ISSN 1067-4136, Russian Journal of Ecology, 2011, Vol. 42, No. 1, pp. 50–56. © Pleiades Publishing, Ltd., 2011.

Distribution of *Stipa purpurea* steppe in the Northeastern Qinghai-Xizang Plateau (China)[1]

P. P. Yue [a, b, c], X. F. Lu [a], R. R. Ye [a], C. X. Zhang [a, b],
S. B. Yang [a, b], Y. B. Zhou [a, b], and M. Peng [a]
[a] *Northwest Institute of Plateau Biology, Chinese Academy of Sciences, Xining 810001, China*
[b] *Graduate School of the Chinese Academy of Sciences, Beijing 100049, China*
[c] *Yulin University, Yulin, 719000 China;*
e-mail: pengm@nwipb.ac.cn

Received July 17, 2009

Abstract—The aims of this study were to examine the spatial distribution pattern of *Stipa purpurea* steppe and to elucidate their possible correlation with environmental factors, by means of multivariate quantitative analysis. Two data sets were subjected to the Two-way Indicator Species Analysis (TWINSPAN), the community similarity analysis and the Detrended Correspondence Analysis (DCA) and Canonical Correspondence Analysis (CCA). The distribution pattern of *Stipa purpurea* steppe showed obvious geographical heterogeneity in different regions and some homogeneity in the same region. And the altitude, longitude and latitude were the three major environmental factors affecting *Stipa purpurea* steppe's distribution.

Keywords: Qinghai-Xizang Plateau, *Stipa purpurea* steppe, classification, ordination.
DOI: 10.1134/S1067413611010140

The Qinghai-Xizang Plateau, occupying an area of about 2500000 km^2, is the highest plateau in the world and influences Eurasian atmospheric circulation and the distribution, structure, function, adaptation and evolutionary process of ecosystems (Chang, 1983). It is also an area highly sensitive to the global change and could be considered as an indicative or forewarning area for global change, and therefore, an area of great significance for monitoring and research (Zhou and Zhang, 1996).

Stipa purpurea, a member of Poaceae (Liu, 1999), is an endemic species distributed in Qinghai-Xizang Plateau, Pamirs Plateau and high mountains in central Asia. It can grow well in alpine adverse environments because of its strong resistance to cold, drought and gale (Zhou et al., 1987). Throughout the Qinghai-Xizang Plateau, *Stipa purpurea* steppe is one of the most important alpine ecosystems (Zheng et al., 1979; Wang and Li, 1982; Zhou et al., 1987; Guo, 1993) and plays an important role in preserving and stabilizing landscape heterogeneity and diversity. It could provide material base for the development of grassland animal husbandry, and the conservation and safeguard of soil and water, windbreak and sand fixation. At present, there are few studies on *Stipa purpurea* steppe in the ecological literature, mainly focusing on the basic vegetation investigation (Guo, 1993), the community degradation (Sun et al., 2003, Ma et al., 2004), the conversion efficiency for solar radiation energy (Wang et al., 2006a) and comparison of underground phytomass (Wang et al., 2006b). However, the study of distribution feature for *Stipa purpurea* steppe in high altitude area is still lack. Thus, we wish to provide a basis for further experimental, mechanistic approaches to understanding *Stipa purpurea* steppe's own rule and characteristic in this study.

More recently, quantitative analysis of vegetation data, such as classification and ordination, is an important and effective method to generate and test hypotheses with respect to vegetation and environment (Hill, 1979; Gao and Zheng, 1991; Martins et al., 1999; Mabry et al., 2000; Podani, 2000; Zhang, 2004). So, in this study, by multivariate analyses in terms of classification and ordination, we attempt to (1) examine the spatial distribution pattern of *Stipa purpurea* steppe, and (2) elucidate ecological relationships between *Stipa purpurea* steppe communities and the environments.

MATERIAL AND METHODS

Study Area

The studied area located in the northeastern Qinghai-Xizang Plateau (34°07' ~ 35°19'N, 95°50' ~ 101°14'E), with an altitude ranging from 3343 to 4567 m and the average altitude above 4000 m (Fig. 1 and Table 1). It includes three geographical areas, Tongde County, Maduo County and Qumalai County. The local cli-

---

[1] The article is published in the original.

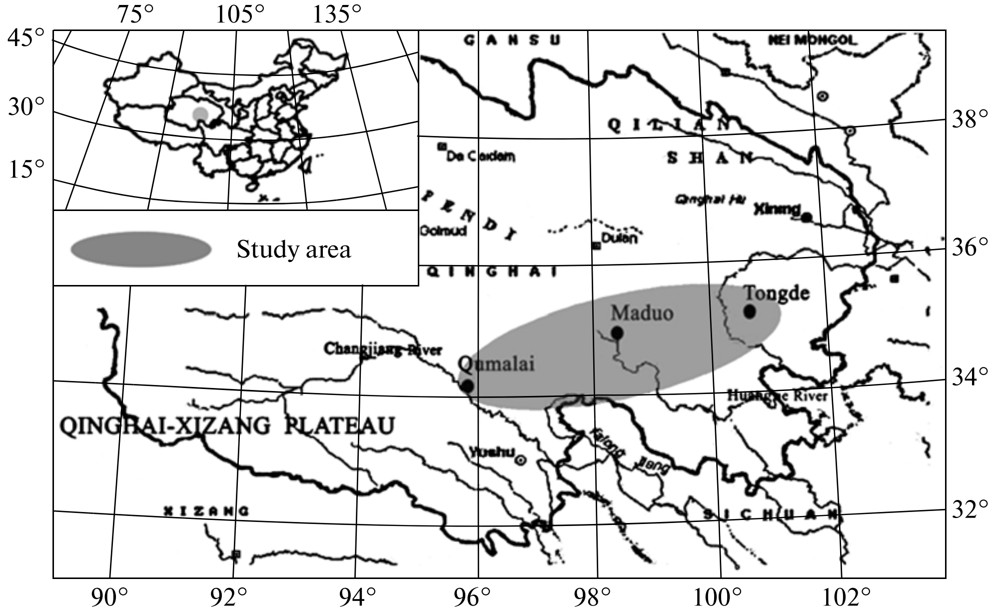

Fig. 1. Location of the studied area in the northeastern Qinghai-Xizang Plateau, China.

mate of the studied area is characterized by long, cold winters and short, relative cool summers. The mean annual temperature decreases from 0.2 to 4.1°C, the length of growing season (the durable days daily mean temperature exceeded 0°C steadily) from 191.5 to 141.4 days, and the mean annual rainfall from 427.0 to 304.0 mm (data source: Database of Natural Resources of China, http://www.data.ac.cn). The data of climate factors were listed in Table 1.

Data Collection

Three typical distribution zones of *Stipa purpurea* steppe in Tongde, Maduo, and Qumalai of Qinghai Province were selected as sample plots. To keep relative consistency, the *Stipa purpurea* steppe communities in the 3 plots presenting evenly growth, concentrative sheet distribution and in relative less different topography were chosen. In each sample plot, 11 100-m line transects were set at minimum 500-m intervals, and 10 quadrates of 1 m × 1 m along each transect were established at 10-m intervals. In each quadrate, all vascular species were identified, and percent coverage and abundance for each recorded vascular species were measured. The arithmetic mean of 10 quadrates along one line transect was calculated and then used as one transect data in the further quantitative analysis. In addition, longitude (long.), latitude (lat.) and altitude (alt.) of each transect were also measured by global position system (GPS). The quantitative survey of the vegetation was carried out in August, 2005 during

Table 1. General conditions of each investigated plots

Items	Plot 1	Plot 2	Plot 3
Sites	Tongde	Maduo	Qumalai
Transect no.	1–11	12–22	23–33
Altitude, m	3343–3555	4210–4355	4290–4567
Longitude	100°54′–101°14′E	97°40′–98°20′E	95°45′–95°05′E
Latitude	35°15′–35°19′N	34°50′–35°07′N	34°06′–34°10′N
Mean annual temperature, °C	0.2	–4.1	–2.5
Mean annual rainfall, mm	427.0	304.0	392.0
Length of growing season, day	191.5	141.4	155.0
Accumulated temperature during growing season, °C	1528.9	745.1	903.5

Table 2. General information and fundamental features for the seven groups of *Stipa purpurea* steppe

Groupings	Transects no.	Total coverage	*S*	*H*	*E*	Dominant species		Second dominant species		Third dominant species	
						Name	*IV*	Name	*IV*	Name	*IV*
I	1, 3, 11	86%	28	2.43	0.84	*Stipa purpurea*	23.81	*Ptilagrostis dichotoma*	8.73	*Koeleria litvinowii*	7.07
II	2, 5–9	96%	36	2.23	0.79	*Stipa purpurea*	35.28	*Poa indattenuata*	8.89	*Heteropappus altaicus*	7.98
III	4, 10	97%	32	2.52	0.79	*Stipa purpurea*	30.77	*Carex parva*	7.23	*Koeleria litvinowii*	7.11
IV	12–15, 17, 21, 22	75%	41	2.18	0.78	*Stipa purpurea*	39.18	*Leontopodium*	6.48	*Potentilla bifurca*	6.45
V	16, 18–20	75%	41	2.21	0.74	*Stipa purpurea*	39.41	*Potentilla bifurca*	7.06	*Saussurea arenaria*	6.02
VI	23–26	91%	35	2.47	0.82	*Stipa purpurea*	28.19	*Carex parva*	11.48	*Potentilla bifurca*	7.05
VII	27–33	88%	28	2.43	0.86	*Stipa purpurea*	25.39	*Carex parva*	11.93	*Ptilagrostis dichotoma* var. *roshevitsiana*	19.58

Note: *S*: species richness index, *H*: Shannon-Wiener's index of diversity, *E*: Pielou's index of evenness, *IV*: importance value.

the peak period of biomasses. A total of 330 quadrates belonging to 33 line transects were obtained from the fieldworks. A total of 96 vascular species belonging to 58 genera and 23 families were recorded in the 33 line transects.

Data Analysis

We used the *Importance Value* ($IV =$ (relative cover + relative frequence)/2) of each species as the data for community analysis and for calculation of diversity indices (Kuramato and Bliss, 1970; Greig-Smith, 1983; Zhang, 1995). Three diversity indices (Whittaker, 1972; Ma and Liu, 1994; Ma and Qian, 1994) were chosen as attribute variables data for community analysis: 1) Species richness index S represented by number of species recorded in each transect; 2) Shannon-Wiener's index of diversity $H = -\Sigma(Pi ln Pi)$; 3) Pielou's index of evenness $E = -\Sigma(Pi ln Pi)/\ln(S)$, where $Pi = Ni/N$, Ni is the individuals of species i, N is the total individuals of all species present, S is number of vascular species present. Then, the IV of every species and three diversity indices were calculated. As a result, two data sets were constituted: 1) the matrix of species data contains the importance values of 96 species in 33 transects; 2) the matrix of attribute variables data consists of three environmental variables (long., lat. and alt.) and three diversity indices (S, H and E) measured in 33 transects.

The Two-way Indicator Species Analysis (TWINSPAN) (Hill, 1979), the Detrended Correspondence Analysis (DCA) and Canonical Correspondence Analysis (CCA) (Hill and Gauch, 1980; McCune and Medford, 2002) were used to analyze community variation (Zhang, 1995) and combine the species data with environmental variables. These calculations were all carried out by program of PC-ORD (McCune and Medford, 2006).

Community similarity was estimated between any two groups classified by TWINSPAN, using the Sorensen's coefficient (Sorensen, 1948): $S = 2W/(a + b)$, where a is the number of total species in one plot and b is that in another plot, and W is the number of common species of the two plots.

RESULTS AND DISCUSSION

Classification

In order to investigate the rule and characteristics of *Stipa purpurea* steppe, the inner classification of community was carried out. Based on the first three splitting steps of TWINSPAN, it was found that 33 transects can be merged into 7 main groups corresponding to 7 major *Stipa purpurea* steppe types distributed in the study area. General information and fundamental features of each group were list in the Table 2. Although each group belongs to *Stipa purpurea* steppe community, there were exactly differences in different type, such as the total coverage, the diversity, co-dominant species, and so on.

Community Similarity

Sorensen's coefficient of community similarity between two different groups classified by TWINSPAN varied from 0.25 to 0.74 (Table 3), which indicated that there was obvious difference in the turnover of species composition among different types. The Sorensen's coefficients between two groups in the same plot were almost greater than that in the different plots. That is, as to *Stipa purpurea* steppe, the species compositions of community types in the same region were much more similar than that in the different region.

Table 3. Sorensen's coefficient of community similarity among *Stipa purpurea* steppe groups classified by TWINSPAN

No. of groups	Plot 1			Plot 2		Plot 3	
	I	II	III	IV	V	VI	VII
I	1						
II	0.59*	1					
III	0.53*	0.74*	1				
IV	0.26	0.42	0.41	1			
V	0.26	0.36	0.41	0.63*	1		
VI	0.25	0.31	0.42	0.48	0.58	1	
VII	0.3214	0.25	0.43	0.41	0.46	0.73*	1

* Sorensen's Coefficient between groups in the same plot.

Table 4. Eigenvalues for the first three axes of CCA and DCA in *Stipa purpurea* steppe

Analysis methods	Eigenvalue		
	Axis 1	Axis 2	Axis 3
CCA	0.402	0.276	0.132
DCA	0.611	0.080	0.042

Ordination of Transects

Ordination of transects by DCA was presented in Fig. 3. The 7 types classified by TWINSPAN were further identified in DCA ordination space, which testified that the TWINSPAN classification of *Stipa purpurea* steppe's internal types was reasonable. Additionally, the distribution of transects in DCA ordination diagram showed an noticeable characteristic: Groups in different region (Tongde, Maduo and Qumalai) were distributed separately from each other, while groups in the same region had some overlap or even next to each other. The analysis of Community similarity had indicated the species composition of groups in the same region was much more similar than that in the different region. The aboved results confirmed that *Stipa purpurea* steppe presented obvious

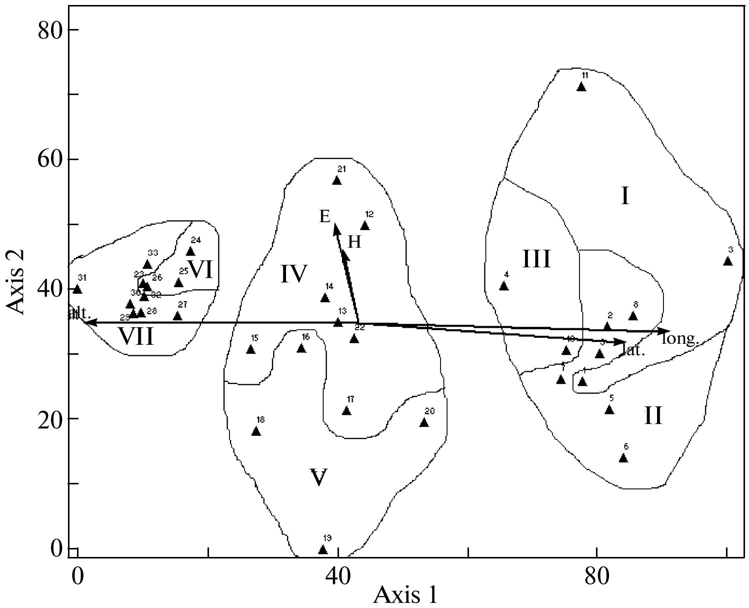

Fig. 2. The DCA ordination diagram of 33 transects and attribute variables of *Stipa purpurea* steppe in the northeastern Qinghai-Xizang Plateau, China. 1 to 33 represent transect number. I to VII refer to community types identified by TWINSPAN. The radiating lines refer to attribute variables (the angle and length of the line tell the direction and strength of the relationship between the variables and ordination scores).

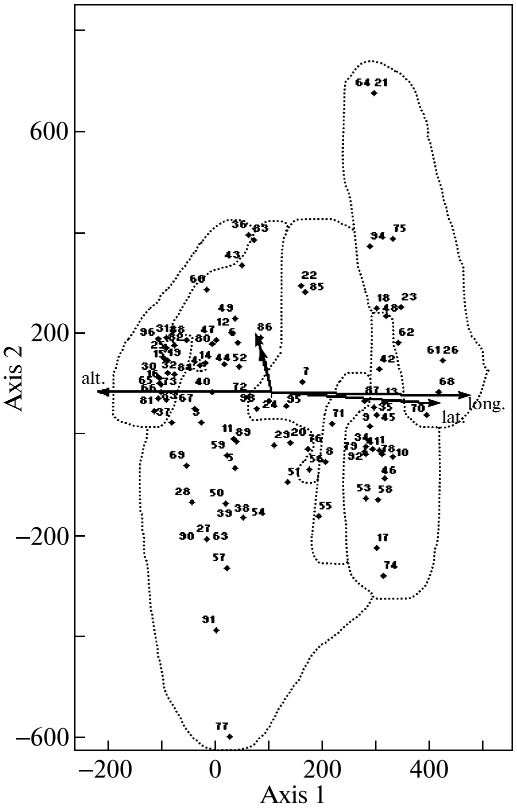

Fig. 3. The DCA ordination diagram of 96 speciess and attribute variables of *Stipa purpurea* steppe in the northeastern Qinghai-Xizang Plateau, China. 1 to 96 refers to 96 vascular species recorded in the study area.

geographical heterogeneity in different region and some homogeneity in the same region.

The relationships between *Stipa purpurea* steppe types and environmental variables were estimated by using both DCA and CCA analysis. Table 4 indicated that the eigenvalue for the axis 1 is much higher than the other two axes, both in DCA and CCA, indicating that the first axis of ordination captured the greater proportion of the variation in species composition among transects. Furthermore, the first axis was significantly related to the altitude, longitude and latitude (see Fig. 3 and Table 5). This suggested that the *Stipa purpurea* steppe vegetation in the northeastern Qinghai-Xizang Plateau was mainly affected by the altitude, longitude and latitude. Along DCA axis 1 from the left-hand side to the right, altitude decreased, while longitude and latitude increased. The *Stipa purpurea* steppe groups (VI and VII) in the left part of the DCA ordination map distributed in Qumalai. They were high altitude, mean coverage and high evenness type. Group IV and V in the central part distributed in Maduo with relative moderate altitude, low coverage and low evenness. Group I, II and III in the right part was relative low altitude, high coverage and mean evenness type (Tongde). Ordination axis 2 with a comparatively low eigenvalue was less important. It might reflect trends of other environment factors, such as slope aspect, soil type. However, along DCA axis 2 from the bottom to the top, one thing could be determined that the index *H* and *E* were both increased. In other words, the diversity and evenness of *Stipa purpurea* steppe were less influenced by altitude, but other environmental factors, such as slope aspect, soil type. The correlation coefficients of species richness (*S*) with both ordination axis 1 and 2 were so lower. It might be due to the special habitat.

Ordination of Species

A distribution pattern of the total 96 species was presented in Fig. 4 by the DCA ordination diagram. Species groups (based on the first three splitting steps of TWINSPAN) from upper side to lower side of the TWINSPAN result matrix mainly spread from left to right in the DCA ordination space. Species on the left part, such as *Astragalus mattam* (4000 ~ 4800 m), *Arenaria bryophylla* (4200 ~ 4250 m), *Androsace tapete* (3800 ~ 5200 m) and *Saussurea eopygmaea* (3300 ~ 4950 m), were basically/mainly found in Qumalai and Ma duo, the relative high altitude zone. Species on the right side, such as *Chenopodium aristatum* (2400 ~

Table 5. Correlations between ordination axes and attribute variables of *Stipa purpurea* steppe in the northeastern Qinghai-Xizang Plateau, China

Attribute variables	Correlation coefficients of CCA			Correlation coefficients of DCA		
	Axis 1	Axis 2	Axis 3	Axis 1	Axis 2	Axis 3
Altitude	–0.982	–0.172	–0.001	–0.920	0.002	0.102
Longitude	0.979	–0.174	–0.069	0.971	–0.160	–0.027
Latitude	–0.868	–0.480	0.119	0.898	–0.245	–0.043
S	0.018	–0.039	–0.034	0.017	0	0.156
E	–0.134	0.835	0.328	–0.273	0.545	–0.312
H	–0.103	0.657	0.285	–0.217	0.471	–0.083

3200 m), *Stipa breviflora* (2230 ~ 3800 m), *Lepidium obtusumwere* (about 2800 m), *Gentiana squarrosa* (2230 ~ 3600 m) and *Heteropappus altaicus* (1800 ~ 4150 m), were mainly presented in the low altitude zone and found in Tongde. And species in the center, such as *Stipa purpurea* (2700 ~ 5200 m), *Potentilla bifurca* (2080 ~ 4300 m), *Potentilla multifida* (1200 ~ 4300 m), *Poa indattenuata* (2600 ~ 4500 m) and *Sibalddia cuneata* (3400 ~ 4500 m) (Liu, 1999), were usually widespread species. And the widespread species were always co-dominant species and primary companion species in *Stipa purpurea* steppe, but their proportion would be changed in different region because of the comprehensive effect of regional environmental factors followed with the changes of latitude and longitude.

As to the species-environment relationship, there are mainly two different opinions. Some authors have found really poor correlations between environmental characteristics and vegetation in the western United States (Lentz and Simonson, 1987; Jensen et al., 1990). However, some other studies have revealed that some soil characteristics are related to species distribution (He et al., 2007). Our results showed that a certain amount of species were strongly concerned with the altitude, while some companion species with wide ecological amplitude almost spread all over. Furthermore, the borderline of each species group was not very obvious. It indicated that the species distribution was continuous for all groups of *Stipa purpurea* steppe types. On the premise of *Stipa purpurea* was the unconditional dominant species, the difference between different types contacted with different companion species and their proportion.

CONCLUSIONS

This was a systematical study on spatial distribution pattern of *Stipa purpurea* steppe and their possible correlation with environmental factors. In the study area, *Stipa purpurea* steppe could be classified into 7 major community types. The distribution of 7 groups presented obvious geographical heterogeneity in different regions and some homogeneity in the same region. And the altitude, longitude and latitude were proved to be three major environmental factors affecting the types and species distribution of *Stipa purpurea* steppe.

ACKNOWLEDGMENTS

We really wish to thank Mr. Y. Liu and Mr. D.M. Liu for their assistance in the fieldwork, and Dr. J. Sun for her useful suggestions in the experiment and revision of the manuscript. This work was supported by the Knowledge Innovation Programs of Chinese Academy of Sciences.

REFERENCES

Chang, D.H.S., The Tibetan Plateau in Relation to the Vegetation of China, *Ann. Missouri Bot. Gardens*, 1983, vol. 70, pp. 564–570.

Gao, Q. and Zheng, H.Y., The Application of Fuzzy ISODATA Clustering to Quantitative Analysis of Grassland Communities. *Acta Phytoecol. Geobot. Sin.*, 1991, vol. 15, pp. 312–318.

Greig-Smith, P., *Quantitative Plant Ecology*, 3rd ed., Oxford: Blackwell, 1983.

Guo, K., Vegetation of Qinghai Hoh Xil Region, *Acta Phytoecol. Geobot. Sin.,* 1993, vol. 17, pp. 120–132.

He, M.Z., Zheng, J.G., Li, X.R., et al., Environmental Factors Affecting Vegetation Composition in the Alxa Plateau, China, *J. Arid Environ.*, 2007, vol. 69, pp. 473–489.

Hill, M.O., *TWINSPAN: A Fortran Program for Arranging Multivariate Data in an Ordered Two-Way Table by Classification of the Individuals and Atributes*, Ithaca, NY: Cornell Univ. Press, 1979.

Hill, M.O., and Gauch, H.G., Detrended Correspondence Analysis: An Improved Ordination Technique, *Vegetatio*, 1980, vol. 42, pp. 47–58.

Jensen, M.E., Simonson, G.H., and Dosskey, M., Correlation between Soils and Sagebrush-Dominated Plant Communities of Northeastern Nevada, *Soil Sci. Soc. Am. J.,* 1990, vol. 54, pp. 902–910.

Kuramato, R. T. and Bliss, L.C., Ecology of Subalpine Meadows in the Olympic Mountain, Washingtion, *Ecol. Monogr.*, 1970, vol. 40, pp. 317–347.

Lentz, R.D. and Simonson, G.H., Correspondence of Soil Properties and Classification Units with Sagebrush Communities in Southeastern Oregon, *Soil Sci. Soc. Am. J.*, 1987, vol. 51, pp. 1263–1271.

Liu, S.W., *Flora of Qinghai,* Xining: Qinghai People's Publishing House, 1999.

Ma, K.M. and Liu, Y.M., Measurement of Biotic Community Diversity: 1. α Diversity (Part 2), *Chinese Biodiv.*, 1994, vol. 2, pp. 162–168.

Ma, K.M., and Qian, Y.Q., *Principles and Methodologies of Biodiversity Studies,* Beijing: Chinese Science and Technology Press, 1994.

Ma, S.Z., Peng, M., Chen, G.C., Zhou, G.S., et al., Feature Analysis of Vegetation Degradation on Alpine Grassland in Yellow River Source Region, *Pratacult. Sci.*, 2004, vol. 21, pp. 19–23.

Mabry, C., Ackerly, D., and Gerhardt, F., Landscape and Species-Level Distribution of Morphological and Life History Traits in a Temperate Woodland Flora, *J. Veget. Sci.*, 2000, vol. 11, pp. 213–224.

Martins, D., Odd, E., Eli, F., et al., Beech Forest Communities in the Nordic Countries: A Multivariate Analysis, *Plant Ecol.,* 1999, vol. 140, pp. 203–220.

McCune, B. and Medford, M. J., *Analysis of Ecological Communities*, Gleneden Beach, OR: MJM Software, 2002.

McCune, B. and Medford, M. J., *PC-ORD Multivariate Analysis of Ecological Data*, 5.18 ed., Gleneden Beach, OR: MJM Software, 2006.

Podani, J., *Introduction to the Exploration of Multivariate Biological Data*, Leiden: Backhuys, 2000.

Sorensen, T., A Method of Establishing Groups of Equal Amplitude in Plant Society Based on Similarity of Species Content, *Biol. Skrifter*, 1948, vol. 5, pp. 1–34.

Sun, J., Peng, M., Chen, G.C., et al., Study on Community Characteristics and Community Diversity in *Stipa* Steppe of Qinghai Lake Region, *Acta Bot. Boreali-Occident. Sin.,* 2003, vol. 23, pp.1963–1968.

Wang, J.T. and Li, B.S., Main Types and Characteristics of High-Cold Steppe in the Qiangtang Plateau of Xizang, *Acta Phytoecol. Geobot. Sin.*, 1982, vol. 6, pp. 1–13.

Wang, X.L., Gan, Y.M., Zhang, L., et al., Study on the Conversion Efficiency for Solar Radiation Energy of Heavy and Moderate Degraded Grassland of *Stipa purpurea* in Qinghai Lake Area, *Pratacult. Anim. Husbandry*, 2006a, vol. 11, pp. 1–4.

Wang, X.L., Zhang, L., Zhang, D.G., et al., Study on Comparison of Underground Phytomass of *Stipa purpurea* Steppe under Moderate and Heavy Degradation, *Grassland and Turf*, 2006b, vol. 4, pp. 15-20.

Whittaker, R.H., Evolution of Measurement of Species Diversity, *Taxon*, 1972, vol. 21, pp. 213–251.

Zhang, J.T., *Quantitative Methods in Vegetation Ecology*, Beijing: China Science and Technology Press, 1995.

Zhang, J.T., *Quantitative Ecology*, Beijing: Science Press, 2004.

Zheng, D., Zhang, R.Z., and Yang, Q.Y., On the Natural Zone in the Qinghai Xizang Plateau, *Acta Geogr. Sin.*, 1979, vol. 34, pp.1–11.

Zhou, G.S. and Zhang, X.S., Study on Climate–Vegetation Classification for Global Change in China, *Acta Bot. Sin.,* 1996, vol. 38, pp. 8–17.

Zhou, X.M., Wang, Z.B., and Du, Q., *Vegetation of Qinghai*, Xingning: Qinghai People Press, 1987.