. Prakash, 2022: Cross-Chapter Paper 5: Mountains. In: *Climate Change 2022: Impacts, Adaptation, and Vulnerability.* Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. In Press.

Baral H, Jaung W, Bhatta LD, Phuntsho S, Sharma S, Paudyal K, Zarandian A, Sears RR, Sharma R, Dorji T and Artati Y. 2017. Approaches and tools for assessing mountain forest ecosystem services. Working Paper 235. Bogor, Indonesia: CIFOR [Accessed on 21 July 2022].

CBD (Convention on Biological Diversity) (2004). Programme of Work on Mountain biological Diversity. Available online at: https://www.cbd.int/doc/decisions/cop-07/cop-07-dec-27-en.pdf [Accessed on 7 April 2022].

FAO (2002). Mountains and the law- Emerging trends. Food and Agriculture Organization of the United Nations, Rome. Available online at: https://www.fao.org/3/Y4181E/Y4181E00.htm [Accessed on 7 April 2022].

FAO and WTO (2023). Understanding and Quantifying Mountain Tourism. Food and Agriculture Organization of the United Nations (FAO) and UN World Tourism Organization (UNWTO), Rome/Madrid. DOI: https://doi.org/10.18111/9789284424023.

Immerzeel, W.W., Lutz, A.F., Andrade, M. *et al.* Importance and vulnerability of the world's water towers. *Nature* **577**: 364–369 (2020). DOI: https://doi.org/10.1038/s41586-019-1822-y.

Romeo R., Russo, L., Parisi F., Notarianni M., Manuelli S. and Carvao S., UNWTO. 2021B. Mountain tourism – Towards a more sustainable path. Rome, FAO. DOI: https://doi.org/10.4060/cb7884en [Accessed on 21 July 2022].

Romeo, R., Grita, F., Parisi, F. and Russo, L. 2020.Vulnerability of mountain peoples to food insecurity: updated data and analysis of drivers. Rome, FAO and UNCCD. DOI: https://doi.org/10.4060/cb2409en [Accessed on 21 July 2022].

Romeo, R., Manuelli, S.R., Geringer, M. and Barchiesi, V. (eds) 2021A. Mountain farming systems – Seeds for the future. Sustainable agricultural practices for resilient mountain livelihoods. Rome, FAO. DOI: https://doi.org/10.4060/cb5349en [Accessed on 21 July 2022].

UN (United Nations) (2015). Transforming our world: the 2030 Agenda for sustainable development. United Nations, New York. Available online at: https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf [Accessed on 7 April 2022].

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Rosalaura Romeo started working on mountain issues more than 21 years ago when FAO was tasked with promoting the first International Year of Mountains in 2002. A unit was created in FAO, and she was asked to transfer there because of her interest in this topic. Later that year, the Mountain Partnership was created, and what started as a small unit has now become the Mountain Partnership Secretariat, where Rosalaura has been working since then. She M.Sc. in Agriculture from the University of Tuscia and her expertise spans from agricultural and forestry research to international advocacy and donor relations. She is the Coordinator of the Mountain Partnership Secretariat hosted at FAO's Headquarters. Rosalaura devoted a large part of her career to the sustainable development of mountain regions and had a crucial role in 2002 in the creation of the Mountain Partnership, the only Multi-stakeholder UN Alliance dedicated to improving the lives of mountain peoples and protecting mountain ecosystems, with over 400 members around the world. The Mountain Partnership is in charge for the celebrations of the International Year of Sustainable Mountain Development 2022.

Chapter 23

Postmodern Transformations of Tourism Development

By Alla Pecheniuk and Alla Kiziun

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Postmodern Transformations of Tourism Development

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Abstract

This chapter examines contemporary scientific approaches to the issues of postmodern transformations of rural tourism development. The contradictions between the present postmodern society and the information-technological development of the rural areas in Ukraine are highlighted. Evidently, Ukraine does not fully use the new opportunities that emanate as a result of globalization of an economy. The main indicators of postmodern influences, such as informational and technological, political, social, socio-cultural, and personal (psychological), are earmarked featured. The characteristics of evolving social relations are also determined as pre-modern (archaic), modern and postmodern relations in the societies in particular context of tourism development. The factors influencing the postmodern tourism consumerism include the awareness of the social crisis, escape from reality, mundane avoidance, search for the self and self-realization, overcoming psychological trauma, the illusion of involvement in certain processes, positioning oneself with the upper class, new experience, and information society.

Keywords

Postmodern society; Rural tourism; Postmodern tourism; Postmodern transformations

Citation

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1. Introduction

The postmodern transformation of tourism development provokes scientific discussions as to whether postmodernism is our future, and, sometimes, it leads to radically opposite conclusions when assessing its impact. This deserves a special meaning in the study of the tourism development in the countries in transition from the standpoint of the global economy. Modern contradictions in postmodern society, economic and information-technological development of rural areas, and personal development of citizens can form the prerequisites for new areas of tourism. Due to the current social demands of reorienting tourism preferences from the mass segment to the individualized one, from the material infrastrcuture to the growth of the intangible components, the rural communities can get certain chance for developing themselves through streamlining the available opportunities. An important aspect can be postmodern personal transformation of consciousness of a tourist, development of his/her knowledge and cognitive intelligence, and exposing his/her to the technological innovations.

The postmodern influence on tourism is considered in the works of many scholars. The research of Zhang and Hui (2016) focuses on the existential problems in tourism. The authors conclude that modern tourism is a way to make up for losses caused by the rhythm of life, a way to escape from reality, by offering individuality and freedom (the spiritual home of utopia). They focus on the evolution of rationality and the links between tourism and reason (neo-rationalism), which includes both scientific and humanistic rationality. Pernecky's (2006) research focuses on the study of New Age tourists involving travelers in New Zealand, where it is empirically proven that these are individualists engaged in their search for extraordinary and transcendent consciousness, which aims at personal, spiritual, and emotional growth. An important place in the study of postmodern tourism transformations belongs to behavioral approaches, the results of which are described in a paper by Chinese scientists (Ying *et al.*, 2021). The authors determined that virtual reality advertisements with greater telepresence generated stronger intentions to visit the destination, and this effect was mediated by cognition (educational component) and attachment (entertainment and aesthetics). The results of the study by Bogicevic *et al.* (2019) point out that virtual reality significantly excites the imagination of tourists and encourages them to "dream" about a tourist offer before they realize them at the hotel in real.

Studies by Marasco *et al.* (2018) determine the impact of virtual reality created with the latest generation devices required to visit places, attractions, or cultural heritage sites. In this context, the authors presented specific theoretical and practical implications. Kang (2020) emphasizes the predominance of the affective nature of desires and decision-making regarding tourism consumption. The scientific findings of Oktadiana and Pearce (2020) are related to the study about user difficulties in the context of tourism technologies. The researchers have identified many annoying and inconvenient aspects of tourism technology interfaces, as well as problems with Internet access, language difficulties, and planning faults. Wei *et al.* (2020) focus their research on the study of cultural worldview and cultural experience in nature-bound tourist attractions. Their conclusions relate to the practical implications embedded in social psychology. Christou *et al.* (2020) highlight narcissism as a modern tourist phenomenon, which is manifested in the self-presentation of the tourist, where he or she is in the foreground, followed by a tourist attraction. This, according to the authors, creates certain obstacles for tourism promotion at certain locations. Paying tribute to the scientific works of the authors, it is believed that the topic of rural tourism development in postmodern society requires some deeper research taking into account the current magnitude of social knowledge, information technology, and reorientation of consumer demand for tourism products. The purpose of this article is to identify areas of postmodern transformations of rural tourism development and determine its basic principles in the light of modern postmodern consumers.

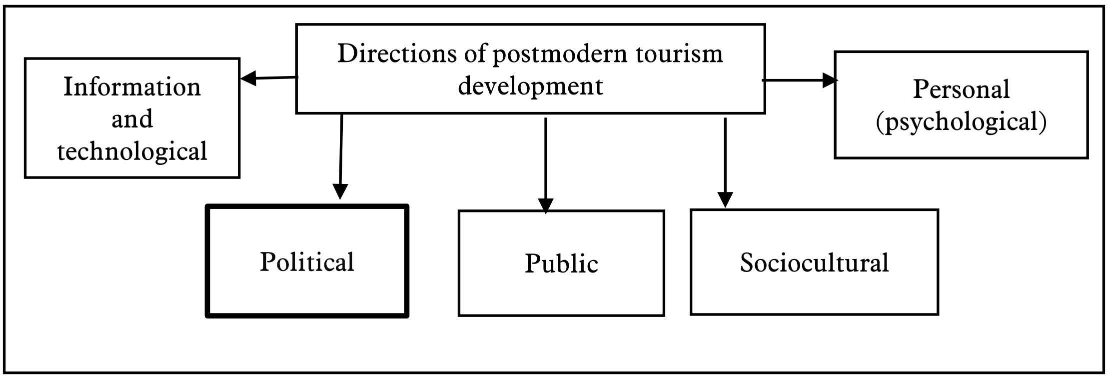

Figure 1: The main aspects of postmodern influence

2. Discussions

The basis of the existing sociological discourse in postmodern tourism is the definition of its two vectors: simulation and search. The first direction is associated with hyperrealistic analysis, imitations, and simulations. The second direction is related to the search for the real, for the deep, for oneself or one's roots. The postmodern tourism defines the attractiveness of natural and rural areas as postmodernist expressions. The first direction is quite successfully implemented in the modern concept of tourism development and has every chance to widely reach a mass consumer. The development of the second direction is determined by the educational-intellectual and spiritual component requiring an appropriate foundation and competencies. The phenomenon of postmodern influences in tourism can be considered from several aspects, as depicted in figure 1. Various aspects are explained as under:

2.1 Information and technological aspect

Rapid technological development and significant social virtualization have led to the emergence of a new type of human consciousness, which is integrated into this process of postmodern tourism. This collective person has the appropriate technological competencies and accompanies his activities by expanding the network of virtual acquaintances, by creating groups for communication, and by carrying a consumer for information. However, modern scientific debates focus on whether such a virtual entity can be considered a personality. Identity issues are increasingly moving into the field of multidisciplinary research, which requires scientists to study themselves thoroughly. Nagy and Koles (2014) identify the virtual personality as a conglomeration of personal, social relations, and material aspects. Soldatova and Pogorelov (2018) in their scientific findings claim the virtual personality not to be unique. It consists of a set of signs, symbols, and virtual material, and is defined as a "repost identity". This identity is not independent in decision-making but has a strong dependence on the signs of support for a virtual dating network determining its status and have nothing to do with reality.

The availability of information technologies at a certain tourist destination is essential for the formation of a virtual personality and virtualization of tourist consumption. World statistics demonstrate that as of early 2021, 96% of the population in Northern Europe has access to the Internet, 93% population in Western Europe. Overall, the global average Internet penetration rate is about 60 percent. The largest number of Internet users in China is more than 854 million and in India about 560 million. However, these countries still have a significant part of the population not having Internet connectivity (Johnson, 2021). The high degree of penetration of Internet technologies contributes to significant virtualization of both the individual and social processes, leading to significant transformational changes in the tourism sector. The household access to the Internet does not reach the world average in rural areas of Ukraine (Table 1), which hinders the development of tourism in the context of attracting mass postmodern tourists. However, this can form the preconditions for those consumers who are in search of a meaning of life, looking for beautiful views, escaping from the urban globalized environment, and wanting a harmony with nature.

Table 1: Access level of Ukrainian households to the Internet, in %

2018	*2019*	*2018*	*2019*
62.6	70.1	47.8	55.9
Urban population		Rural population	

Source: State Statistics Service of Ukraine (2020)

2.2 Political aspect

Postmodernism is closely linked to globalization and the emergence of new forms of interaction between political representatives of different countries. In the political context, significantly open borders and existing movement of tourists lead to the nomadism phenomenon. This phenomenon is especially vividly manifested in the case of the migration crisis, which is a consequence of the unequal world development. Undoubtedly, postmodernism erases national borders, strengthens communication processes, and exposes the illusion of understanding between cultures, leading to the development of tourism and intercultural integration. However, the existing unresolved problems of a global scale form the foundation of a civilization crisis with a certain turning point in the modern history of mankind. Considering that world development is characterized by significant polarization between poor and rich countries, between Western and Eastern civilizations, it can be argued that a significant part of the world at this stage is under the influence of a traditional (premodern) society having distinct corresponding characteristics. Postmodernism has developed mainly in Europe, but Western traditions significantly influence the culture of the East. The significant interest of tourists from the West in the culture and touristic heritage of the Eastern countries, the growing magnitude of tourist travel to poor countries are significant examples. A wealthy tourist enjoys the contemplation of a different life, a different culture and customs, causing negative emotions in the local population, realizing their hopelessness and despair. Many of these countries in modern conditions demonstrate high rates of economic and demographic growth and differ from the Western vision of the world, which contradicts postmodern liberal ideals. In this case, society may come to a fierce confrontation, and possibly change the vectors of development discourse.

Peters *et al.* (2019) define postmodernism as a form of anti-fundamental thinking and as anti-philosophy. It is argued that today postmodernism does not provide security, forcing the society to think and live outside the paradigm of fundamentals. In this context, the postmodern paradigm is seen as a prospective intercultural global philosophy, although quite distant. For example, Yin (2018) criticizes the Eurocentric nature of postmodernism and argues that, to preserve their identity in the age of globalization, non-Western nations should go beyond postmodernism. Postmodernism is characterized by the emergence of new social movements: pacifist, feminist, environmental, and social. They have become possible through the spread of the knowledge industry, which the new information age defines as the most significant value. A special place is occupied by ecological movements and the formation of ecological consciousness of citizens, which causes a significant need for the development of ecological tourism in postmodern society, as well as the formation of a special system of ecological values directly related to rural development.

2.3 Public aspect

Postmodern philosophy determines the prospects for the development of society not only from the standpoint of consumption of symbols and images but also from the standpoint of imitation and simulation of cultural goods, which are defined as hyperreality. This is due to the formation of a society of spectacles, the end product of which is the image. The significant mobility of citizens is a specific feature of the postmodern organization of public relations. Conceptually, postmodernism is closely linked to the new economy, which is characterized by the use of high technology and information coupled with a global integration. Some research (Pecheniuk, 2020) defines the basis of the new economy in knowledge and intelligence under the influence of economic growth, priorities of creativity and art, increasing competition among global communication networks, and the dominance of service industry. For the completeness of the study of postmodern society, it is important to consider the characteristics of the evolution of social relations in the context of tourism development, which are illustrated in table 2.

The characteristics illustrated in table 2 are not final and non-arbitrary, because, at different historical stages of social development, there is an overlap of events, repetition at certain intervals, and a shift in the centre of attention, etc. However, the above information indicates the presence of similar features between archaic society (pre-modern) and postmodern society. Common features include the focus on the individual consumer's liberalization and the absence of strict guidelines (while subordinating to global mechanisms in postmodernism). The person's preferences and the choices of his place in tourist consumption have a relevance. Poverty is coupled with challenges of maintaining human integrity in the first place, and a decrease in social contacts and an increase in the fragmentation of life in the second place. The growing marginalization of the population also affects the tourism requiring not only a material component but is also determined by various factors such as quality of education.

In this context, applying neoliberal approaches in the educational environment, which is the basis for further social development, is of considerable concern. The world community is also anxious about the low educational status. Arran (2021) sharply criticizes the modern educational and scientific environment. He argues that the corporatization of universities and the work of scholars on specific research for which funding is allocated, undermines the intellectual movement, fragmentation of research, and, in fact, the refusal to find optimal ways to develop social relations based on philosophical and moral principles of world development. According to the author, this has led to a significant vulnerability of scientists and marginalization of the university environment, which, along with reducing the overall education of citizens, poses a significant threat to the development of intellectual tourism. However, this is a global trend, not particular to a country.

Table 2: Types of social relations and their features in the context of tourism

Archaic society (pre-modern)	*Modernism*	*Postmodernism*
Individual tourist consumption (pilgrimage, summer accommodation in estates)	Transition to mass consumption of a tourist product	Transition to individual tours based on modern information technologies
The liberalism of tourist travel	Strengthening of state control over the subjects of tourist activity, manufacturability, and predictability of the tourist product	Freedom and mobility of tourist consumption, subordination to global mechanisms
Decentralization, lack of standards of tourist consumption	Standardization and concentration of tourist activity	Decentralization and individualization, but with pronounced global standardization
The integrity of human existence in society, but its miserable existence	Forming a society of consumption, imposing needs that make people their slaves, increasing alienation	Total alienation, reduction of social contacts, fragmentation of human existence, transition of tourist consumption to non-material, emotional level
The majority of the population is marginalized in tourism, they form a low social stratum, the "bottom" has no chance to escape from it.	Formation of a welfare society, the opportunity to take advantage of tourist offers to the lower classes due to the relatively cheap supply and mass tourist consumption	Significant socioeconomic polarization of members of society, democratization, the emergence of a mass marginal layer, precarization, total dependence on external living conditions

It is believed that the poorest countries in the Global South are least affected by neoliberal postmodernist trends, and are least affected by "collapse" too because they are close to nature (Daniel, 2021). The works of Desmond (2017), Ngonghala *et al.* (2017), Fisher *et al.* (2013), Broad and Cavanagh (2015), Alix-Garcia *et al.* (2013), and Cobbinah *et al.* (2015) lead to the assumption that the way out for the current situation in the context of balancing postmodernism influences the tourism activities and recommend the application of the concept of the ecology. According to them, a potentially exploited society has its own ecology, and it presupposes the ecologization of the worldview. The above conclusion is confirmed by the studies of Zhang and Hui (2016), which analyze the integral relationship between mind, modernity, and tourism, with the possibility of eliminating negative aspects of postmodernism by promoting neo-rationalism. According to them, this will lead to the healthy development of society as a whole. In addition, the authors expect the academic environment to exacerbate the studies on neo-rationalism in the context of tourism theory and philosophy. This will contribute to the formation of a new tourist behavior meeting the unitarity of society, nature, and man, and the improvement of the tourism industry and public life. The concept of neo-rationalism combines Western traditional rationalism with traditional Chinese culture. It is based on the critique of the unlimited influx of pleasure and satisfaction of human physiological instincts. A new humanistic spirit is proposed, which includes the mutual relations between human society, technology, and nature, care for the existence and fate of man forming the desire for the spiritual value of the nation and human existence.

2.4 Sociocultural aspect

Current trends in the creation and consumption of tourism products are characterized by a complex socio-cultural environment that takes into account the history, culture, and lifestyle of people. According to the recommendations of the European Parliament and the Council of Europe, the cultural component is included in the eight basic civic competencies necessary for active public life, personal realization, development, and social cohesion. Undoubtedly, the cultural competence of citizens has a significant impact on tourism. A high degree of its development, wide knowledge of local, state, European and world cultural heritage, understanding of their influence and place on a global scale, insight of cultural and linguistic aspects, skills in determining comprehension of social and economic opportunities in tourism activities lead to a decrease in the prerequisites for the formation and dissemination of tourist emptiness. It is associated not only with material aspects but also with several non-material factors, to include: low level of education, low level of social, economic, and cognitive activity, lack of motivation to travel, discontent for tourist consumption, and lack of a State policy for the development of culture (Pecheniuk, 2019). It should be noted that, in the Ukrainian context, these processes require an appropriate conceptualization and understanding of transformational conversions.

Pecheniuk (2019) identifies the main problems concerning cultural competence in the context of studying the conditions of Ukraine. This is manifested in the distortion of historical memory, disagreements in the vision of culture in the country, slow shifts in society, significant distrust, a propensity for hypothetical support to European values, selective implementation of values in everyday practice, and educational and informational competence of citizens. As Kostiuk (2016) points out, in general, the culture of the 21st century, as in antiquity, continues to be captivated by mythologies and the "sacredness" of society. The myths also take on other cultural forms. At the same time, the myth is not only dependent on the cultural context of that time but also acts as a means of social self-identification of individuals and society, indicating a social and psychological phenomenon in itself.

When determining modern tourist destinations, the growth of interest of the postmodern tourist in mysticism, which is associated with the spiritual and cultural sphere and satisfies information and psychological needs. Often, the interest in such travel among tourists is due to overcoming childhood fears, searching for something new, and interest in the past, spiritual and mental images, or mystical motives. The modern world has not completely ruled out mythological behavior, it has been pushed to more hidden levels of the psyche. The interaction of the collective unconscious and the individual, the strengthening of existing myths, and the formation of new ones lead to the creation of a secular religion, which is defined as a form of modeling the worldview and social behavior of participants in the context of the tourism process.

When analyzing the Ukrainian issue, it should be borne in mind that historically there have been two ways of forming national consciousness in Ukraine: Western, determined by civil liberties, and Eastern, the basis of which is adherence to traditions. In this context, a rather difficult task today is the transformation of the rural areas of Ukraine into well-known tourist centers, considering the lack of development of the infrastructure necessary for the tourism business and the insufficient preparedness of the population for accepting such activities. Ukraine in the historical context, compared to the Western world, entered much later into the enlightenment era and modernism. That is why a significant part of the rural population lives in an eclectic world, where there is a high degree of dependence on the agricultural sector along with the introduction of technological change. However, it should be noted that in places where the tourism industry interacts with cultural heritage and traditions, they begin to work for the tourist, changing the traditional way of life of the inhabitants and their life philosophy.

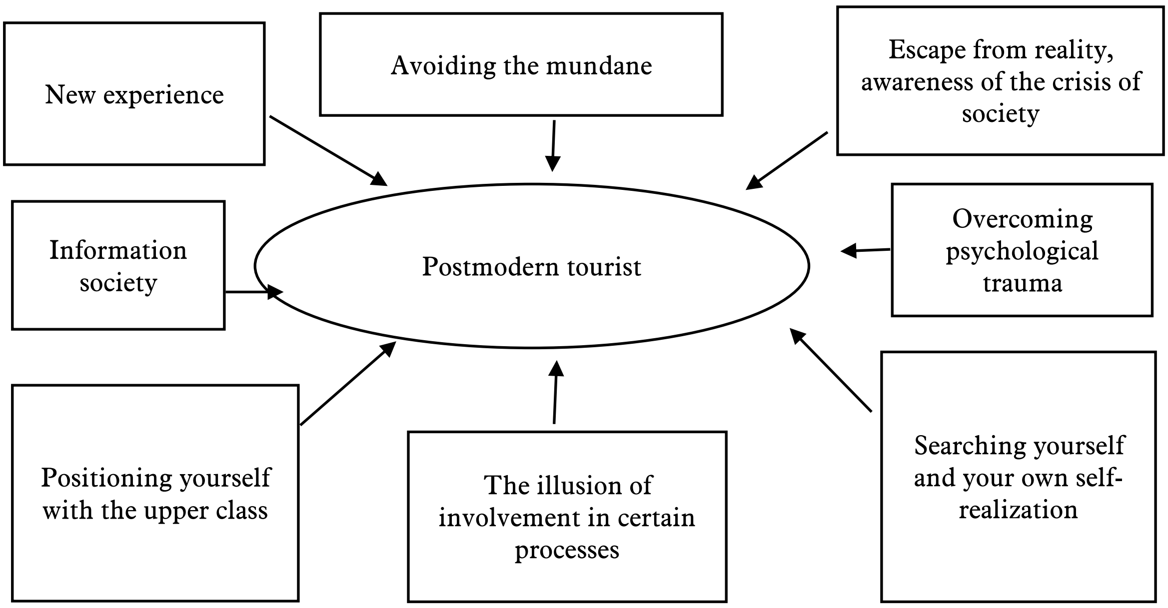

Figure 2: Factors of formation of postmodern tourist

2.5 Personal (psychological) aspect

In the general cultural sense, according to Moshniaha (2014), postmodernism is a new cultural and historical situation, a new order, a type of self-awareness, a thinking, a worldview, and an assessment of human cognitive abilities determining tourist's place in the world. Characteristic features of the postmodern personality include reorientation from the material and spiritual beings to the sensory experience of cognition; focus on spiritual and moral unity, meaningful work and forming an environment of like-minded people; freedom of individual expression, a departure from traditions and religion; emphasis on social status and quality of life; readiness and openness to political, cultural and social changes. Postmodern influences have formed a new personality - the post-tourist. This is a modern type of consumer who has considerable experience of tourist travel but is satisfied with imitation of reality, staging artifacts, and simulation, and is fully aware of the game that he or she enjoys and in which he or she is involved. The main generalizing incentives of consumption are emotions, experiences, and memories. This makes it possible to identify the factors shaping the postmodern tourist (Figure 2). These include awareness of the crisis of society, escape from reality, mundane avoidance, search for self and self-realization, overcoming psychological trauma, the illusion of involvement in certain processes, positioning oneself with the upper class, new experience, and information society.

Undoubtedly, the development of postmodernism is possible only in a globalized environment, in a consumer society, and wide information space. Postmodern transformations create certain opportunities for tourist destinations. Taking into account the tourism concept of the dream industry in the rural community development strategy can be defined as hyperreality with the appropriate content. These can be a variety of creative objects or events - simulators that are concentrated under a particular brand and are a tourist attraction where tourists become participants in a particular event, experiencing the appropriate emotions, feelings, and experiences. Examples of such objects include theme parks and museums, amusement parks, historical reconstructions of certain events, festivals, mystical tourism, etc. It is worth noting that COVID quarantine restrictions and the progress of online and on-site computer technologies have caused the development of virtual offers of tours and excursions.

The phenomenon of postmodernism has led to the fact that the tourist prefers an artificially created reality and it is much more attractive to him due to its cultural and semiotic filling with signs, meanings and images that promise a much higher emotional level of pleasure than when staying in ordinary conditions. In this sense, the main goal of a tourist trip will not be the physical visit of a tourist destination, but the satisfaction of one's own sensory components and emotional relaxation.

That is why, in postmodern society, it is important to bring out and advertise in the tourism market the very idea of travel, which will contain some properties: emotions and play, a sense of freedom and joy of life, gaining new experiences and impressions. However, some scientists, such as Volkov (2012), Upadhyay (2019) and Yin (2018), point to the negative consequences of postmodernism. These include destruction of national identity and culture, natural environment, depopulation of rural areas, formation of artificial reality to expect tourists, significant mythologizing of sacred places, hypertrophy of the effect of presence, perception of local cultural features as a way of earning, their conservation, absolutization, and hyperbolization, accompanied by a sense of play and falsehood, the illusion of understanding between cultures, the reduction of public space in rural communities, the orderliness of real life and the world, and the spread of the phenomenon of nomadism.

3. Conclusion

Postmodernist transformations significantly affect tourism development and tourism activities, which require a change in the general concept of tourism. A significant leap in the development of information technology has entailed considerable virtualization of tourist consumption and the postmodern consumer of a tourist product. This necessitates the transition of tourism to another level, which will cover the direction of virtual social life. At the same time, today the debatable issues are to determine the positive and negative benefits of postmodern tourism transformations, which can be considered both from the standpoint of mass postmodern tourism consumers and from the standpoint of personal development. Based on modern conditions of access to Internet technologies within rural areas of Ukraine, it can be stated that their level and quality do not correspond to the average European indicators, which is a significant deterrent to the spread of postmodern influences on the first (unreal, simulation) type of postmodern tourism. However, it can become a platform for those tourists who want to enjoy communication with wildlife, improve the emotional and sensory component, immerse themselves in the authentic environment of rural life, get to know themselves and the culture of the Ukrainian people.

Analysis of the evolution of types of social relations, starting with archaic society, modern and postmodern, in the context of tourism development and determining the place of man in tourism consumption, led to disappointing conclusions, as there are similarities between pre-modern and postmodern tourism, the main characteristic of which is a significant human problem and its place in society. In the first case, it is due to the impossibility to break out of the social bottom; in the second case, there is a significant social alienation, fragmentation of life, and precarization of the individual. The tourist marginalization of the population and the misery of human existence is the common problem.

4. References

Arran, G. (2021). Against Posthumanism Against Posthumanism: Posthumanism as the World Vision of House-Slaves. *Borderless Philosophy*, 4: 1-56. Available online at" https://philpapers.org/rec/GARAPP (accessed on 10 May 2022).

Alix-Garcia, J., McIntosh, C., Sims, K.R. E. and Welch, J.R. (2013). The Ecological Footprint of Poverty Alleviation: Evidence from Mexico's Oportunidades Program. *The Review of Economics and Statistics*, 95(2): 417–435. DOI: https://doi.org/10.1162/REST_a_00349.

Bogicevic, V., Seo, S., Kandampully, J.A., Liu, S.Q. and Rudd, N.A. (2019). Virtual reality presence as a preamble of tourism experience: The role of mental imagery. *Tourism Management*, 74: 55-64. DOI: https://doi.org/10.1016/j.tourman.2019.02.009.

Broad, R. and Cavanagh, J. (2015). Poorer Countries and the Environment: Friends or Foes? *World Development*, 72: 419-431. DOI: https://doi.org/10.1016/j.worlddev.2015.03.007

Christou, P., Farmaki, A., Saveriades, A. and Georgiou, M. (2020). Travel selfies on social networks, narcissism and the "attraction-shading effect". *Journal of Hospitality and Tourism Management*, 43: 289-293. DOI: https://doi.org/10.1016/j.jhtm.2020.01.014.

Cobbinah, P.B., Erdiaw-Kwasie, M.O. and Amoateng, P. (2015). Rethinking sustainable development within the framework of poverty and urbanisation in developing countries. *Environmental Development*, 13: 18-32. DOI: https://doi.org/10.1016/j.envdev.2014.11.001.

Daniel, T. (2021). Too late for pessimism! Ecosocialism or collapse. *Spil'ne*. Available online at: https://commons.com.ua/uk/zanadto-pizno-dlya-pesimizmu-ekosocializm-abo-kolaps/ (accessed on 10 May 2022).

Desmond, C. (2017). The ecology of rural poverty. *Nat Ecol Evol*, 1: 1060–1061. DOI: https://doi.org/10.1038/s41559-017-0251-2.

Fisher, J.A., Patenaude, G., Giri, K., Lewis, K., Meir, P., Pinho, P., Rounsevell, M.D.A. and Williams, M. (2014). Understanding the relationships between ecosystem services and poverty alleviation: Aconceptual framework. *Ecosystem Services*, 7: 34-45. DOI: http://dx.doi.org/10.1016/j.ecoser.2013.08.002.

Johnson, J. (2021). Worldwide digital population as of January 2021. Available online at: https://www.statista.com/statistics/617136/digital-population-worldwide/ (accessed on 16 May 2022).

Kang, H. (2020). Impact of VR on impulsive desire for a destination. *Journal of Hospitality and Tourism Management*, 42: 244-255. DOI: https://doi.org/10.1016/j.jhtm.2020.02.003.

Kostiuk, I. (2016). Culture of the XXI century in the captivity of mythologies: Causes and prospects. *Bulletin of LNAM. Series: Culturology*, 29: 37-46.

Marasco, A., Buonincontri, P., van Niekerk, M., Orlowski, M. and Okumus, F. (2018). Exploring the role of next-generation virtual technologies in destination marketing. *Journal of Destination Marketing & Management*, 9: 138-148. DOI: https://doi.org/10.1016/j.jdmm.2017.12.002.

Moshniaha, E.V. (2014). The development of tourism in the postmodern era. *Vestnik RMAT*, 2: 15-20.

Nagy, P. and Koles, B. (2014). The digital transformation of human identity: Towards a conceptual model of virtual identity in virtual worlds. *Convergence*, 20(3): 276-292. DOI: https://doi.org/10.1177/1354856514531532.

Ngonghala, C.N., De Leo, G.A., Pascual, M.M., Keenan, D.C., Dobson, A.P. and Bonds, M.H. (2017). General ecological models for human subsistence, health and poverty. *Nat Ecol Evol*, 1: 1153–1159. DOI: https://doi.org/10.1038/s41559-017-0221-8.

Oktadiana, H. and Pearce, P. L. (2020). Losing touch: Uncomfortable encounters with tourism technology. *Journal of Hospitality and Tourism Management*, 42: 266-276. DOI: https://doi.org/10.1016/j.jhtm.2020.01.011.

Pecheniuk, A. (2019). Tourist poverty as a cultural and humanitarian determinant. *Innovatsiyna ekonomika*, *7-8*, 118-122. https://doi.org/10.37332/2309-1533.2019.7-8.17

Pecheniuk, A. (2020). Information and innovation principles of rural tourism development in the new economy. *Prychornomors'ki ekonomichni Studiyi*, 49: 39-43. DOI: https://doi.org/10.32843/bses.49-6.

Pernecky, T. (2006). Co-creating with the universe: A phenomenological study of New Age tourists. Tourism: *International Interdisciplinary Journal*, 54(2): 127-143. Available online at: https://hrcak.srce.hr/161463 (accessed on 21 April 2022).

Peters, M.A., Tesar, M., Jackson, L. and Besley, T. (2019). Postmodernism in the afterlife. *Educational Philosophy and Theory*, 54(4): 325-327. DOI: https://doi.org/10.1080/00131857.2019.1686947.

Soldatova, E.L. and Pogorelov, D.N. (2018). The phenomenon of virtual identity: The contemporary condition of the problem. *The Education and Science Journal*, 5(20): 105–1024. DOI: https://doi.org/10.17853/1994-5639-2018-5-105-124.

State Statistics Service of Ukraine (2020). Ukrainian household access to the Internet in 2019. *Statystychnyy zbirnyk*. Available online at: https://ukrstat.org/uk/druk/publicat/kat_u/2020/zb/07/zb__dd_in19.pdf (accessed on 1 April 2022).

Upadhyay, P. (2019). Tourism in Nepal, Real or Hyperreal: A Postmodern Perspective. *Nuta Journal*, 6(1&2): 2075.

Volkov, V.N. (2012). Tourism in the postmodern era. *Context and Reflection: Philosophy about the World and Man*. 1: 77-86.

Wei, C., Dai, S., Xu, H. and Wang, H. (2020). Cultural worldview and cultural experience in natural tourism sites. *Journal of Hospitality and Tourism Management*, 43: 241-249. DOI: https://doi.org/10.1016/j.jhtm.2020.04.011.

Ying, T., Tang, J., Ye, S., Tan, X. and Wei, W. (2021). Virtual Reality in Destination Marketing: Telepresence, Social Presence, and Tourists' Visit Intentions. *Journal of Travel Research*, 00(0): 1-19. DOI: https://doi.org/10.1177/00472875211047273.

Yin, J. (2018). Beyond postmodernism: a non-western perspective on identity. *Journal of Multicultural Discourses*, 13(3): 193-219. DOI: https://doi.org/10.1080/17447143.2018.1497640.

Zhang, B.H. and Hui, Z.Y. (2016). Theoretical Exploration of Tourism, Postmodernity and Reason. *Journal of Service Science and Management*, 9: 83-91. DOI: http://dx.doi.org/10.4236/jssm.2016.91011]/.

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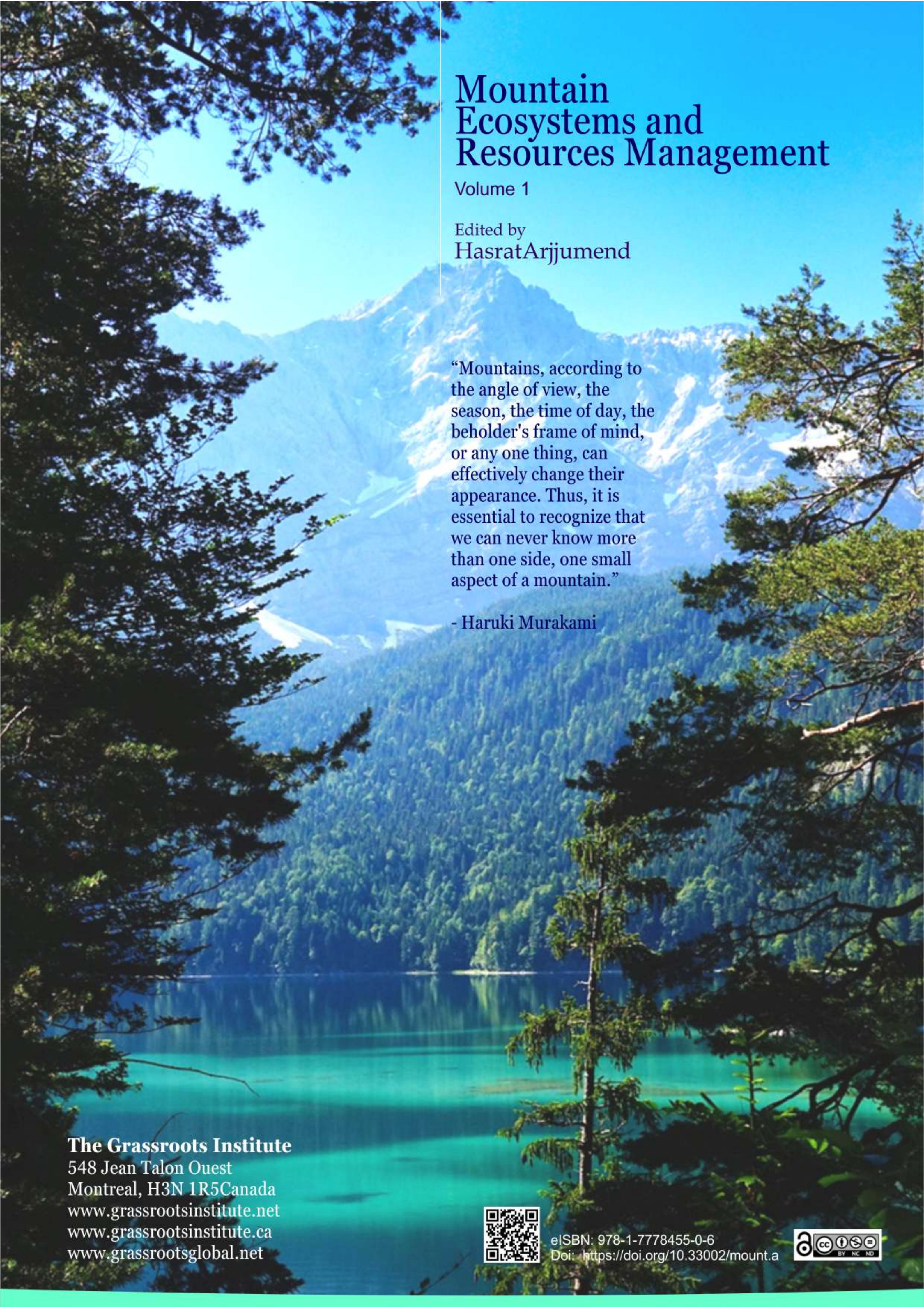

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"Mountains, according to the angle of view, the season, the time of day, the beholder's frame of mind, or any one thing, can effectively change their appearance. Thus, it is essential to recognize that we can never know more than one side, one small aspect of a mountain."

- Haruki Murakami

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