Chapter 6

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

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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).

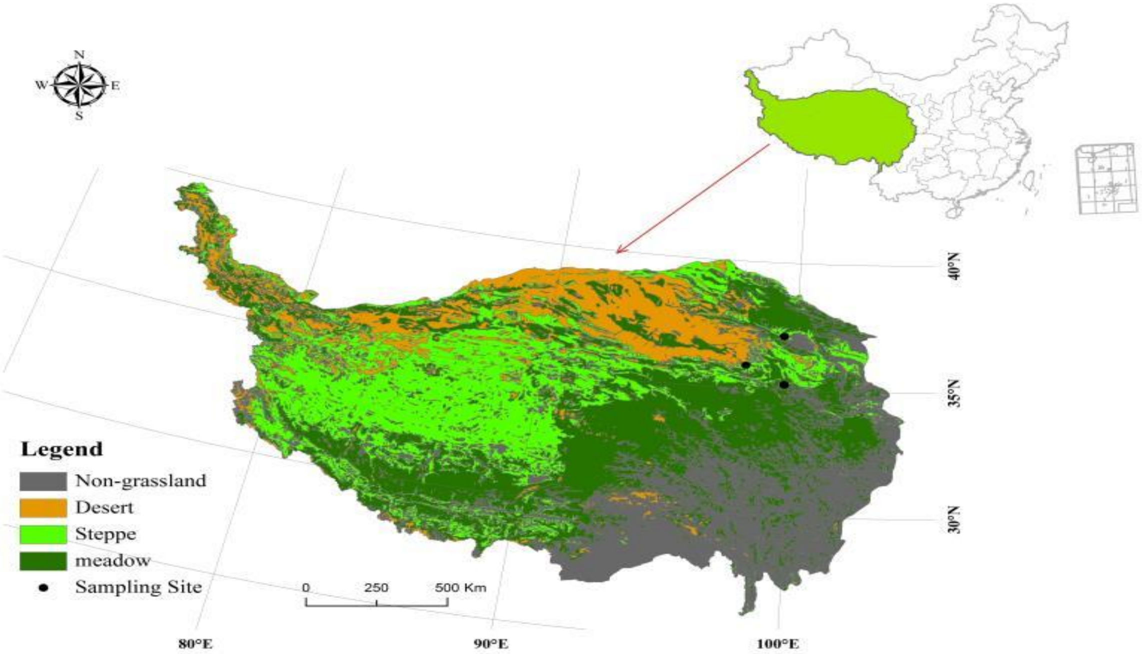

Figure 1: Map showing the study area

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).

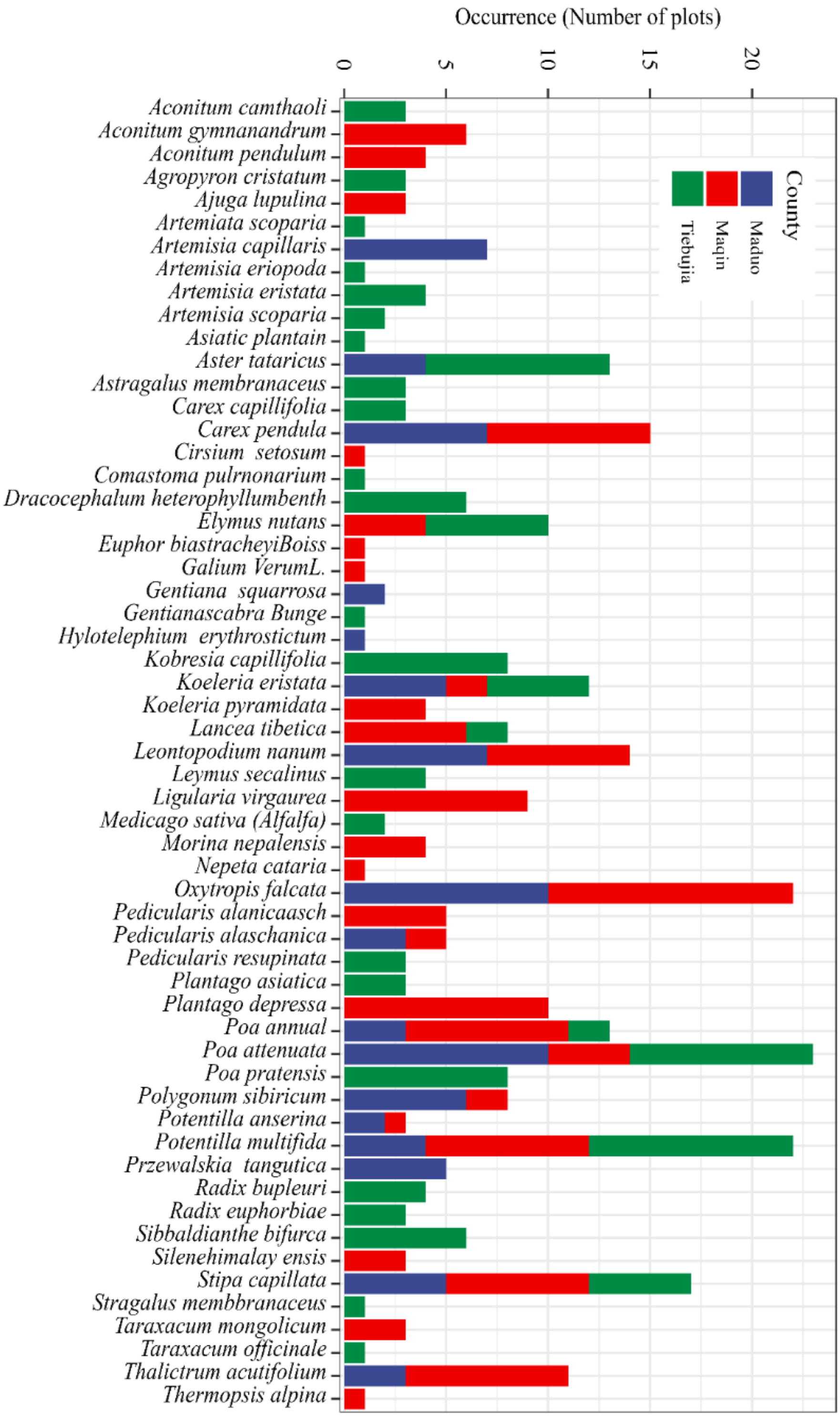

Figure 2: Species abundance according to grassland type

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.

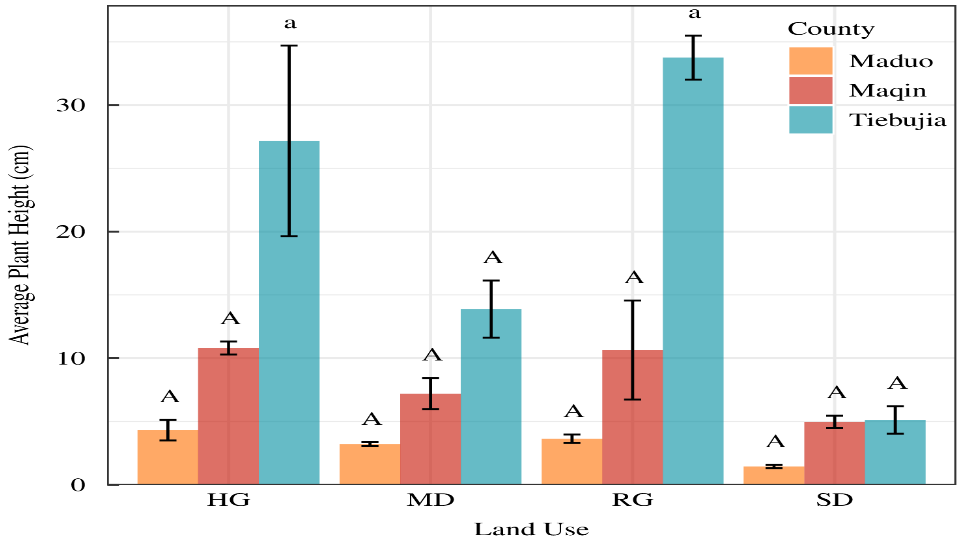

Figure 3: Average plant heights in the four land-uses. The significant differences among diverse land-use are depicted by different alphabetical letters ($p < 0.05$)

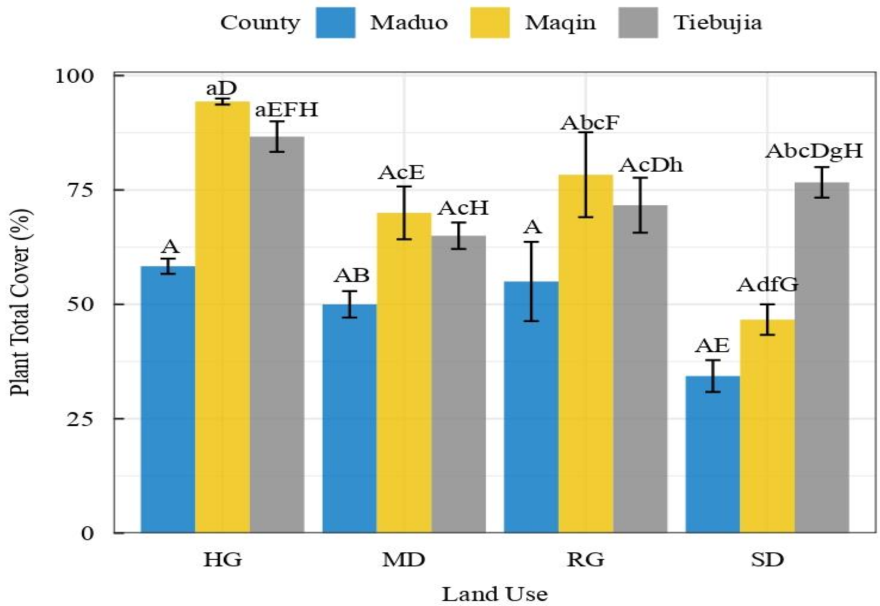

Figure 4: Total plant coverage across four land use. The significant differences among different land use are depicted by different alphabetical letters ($p < 0.05$)

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.

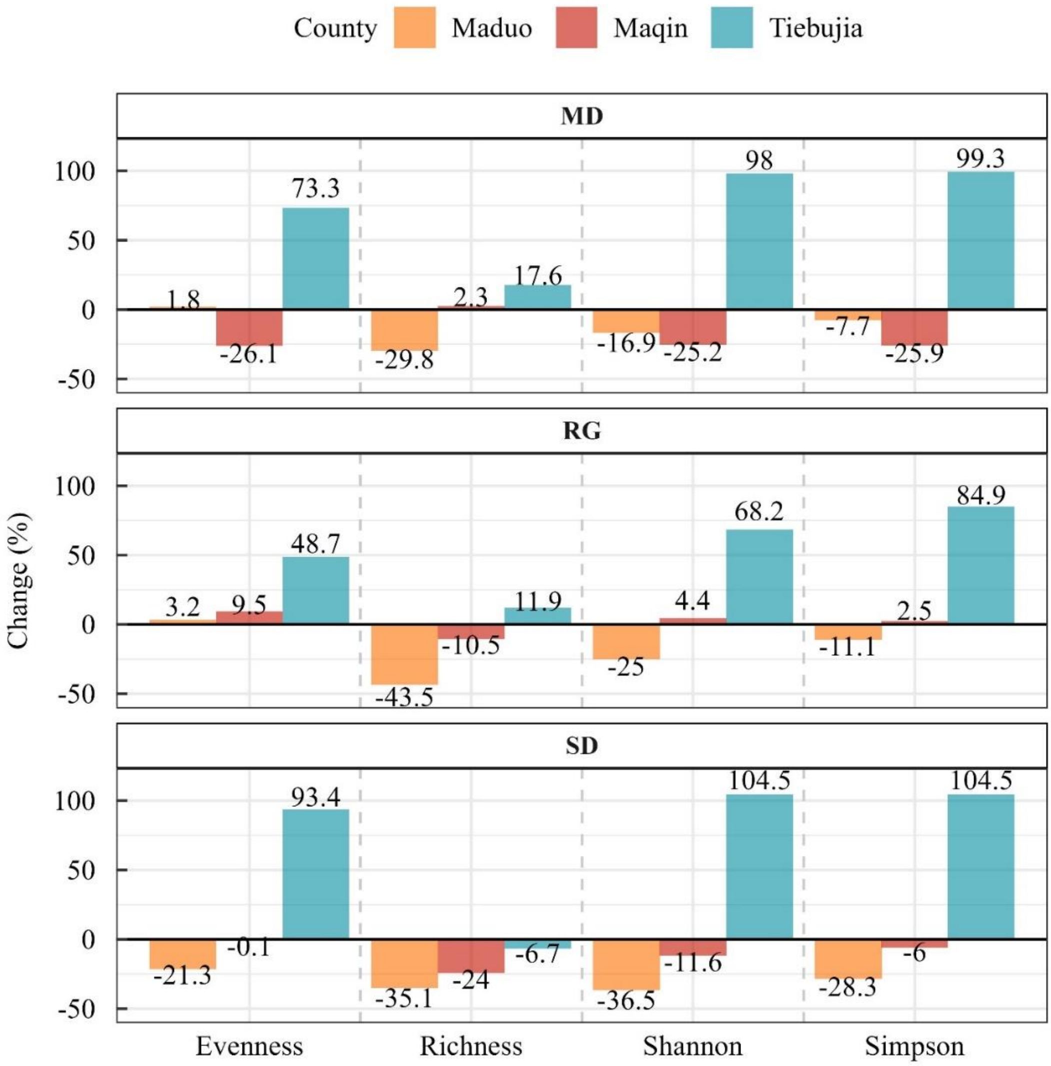

Figure 5: Mean change percentage of plant diversity indices in MD; RG and SD base of comparison with HG on the QTP

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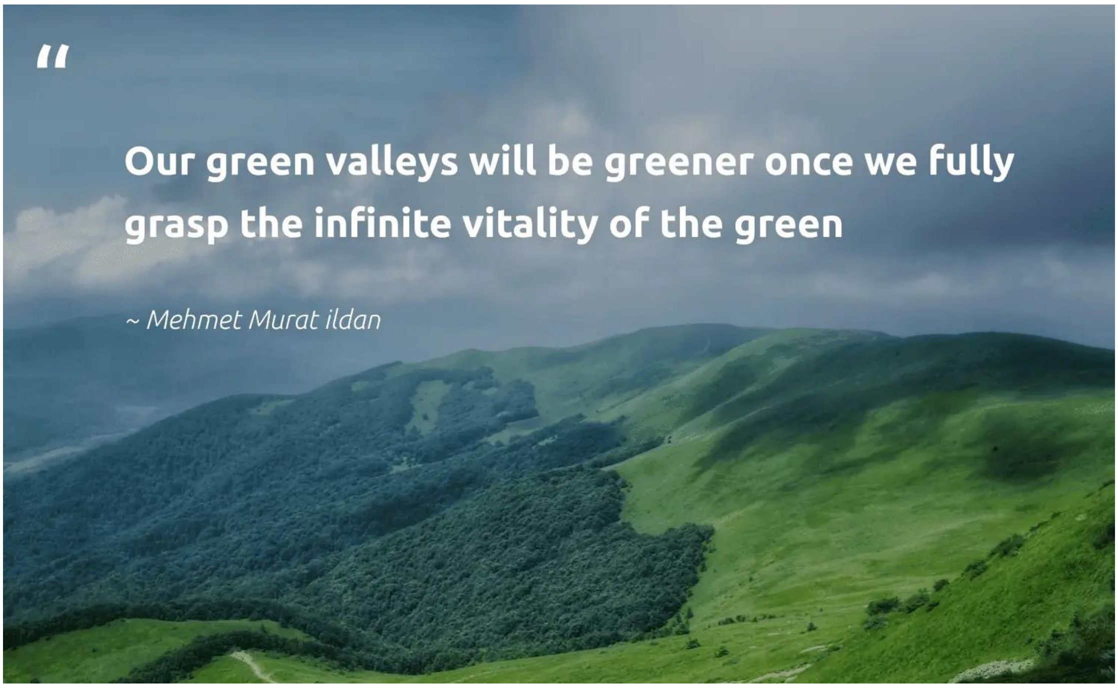
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Our green valleys will be greener once we fully grasp the infinite vitality of the green
~ Mehmet Murat ildan