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Classification of plant functional types based on the nutrition traits: a case study on alpine meadow community in the Zoigê Plateau

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Abstract: The ecological concept of Plant Functional Types (PFTs), which refers to the assemblage of plants with certain functional traits, has been introduced for the study of plant responses to the environment change and human disturbance. Taking the alpine meadow community in the Zoigê Plateau as a study case, this paper classified PFTs in terms of plant nutrition traits. The sequential results are as follows. (1) The main herbages in the Zoigê Plateau included 16 species in 5 families. Among the five families, *Cyperaceae* vegetation accounted for 81.37% of herbage area in total, while the remaining 4 families occupied less than 20%. As for the species, *Kobresia setchwanensis* Hand.-Maizz. was dominant, accounting for 48.74% of the total area; while the remaining 51.26% was comprised of *Polygonum viviparum* L., *Anaphalis fiavescens* Hand.-Mazz., *Stipa aliena* Keng and other species. (2) By using the Principal Component Analysis (PCA), the assessment of herbages nutrition was carried out based on the comprehensive multi-index evaluation model. *Polygonum viviparum* L. had the highest nutritional value score (1.43), and *Stipa aliena* Keng had the lowest (-1.40). Nutritional value of herbage species had a significantly positive correlation with altitude (P<0.01) in the Zoigê Plateau. (3) Based on the nutritional values, herbages in the Zoigê Plateau could be grouped into 3 nutrition PFTs (high, medium and low) by using the Natural Breaks (Jenks) method.

Keywords: Plant functional types; Nutritional value; Forage resource management; the Zoigê Plateau

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Introduction

Environmental change and human disturbance have the capability to exert large influences on the nature and function of terrestrial vegetation (Mintzer 1992). Studies on plant responses to global changes have become an important issue (Pettorelli 2005). However, it is excessively complex and unrealistic to establish the response relationships of plant species with global changes (Weng and Zhou 2005). The method of plants function classification can be used to reduce this complexity, and has been more and more popular (Harrison et al 2010; Wana and Beierkuhnlein 2011; Silva and Batalha 2011; Li et al. 2016). Independently of the functional classification method applied, the right choice of plant traits is essential (Sun et al. 2004). Plant traits contain two aspects, effect traits and response traits. The former determines the effects of plants on ecosystem functions, such as resource availability, biogeochemical cycling, propensity to disturbance, etc. In contrast, response traits refer to the responses of plants to environmental factors, such as dispersal mode, nutrient uptake strategy, lifespan, etc. (Laliberte et al. 2010). For a specific research objective, vegetation can be classified into several groups of plant species which possess similar response traits and/or effect traits (Lavorel and Garnier 2002). These groups can be defined as Plant functional types (Skarpe 1996).

As an efficient tool to simplify the complexity of ecosystem research, the classification of Plant Functional Types (PFTs) has been applied by numerous researchers in grassland studies. For confirmation on the influences of soil texture and water availability in the environmental filtering, Negreiros et al. (2014) evaluated the relationships between plant functional traits and several environmental factors in the Brazilian mountain grassland ecosystem, and classified 48 herbal species into 3 PFTs: plants with big stature in growth and rapid uptake of resources (C PFT); plants with moderate stature and high longevity in durable and well-defended structures (S PFT); and plants with small stature, short longevity and high reproductive capacity (R PFT). For the interpretation of relationships between plants and grassland use, Wang (2004) grouped 150 plants species of saline grassland into 8 PFTs (i.e., high perennial grasses, short perennial graminaceous plants, annual grasses, annual forbs, perennial forbs, halophytes and hydrophytes), according to their photosynthetic pathways and morphological traits. Accordingly, the classification of PFTs in grasslands varies depending on the different purposes and spatial scales used by researchers in their studies. Such variability greatly hinders the application range of PFTs in grassland studies. Therefore, more advanced and more integrated classification of PFTs that can be widely applied in all kinds of grassland ecosystems is still lacking.

Nutrition traits can comprehensively reflect the capability of photosynthesis and nutrient uptake of grassland plants (Ai et al. 2011; Wang et al. 2010). A combination of different response traits (e.g., dispersal mode, nutrient uptake strategy, etc.) and/or effect traits (e.g., resource availability, biogeochemical cycling, etc.) indicates similar nutrition traits, so intricate PFTs can be regrouped into simple ones. As a result of combining biotic and abiotic factors, a simplified classification method of PFTs would be proposed based on nutrition traits. This new method can be used for comparative analysis of various grassland ecosystems.

In the matter of rangeland, nutritional value determined by nutrition traits of herbage species is not only directly related to the quality of rangeland, but also closely connected with the local animal husbandry (Wang et al. 2010). Highly nutritious meadows supply sufficient nutrition to livestock, meeting the needs for maintenance and production. Plenty of livestock (10.47 million sheep equivalent units in 2005 (Li et al. 2008) are bred in the Zoigê Plateau, the largest alpine steppe in China and one of the most natural meadows in Asia. The conflict between the large number of livestock and poor natural environment will inevitably exert negative impact on the Zoigê Plateau plants. Thus, it is urgent to predict the vegetation response to environmental changes and human disturbance in the Zoigê Plateau. Under such conditions, the alpine meadow community's nutrition PFTs classification has been adopted as the theoretical base to obtain the following objectives: (1) to extract and investigate information of all herbage species; (2) to deduce the comprehensive multi-index evaluation model and to assess the nutritional value of herbage species; and (3) to classify the PFTs according to the nutritional value of herbage species in the Zoigê Plateau.

1 Materials and Methods

1.1 Study area

The Zoigê Plateau lies on the southeast edge of the Qinghai-Tibet Plateau (32°10′-34°30′N, 100°40′-103°40′E), which includes Zoigê County, Hongyuan County and Aba County in Sichuan Province, Luqu County and Maqu County in Gansu Province, and Jiuzhi County in Qinghai Province, covering a total area of 33,800 square kilometers (Figure 1). This area is a flat plateau which is adjacent to Minshan Mountain in the east, Qionglai Mountain in the south, Golog Mountain, Animaqing Mountain and Xiqing Mountain in the west, and Tsinling Mountains in the north. The mean annual temperature (1.6°C) and average annual rainfall (400-800 mm) combine to create the ideal environment to allow the grasslands to flourish and thrive. The Zoigê Plateau includes 7 land use types (cropland, woodland, grassland, wetland, water body, construction land and unused land), and the grassland is dominant (Li et al. 2010). On account of high elevation (the average elevation is 3763 m above sea level) and harsh environment in the Zoigê Plateau, livestock feeding, yak herding in particular, is the dominant local industry. The nomads have formed their unique lifestyle characterized by moving their home along with grass over multiple generations (Goldstein and Beall 1991). The meadow quality directly relates to providing sustainable livelihood conditions for the herders in the Zoigê Plateau. The situation mentioned above makes the study area worthy of further research.

1.2 Data source and processing

In this study, the vegetation data was obtained from the Vegetation Atlas of China (Editorial Board of Vegetation Map of China, Chinese Academy of Sciences 2001) and field investigation (Table 1).

The composition and nutrition data of herbage species were acquired from the results of previous researches at the heading stage (Zhang 2012; Ai et al. 2011; Wang et al. 2010; Xin and Zhang 2011). Other data include the Landsat TM data and the ASTER GDEM data, both with the spatial resolution of 30m. The statistical data was analyzed by using SPSS 17.0. The spatial data was extracted, stored, managed, operated and analyzed based on ArcGIS 9.3.

1.3 Methods

1.3.1 Principal component analysis (PCA)

Generally speaking, the nutritional value of forage can be represented by a variety of related nutrients, such as crude protein, crude fat, ash, nitrogen free extract and crude fiber (Ai et al. 2011; Wang et al. 2010). Because the livestock's ability to absorb nutrients varies, the analysis of single phytonutrient is usually one-sided (Xia et al. 2000). Therefore, it is vital to simplify the multi-index model into an integrated one for the process of nutrition evaluation. Widely adopted methods include the index weight method and the Analytical Hierarchy Process (AHP). However, these methods are over-reliant on experts' experience and judgment, and cannot avoid the subjectivity (Li

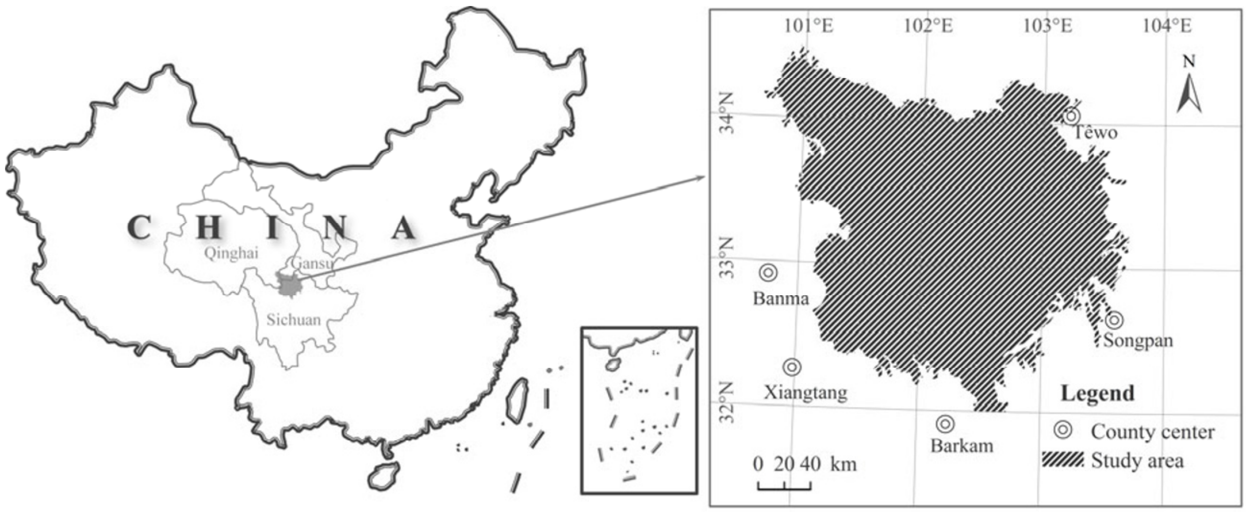

Figure 1 Geographic location of the Zoigê Plateau in China.

Table 1 Sampling sites of field investigation in the Zoigê Plateau

Sites	Coordinate	County	Herbage species
1	32°47′55″N, 102°24′39″E	Hongyuan	*Kobresia capillifolia* (Decne.) C.B.Clarke
2	33°23′57″N, 102°30′25″E	Hongyuan	*Polygonum macrophyllum* D.Don = P.Sphaerostachum Meisn.
3	33°49′48″N, 102°30′38″E	Zoigê	*Kobresia humilis* (C.A.Mey.ex Trautv.) Sergiev
4	33°48′35″N, 102°40′14″E	Zoigê	*Kobresia setchwanensis* Hand.-Maizz.

et al. 2006). Fortunately, PCA, a method of multivariate correlation analysis, can overcome the above-mentioned shortcoming. The PCA is a classic statistical tool and easy to operate when extracting relevant information from complicated datasets. It can identify fundamental variables that explain the correlations within a set of observed variables. In the case of herbage nutritional value, the PCA was used in data reduction to identify a small number of nutrients that explain most of the variance observed in a much larger number of nutrients.

The steps of assessing herbage nutritional values based on the PCA are as follows: (1) setting up a $b \times p$ raw data matrix M (b species and p nutrition indexes); (2) standardizing the matrix M and calculating correlation matrix R; (3) calculating contribution rate and cumulative contribution rate and obtaining the n eigenvalues of principal components; (4) acquiring principal components' loading matrix L of nutrition indexes, then calculating eigenvectors and various nutrients weights;

According to the correlations of principal components and nutrition indexes, weights and eigenvectors of n principal components can be calculated by using the Eqs. (1) and (2) respectively. Then, the synthetic weighted vector can be worked out by using Eq.(3).

$$W_i = E_i \Big/ \sum_{i=1}^{n} E_i \tag{1}$$

$$V_i = L_i \Big/ \sqrt{E_i} \tag{2}$$

$$A = \sum_{i=1}^{n} V_i \cdot W_i \tag{3}$$

In the equations, A is the synthetic weighted vector for assessment, L_i is the i^{th} load vector, V_i is the i^{th} eigenvector, W_i is weight of the i^{th} principal component, E_i is eigenvalue of the i^{th} principal component, and n is the number of principal components.

Deduce comprehensive weighted multi-index evaluation model as Eq.(4) below, then assess the nutritional value of herbage species.

$$C = \sum_{i=1}^{p} S_i \cdot A_i \tag{4}$$

In the equation, C is the comprehensive evaluation value of every herbage species, S_i is the i^{th} standardized nutrition index value, A_i is the i^{th} coefficient of A and p is the number of nutrition indexes.

1.3.2 Plant Functional Types (PFTs) classification

When studying the common characteristics or functionalities of multiple plant species, the key features used for the PFTs classification can be selected on the basis of research concern (Bugmann et al. 1996). After obtaining it through the PCA, herbage nutritional value was selected as the key feature to classify the PFTs to study the quality of rangeland in the Zoigê Plateau.

(1) adapting the existing conceptual framework of PFTs;

The existing conceptual framework of PFTs (Díaz and Cabido 1997) was adapted to the use in the alpine meadow community of the Zoigê Plateau (Figure 2). Nutrition traits, which indicated response traits and/or effect traits, could be used to establish the linkages between the plant community and the ecosystem functioning.

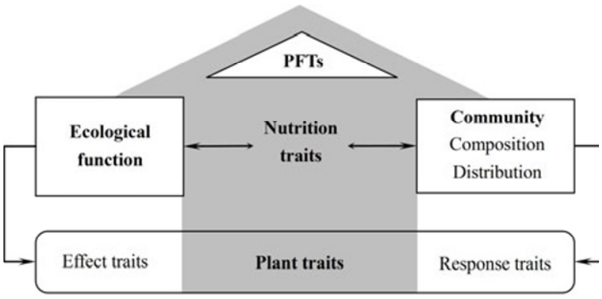

Figure 2 Conceptual framework of Plant Functional Types (PFTs).

(2) extracting and investigating the data of herbage species in the Zoigê Plateau;

(3) calculating nutritional values of herbages species and grading the calculation results by using the Natural Breaks (Jenks) method;

The Natural Breaks (Jenks) method is a statistical analysis which can sectionalize data on the basis of the value types and distributional rules (Guo et al. 2015). It can set up class limits where the largest breaks occur in the data array and maximize the differences among data at various levels (Tang et al. 2006). In this paper, the Natural Breaks (Jenks) method provided by ArcGIS was selected as the standard classification to grade nutritional value scores of herbages species.

(4) classifying herbage species into the different PFTs in the Zoigê Plateau.

2 Results and Discussion

2.1 Taxonomic results of herbages in the Zoigê Plateau

The meadow community in the Zoigê Plateau consists of 16 grass species distributed in 5 families (Table 2). *Cyperaceae* vegetation occupied the largest proportion, accounting for 81.37% of the total area, and the remaining 4 families, *Polygonaceae*, *Gramineae*, *Rosaceae* and *Asteraceae* were less than 20% in total. Within the 16 species, *Kobresia setchwanensis* Hand.-Maizz. was preponderant in the Zoigê Plateau, occupying 48.74% of the total area. The remaining area (51.26% of the total) was taken up by other species including K*obresia capillifolia* (Decne.) C.B.Clarke, *Kobresia pygmaea* (C.B.Clarke) C.B.Clarke, *Polygonum viviparum* L., *Polygonum macrophyllum* D.Don = P.Sphaerostachum Meisn., *Roegneria nutans* (Keng) Keng, *Elymus nutans* Griseb., etc.

In the Zoigê Plateau, the composition and distribution of plant community are closely related to the habitat (Tian 2005). After the rising of the Qinghai-Tibet Plateau, the old atmospheric circulation was destroyed around early Pleistocene, forming the current particular climate of the Qinghai-Tibet Plateau (Wang and Li 1982). The Zoigê Plateau is influenced not only by the southwest and southeast monsoon, but also by the Siberian high and Tibetan high. It is characterized by significant regional difference of hydrothermal conditions (Zhang et al. 2009), notable diversity of plant families and species. Surrounded by mountains, the Zoigê Plateau is a basin where the Heihe River and the Baihe River run from the north to the south. Populated with lowlands and old waterways, the research area is abundant with water. Due to the wide distribution of peaty soil and subalpine meadow soil, humidogene *Cyperaceae* plants play a predominant role in the Zoigê Plateau (Tian 2005). The *Cyperaceae* plants have engendered a series of physiological adaptations and species replacement during the long evolutive process (Grabherr et al. 1994). *Kobresia setchwanensis* Hand.-Maizz. becomes the winner in such interspecific competition with strong tiller ability, low plant architecture and high grazing tolerance (Gao et al. 2008). Based upon the clonal phenotypic variations and reproductive strategies along altitudes in the Northern Tibet, Xie et al. (2014) drew a similar conclusion: the distribution range of *Kobresia setchwanensis* Hand.-Maizz. would be further expanded with more intensive global warming and human activities, which were the causes for its occupation of nearly half of the habitat area.

2.2 Assessment on the nutritional value of herbages species in the Zoigê Plateau

The 5×13 normalized data matrix was composed of 5 nutrition indexes (crude protein,

Table 2 Phytological classification of the herbage species in the Zoigê Plateau

Family	Species	Area (hm^2)	Proportion (%)	Subtotal (%)
Cyperaceae	*Kobresia setchwanensis* Hand.-Maizz.	1646257.58	48.74	81.37
	Kobresia capillifolia (Decne.) C.B.Clarke	526816.35	15.60	
	Kobresia pygmaea (C.B.Clarke) C.B.Clarke	403089.57	11.93	
	Carex tristachya Thunb.	83706.66	2.48	
	Kobresia tibetica Maxim.	72817.76	2.16	
	Kobresia myosuroides (Villars) Fiori	10888.89	0.32	
	Kobresia humilis (C.A.Mey.ex Trautv.) Sergiev	4763.64	0.14	
Polygonaceae	*Polygonum viviparum* L.	168985.84	5.00	9.24
	Polygonum macrophyllum D.Don=P.Sphaerostachum Meisn.	143013.79	4.23	
Poaceae	*Roegneria nutans* (Keng) Keng	88829.06	2.63	6.96
	Elymus nutans Griseb.	88829.06	2.63	
	Stipa aliena Keng	57405.12	1.70	
Rosaceae	*Potentilla fruticosa* L.	71942.10	2.13	2.23
	Spenceria ramalana Trimen	3425.12	0.10	
Asteraceae	*Anaphalis fiavescens* Hand.-Mazz.	3425.12	0.10	0.20
	Leontopodium longifolium Ling.	3425.12	0.10	
Total		3377620.79	100.00	

crude fat, crude fiber, ash and nitrogen free extract) and 13 herbages species. The 3 herbage species (*Spenceria ramalana* Trimen, *Anaphalis fiavescens* Hand.-Mazz., and *Leontopodium longifolium* Ling.) were kept for medicinal purposes by the local residents, therefore were not included in the data matrix. The eigenvalues, contribution rates and cumulative contribution rates of principal components were calculated and stated in Table 3.

Table 3 Eigenvalue (E_value) and contribution rate (C_rate) of principal component

Component	Initial Eigenvalue		
	E_value	C_rate (%)	Cumulative C_rate (%)
1	2.44	48.84	48.84
2	1.42	28.31	77.14
3	1.03	20.61	97.76
4	0.11	2.24	100.00
5	6.66×10^{-12}	1.33×10^{-10}	100.00

The contribution rates of the first 3 principal components were 48.84%, 28.31% and 20.61% respectively, and the cumulative contribution rate was 97.76%. The vast majority of the total variation was incorporated in the first 3 principal components, and the information loss rate of the original data matrix was only 2.24%. The calculation of load vectors and eigenvectors of the three principal components were shown in Table 4.

When the data of the 5 nutrients (crude protein, crude fat, ash, nitrogen free extract and crude fiber) were obtained, the nutritional value of each herbage species was evaluated using the synthetic weighted vector as a coefficient. The comprehensive multi-index evaluation model was represented as Eq.(5).

$$C = 0.17S_{CP} + 0.37S_{CFa} + 0.39S_{ASH} + 0.04S_{NFE} - 0.26S_{CFi} \quad (5)$$

where, C was the nutritional value score of herbage species. S_{CP}, S_{CFa}, S_{CA}, S_{NFE} and S_{CFi} were standardized the values of crude protein, crude fat, ash, nitrogen free extract and crude fiber respectively.

Eq.(5) suggested that the nutritional value of herbage species was positively correlated with crude protein, crude fat, ash and nitrogen free extract, but negatively with crude fiber. Such results have been verified by numerous empirical studies. Based on seasonal forage nutrition and sheep weight, Li et al. (2001) carried out studies on the grassland on the northern slope of the Tianshan Mountain. The results showed that the high protein, fat, ash, nitrogen free extract and low crude fiber indicated high nutrition. By analyzing the digestibility of different forages in cattle rumens, Liu et al. (2008) pointed out that the high fiber was not good for cattle to absorb the other nutrients. However, the quantifying standard of nutrition evaluation has not been established yet in these studies. To make up for the deficiency, the performance and accuracy of Eq.(5) should be tested in various grasslands.

For every herbage species in the Zoigê Plateau, the calculated nutritional value score and the average distribution altitude were presented in Table 5.

Through the SPSS 17.0 statistical analysis software, it was certified that the nutritional value of herbage species presented a significantly positive correlation with altitude (P<0.01) in the Zoigê Plateau. The changing regularity was summed up as follows: the higher the altitude, the higher the nutritional value of herbage species was. Altitude variation is an integrated gradient effect combining temperature, light and other environmental factors (Lu et al. 2015), thus, such changing regularity can be explained from the following aspects. The relationship between temperature change and herbage nutrition has been extensively studied over the past two decades. Using *Kobresia humilis* (C. A. Mey. ex Trautv.) Sergiev at different temperatures as the study material, Han et al. (1997) found that low temperature had a greater degree of promotion on the synthesis and accumulation of protein.

Table 4 Load vectors and eigenvectors of the three principal components

Nutrition index	Load vector			Eigenvector			Synthetic weighted vector
	L_1	L_2	L_3	V_1	V_2	V_3	
Crude protein (CP)	0.78	0.15	-0.58	0.50	0.13	-0.57	0.17
Crude fat (CFa)	0.78	0.57	-0.11	0.50	0.48	-0.11	0.37
Ash (ASH)	0.27	0.59	0.75	0.17	0.49	0.74	0.39
Nitrogen free extract(NFE)	0.54	-.079	0.30	0.34	-0.66	0.29	0.04
Crude fiber (CFi)	-0.93	0.32	-0.19	-0.59	0.27	-0.18	-0.26

While working with the impacts of climate warming on the nutrient contents of herbage grown in the Qinghai-Xizang Plateau, Xu et al. (2002) found that there were significant downtrends in crude protein, ether extract and nitrogen free extract contents of herbage along with the increase of temperature. These results indicate that in lower temperature environment, slower growth of herbages is beneficial for nutrient accumulation. With the sugar, fat and protein increasing, the nutritional value increases accordingly (Wang et al. 2010). Another important environmental factor related to plant nutrition is light. Light is the only energy source of photosynthesis, which influences the production of plant nutrients. In areas with high altitude, long duration of sunshine proves to be conducive to the photosynthesis, enabling herbages to get more light energy in the growing period (Liu et al. 2000). Furthermore, if the light saturation point is high while the compensation point is low, the grass photosynthesis in these areas may develop from the lower light intensity to the higher (Zhang et al. 1992), which is advantageous to the nutrient accumulation.

2.3 PFTs classification in the Zoigê Plateau

By using the Natural Breaks (Jenks) method, the nutritional value scores of all herbages species in the Zoigê Plateau were divided into the high (0.39 ~ 1.43), medium (-0.38 ~ -0.12) and low (-1.40 ~ -0.55) grades. On this basis, 13 varieties of herbages in the Zoigê Plateau were grouped into the high, medium, and low nutrition PFTs (Table 6). These 3 nutrition PFTs was introduced as a general measure at a relatively high level of plant traits and thus greatly simplify the complexity of plant community research.

Through the information spectrum technology, the distribution pattern of 3 nutrition PFTs in the Zoigê Plateau was shown in Figure 3, and the average elevations of the areas where the 3 PFTs appeared were extracted into Table 7.

As mentioned previously, the distribution of nutrition PFTs in the Zoigê Plateau changed along with the altitude variation (Table 7). The medium nutrition PFT at middle altitude (nearest to the average altitude of the Zoigê Plateau) was distributed most widely, while the high and low nutrition PFTs were interspersed in the high and low altitude areas separately. It indicated that herbage species in the same nutrition PFT had similar responses to environmental change, especially to the changes of temperature and light.

The nutrition PFTs can be used to analyze plant responses to human disturbance. After fire, grazing is the second most important disturbance (Huntly 1991). When grazing, the priority selection of livestock is high nutritional herbage with high crude protein, high crude fat, high ash, and low

Table 5 Nutritional value score and average altitude of every herbage species in the Zoigê Plateau

Herbage species	Score	Average altitude (m)
Polygonum viviparum L.	1.43	3832.49
Polygonum macrophyllum D.Don=P.Sphaerostachum Meisn.	1.11	3766.33
Kobresia pygmaea (C. B. Clarke) C. B. Clarke	0.85	4054.09
Kobresia humilis (C. A. Mey. ex Trautv.) Sergiev	0.70	3914.04
Kobresia tibetica Maxim.	0.41	3543.80
Kobresia myosuroides (Villars) Fiori	0.39	3780.79
Kobresia setchwanensis Hand.-Maizz.	-0.12	3740.00
Potentilla fruticosa L.	-0.38	3746.64
Roegneria nutans (Keng) Keng	-0.55	3629.29
Kobresia capillifolia (Decne.) C. B. Clarke	-0.55	3752.54
Carex tristachya Thunb.	-0.84	3574.44
Elymus nutans Griseb.	-1.03	3629.29
Stipa aliena Keng	-1.40	3458.37

Table 6 The Plant Functional Types (PFTs) classification in the Zoigê Plateau

Herbage species	Score	Average altitude (m)
Polygonum viviparum L.	1.43	3832.49
Polygonum macrophyllum D.Don=P.Sphaerostachum Meisn.	1.11	3766.33
Kobresia pygmaea (C. B. Clarke) C. B. Clarke	0.85	4054.09
Kobresia humilis (C. A. Mey. ex Trautv.) Sergiev	0.70	3914.04
Kobresia tibetica Maxim.	0.41	3543.80
Kobresia myosuroides (Villars) Fiori	0.39	3780.79
Kobresia setchwanensis Hand.-Maizz.	-0.12	3740.00
Potentilla fruticosa L.	-0.38	3746.64
Roegneria nutans (Keng) Keng	-0.55	3629.29
Kobresia capillifolia (Decne.) C. B. Clarke	-0.55	3752.54
Carex tristachya Thunb.	-0.84	3574.44
Elymus nutans Griseb.	-1.03	3629.29
Stipa aliena Keng	-1.40	3458.37

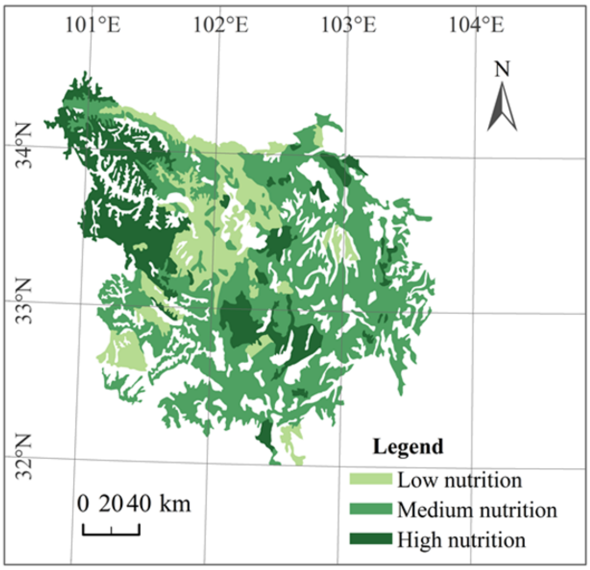

Figure 3 The spectrum of the 3 nutrition Plant Functional Types (PFTs) in the Zoigê Plateau.

Table 7 Distribution of the 3 nutrition Plant Functional Types (PFTs) in the Zoigê Plateau

Nutrition PFTs	Average elevation (m)	Area (hm²)	Area (%)
High	3958.21	777764.60	23.12
Medium	3726.26	1957555.10	58.20
Low	3633.88	628373.13	18.68
Total	3762.88	3363692.83	100.00

crude fiber (Zhang et al. 2011). The selective grazing behavior of livestock will not only change the structure of plant community, but also affect the nutrient content of plants (Hou et al. 2006). Previous empirical researches have been carried out on the relationship between herbage nutrient and grazing. Dong et al. (2007) found that the grazing intensity and date (from July 5 to September 20) had a significant negative correlation with the forage nutrition contents in alpine mixed-sown grasslands. However, Heitshcmidt et al. (1989) held an opposite opinion that a higher grazing intensity would increase the nutritional value of herbages because grazing kept herbages fresh and tender. The two controversial conclusions actually complement each other. Grazing will lead to composition and proportion changes of the herbage species (Zhang et al. 2011). In this sense, moderate grazing is beneficial to improve the nutrition of herbages species (Fu et al. 2013). However, under overgrazing, the high nutrition herbages withdraw in succession from rangeland and the low nutrition herbages dominate (Zhao et al. 1999). The increase of nutritional value of the PFT suggests that most herbages are in moderate grazing. On the contrary, a decrease of nutritional value indicates a replacement of nutrient-rich herbage species by nutrient-poor ones due to overgrazing. Therefore, according to the distribution of the 3 nutrition PFTs (Figure 3), reasonable grazing policies can be made by regularly monitoring the nutritional value of the 3 PFTs in the Zoigê Plateau.

At present, the main problem of this nutrition PFTs classification is the intraspecific variation of herbage nutrition. Nutrition data of this paper, acquired at the heading stage of herbages, will change with the sampling season and environmental conditions. Such changes will have some effect on the ascription of some plants to nutrition PFTs. Besides, it is crucial to establish quantitative relationship between nutrition PFTs and grazing intensity to improve the animal husbandry management in the Zoigê Plateau. Therefore, optimizing the classification of the 3 nutrition PFTs and quantifying the effect of moderate grazing are worthy of further study.

3 Conclusions

(1) The main herbages in the Zoigê Plateau included 16 species distributed in 5 families. *Cyperaceae* vegetation occupied the largest proportion and *Kobresia setchwanensis* Hand.-Maizz. was preponderant in the distribution area.

(2) Nutritional values of herbages species in the Zoigê Plateau were evaluated by using the PCA and comprehensive multi-index evaluation model. *Polygonum viviparum* L. had the highest nutritional value, while the nutritional value of *Stipa aliena* Keng was the lowest. Nutritional value of herbage species had a significantly positive correlation with altitude (P<0.01) in the Zoigê Plateau. The higher the altitude is, the higher the nutritional value of herbage species is.

(3) Based on the nutritional values, herbages in the Zoigê Plateau were grouped into 3 nutrition PFTs. These plant groups can be used to establish the relationship between herbages and environmental change and human disturbance

more simply in the Zoigê Plateau. According to the above research results and the related discussion, the plant nutrition PFTs can be defined as the functional groups which are classified based on the plant nutrition traits. As an exploratory functional classification method, the nutrition PFTs need to be improved in many respects, but the advantages in analyzing the biological response of plants to environmental change and human disturbance cannot be ignored.

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