Patterns of floristic composition under different grazing intensities in Bulgan, South Gobi, Mongolia

Patterns of floristic composition in Bulgan, Mongolia

Takehiro Sasaki, Tomoo Okayasu, Kazuhiko Takeuchi,
Undarmaa Jamsran*, Sanjid Jadambaa**

Graduate School of Agricultural and Life Sciences, The University of Tokyo, 1-1-1 Yayoi, Bunkyo-ku, Tokyo 113-8657, Japan

*Center for Ecosystem Study, Mongolian State University of Agriculture, 210153 Ulaanbaatar, Mongolia

**Institute of Botany, Mongolian Academy of Sciences, 210351 Ulaanbaatar, Mongolia

This work was supported by the Global Environmental Research Fund of the Ministry of the Environment, Government of Japan.

Synopsis

Sasaki, T., T Okayasu, K. Takeuchi, U. Jamsran, and S. Jadambaa (year presented): Patterns of floristic composition under different grazing intensities in Bulgan, South Gobi, Mongolia. Grassland Science (vol. no.), (no. of pages).

We surveyed the floristic composition and analyzed the patterns of floristic composition under different grazing intensities in the semi-arid area of Bulgan, in the South Gobi of Mongolia. We sampled 90 quadrats at six points (15 quadrats each) along a transect from a spring and grouped them into five vegetation types by using TWINSPAN. All or most of the quadrats at each point corresponded to one of the five vegetation types. The DCA axis 1 arranged all the quadrats in order of grazing intensity, and the floristic composition changed dramatically in a lopsided stepwise-pattern along this axis. The composition ratio for five groups clustered by TWINSPAN according to plant functional types (toxicity or palatability, and life-form) and family varied to a greater or lesser extent. Background environmental factors such as soil moisture or landform did not effect much on the pattern of the floristic composition at this site. The patterns of floristic composition were determined by grazing intensity (determined as distance from the spring) together with palatability, which was the dominant environmental effect at the site.

Key words : Floristic composition, Grazing intensity, Land degradation, Mongolia, Plant functional types.

Introduction

Land degradation problems in arid and semi-arid areas have been the focus of numerous studies; some of these studies have found overgrazing to be the most serious of all factors causing land degradation (Dregne *et al*. 1991 ; UNEP 1992). In Mongolia, most of which forms part of the semi-arid area of north-eastern Asia, the main cause of land degradation is also overgrazing (Gunin *et al*. 1999).

According to Ohkuro (1997), analysis of grassland ecosystems under various grazing intensities at the floristic composition level is a valid method of diagnosing grassland condition. Such studies have reported that floristic composition changes with grazing intensity (Li 1989 ; Nemoto *et al*. 1994, 1997 ; Wang and Ripley 1997 ; Nakamura *et al*. 1998, 2000 ; Wuyunna *et al*. 1999 ; Yiruhan *et al*. 2001). In most of these studies, however, background environmental factors such as landform and soil moisture have not been described, therefore their potential effects on the changes of floristic composition can not be discussed. Fernandez-Gimenez and Allen-Diaz (2001) also pointed out this and actually they attempted to reveal the effect of different grazing intensities on the patterns of floristic composition with measurement of background environmental factors. According to their results, such background environmental factors varied with distance from water source, and those factors had the potential correlation with vegetation changes. Therefore we considered that variations of such background environmental factors make it difficult to distinguish grazing effect from other environmental effects.

We selected a study site where landform did not appear to be a major influence for screening the effects other than grazing effect and we gave the evidence for this setting of condition by grasping background environmental factors such as soil moisture and landform at the study site. We then analyzed the patterns of change in floristic composition with changes in grazing intensity.

Materials and Methods

1. Study site

The study site was located in Bulgan, in the South Gobi of Mongolia (Fig. 1). The latitude was 43°54′N to 43°56′N and the longitude 103°30′E to 103°32′E, at an elevation of 1660 to 1690 m asl. From 1993 to 2001, the mean annual air temperature is about 4 °C and the total annual precipitation ranges from 100 to 150 mm. At the foot of a mountain there is a spring from which

Fig.1.

Fig.1.

Fig.2.

a flat pediment spreads out (Fig. 2). This spring locates about from 20 to 25 km away from Bulgan village, and there are six gers (Mongolian traditional circular tent-house) within 4 or 5 km from this spring. Because livestock (mainly sheep and goats, about 5000 head around this site) concentrate around the spring to drink, we hypothesized that the grazing intensity would decreases radially outward from the spring. After performing a preliminary survey we set six points at which both floristic composition and soil structure appeared characteristic along a transect from the spring. The distances from the spring to each point are shown in Table 1. Because we expected the grazing intensity to increase toward point 1, which was located closest to the spring, we used the distance of each point from the spring (transformed logarithmically) as an indicator of grazing intensity. The changes in the slope along the transect are shown in Fig. 3.

Table1.

Fig.3.

2. Survey methods

We performed vegetation survey in early August, 2004. At each point, we set 15 quadrats (1 m × 1 m) randomly and recorded the total coverage of each quadrat, the coverage and the maximum height of all plant species. Soil hardness (n = 15) was also measured at each point using Yamanaka’s soil hardness tester. As background environmental factors, we measured soil moisture (at the depth of 0 to 12 cm, n = 5) at each point by using TDR (time-domain reflectometry) and surveyed the slope of the pediment from points 1 to 6 along the transect.

3. Data analysis

We calculated the species volume of each plant species in each quadrat by multiplying the coverage and maximum height of each plant species to give the volume of space occupied by the species (Ohtuka *et al*. 1993), and after calculating the sum of species volume (we called this summed value a vegetation volume) of each plant species at each point we format the vegetation volume to a relative value as the relative species dominance. We then determined the dominant species on the basis of a dominance analysis (Ohsawa 1984) and compiled a table of floristic composition (Table 2).

Table2.

We compared some community and soil attributes among the points by using one-way analysis of variance (ANOVA). Because we could not find the trends of change from a result of one-way ANOVA (only differences among the points could be found from this), we then examined the correlations between some community attributes, soil hardness which differed among the points and distance from the spring (transformed logarithmically) using Pearson’s correlation coefficient.

Data for each point were subjected to two-way indicator species analysis (TWINSPAN ; Hill 1979b) and detrended correspondence analysis (DECORANA ; Hill 1979a) using values for relative species dominance. We examined the correlations between the DECORANA axes and some community attributes using Pearsons' correlation coefficient.

The 20 plant species that we found were classified by family and by plant functional types, which we defined as toxicity or palatability, and life-form. Toxicity and relative palatability in this site were classified according to the information from our field survey and a plant dictionary (Jigjidsuren and Johnson 2003). We then compared the composition ratio by family and by plant functional types among five vegetation groups clustered by TWINSPAN to reveal the changes in them.

Results and Discussion

1. Floristic composition

At the six points, 20 species were recorded (Table 2). Floristic composition changed dramatically along the transect. At point 1, *Peganum nigellastrum* dominated, and annual species such as *Salsola collina* or *Tribulus terrestris* appeared. Through points 2 to 4, *Artemisia pectinata* dominated, and prostrate species such as *Sibbaldianthe sericea* or *Convolvulus ammanii* appeared. At points 5 and 6, grasses such as *Stipa gobica* or *Cleistogenes soongorica* appeared.

2. Characteristic of some community attributes and soil attributes at each point

Characteristic of some community attributes and soil attributes at each point was shown in Table 1. From the results of one-way ANOVA, total coverage, community height, vegetation volume, and soil hardness varied significantly (ANOVA $P < 0.001$) with distance of the point from the spring, but soil moisture did not (Table 3), and was therefore not a major influence on the patterns of floristic composition. Fig. 3 shows that the slope from points 1 to 6 ranged from 0.7° to 1.8°; i.e. the slope was very shallow. Therefore, at this site the background environmental factors of soil moisture and landform (see Figs. 2 and 3) did not have a significant potential effect on the pattern of floristic composition.

Table3.

2.1. Correlations between some community attributes and distance from the spring

We then searched for correlations between some community attributes and distance from the spring (transformed logarithmically). There was a moderate positive correlation ($r = 0.59$; $P < 0.001$) between total coverage and distance, whereas there was a moderate negative correlation ($r = -0.49$; $P < 0.001$) between community height and distance. There were no significant correlations between vegetation volume and distance. With the exception of the correlation between total coverage and distance, this result did not agree with general view from those of previous studies (Li 1991 ; Ohkuro 1997 ; Wang and Ripley 1997 ; Wuyunna *et al*. 1999 ; Nakamura *et al*. 2000 ; Yiruhan *et al*. 2001), which have reported that quantities of the vegetation cover such as total coverage, community height, vegetation volume, and biomass decrease as grazing intensity increases. However, this result agreed with Fernandez-Gimenez and Allen-Diaz (2001) in which they surveyed vegetation at the desert steppe in Mongolia. The Bulgan site is also part of the desert steppes in Mongolia and is characterized by the presence of sparsely distributed short grasses and the very low biomass (about 20g/m^2). Because vegetation volume of non-palatable or toxic species which appeared with grazing intensity increase (see latter) was much higher than other species at points 1 and 2 in spite of heavy grazing intensity and so was the maximum height of them, we considered that decrease in quantities of the vegetation cover as grazing intensity increases did not be recognized.

This result and previous study (Fernandez-Gimenez and Allen-Diaz 2001) suggested that quantities of the vegetation cover do not always decrease as grazing intensity increases. Thus, we considered that analyzing the effect of grazing intensity on vegetation from a quantitative viewpoint would not give a valid measure of the effect of grazing intensity at our site.

2.2. Correlation between soil hardness and distance from the spring

We also searched for correlations between soil hardness and distance from the spring (transformed logarithmically). There were no significant correlations between soil hardness and distance. Ohkuro (1997) reported that soil hardness was well correlated with grazing intensity, but at our site there was no such correlation. We considered that at our site the soil compaction caused by livestock was inconsistent because the ground surface was rudaceous. But we can not examine the generality of this result because previous studies are scarce.

3. TWINSPAN classification

TWINSPAN cluster analysis categorized the 90 quadrats into five vegetation groups (Fig. 4). All the quadrats in group 1P were located at point 1, and all those in group 5P were located at point 2 (Table 1). Most quadrats in group 5N were found at points 3 and 4, and most quadrats in groups 4N and 4P were located at points 5 and 6, respectively.

Fig.4.

4. Ordination

The quadrats at each point that corresponded to most or all of the five vegetation groups identified by TWINSPAN were ordered along the first axis of the DECORANA (DCA) ordination (Fig. 5). This order was a good indicator of grazing intensity. Because the background environmental factors of landform and soil moisture did not have a significant potential effect on the changes of floristic composition along the transect, we considered that the characteristics of the floristic composition were directly represented by the second axis of the DCA. This result agrees with the fact that ordination by DCA gives an accurate output when the first environmental factor has a

Fig.5.

dominant effect (Kenkel and Orloci 1986). Therefore, we considered that the patterns of floristic composition were summarized well by the DCA, and that grazing intensity was the dominant environmental factor at this site.

We also examined the relationships between DCA axis 1 and some community attributes (Fig. 6). Total coverage was increased ($r = 0.56$; $P < 0.001$) and community height was decreased with decreasing values along DCA axis 1 ($r = -0.52$; $P < 0.001$). Vegetation volume had no significant relationship with DCA axis 1. Thus, the relationship between DCA axis 1 and some community attributes was similar to the relationship between distance from the spring and the same community attributes. We therefore confirmed that DCA axis 1 represented grazing intensity well.

Fig.6.

5. Community composition ratio by family and by plant functional types

We also compared the community composition ratio by family and by plant functional types for five groups clustered by TWINSPAN (Fig. 7). Comparison of the composition ratio for five groups by family revealed that the composition ratio of the Compositae, Zygophyllaceae, and Chenopodiaceae was very high in 1P and 5P, whereas that of the Poaceae increased from 5N toward 4P. Exceptionally, Poaceae appeared in 1P, but the species was *Achnatherum inebrians*, which is toxic. Comparison of the composition ratio for five groups by plant functional

Fig.7.

types revealed that non-palatable or toxic species tended to increase in prevalence as the transect moved toward extremely (1P) and heavily (5P) grazed stands. If there were few non-palatable or toxic species present, then secondarily annual or biennial herbs replaced perennial herbs as the transect moved toward extremely and heavily grazed stand. The prevalence of palatable species tended to increase as the transect moved toward lightly grazed stands.

These results, with the exception of our analysis of composition ratio by family, agree more or less with the general results of some previous studies (Newsome and Noble 1986 ; Pettit *et al*. 1995 ; Crawley 1997 ; Ohkuro 1997). From the above findings and these studies, we concluded that grazing intensity, together with palatability to livestock, affected the pattern of floristic composition.

Conclusion

We conclude that the patterns of floristic composition was determined by the grazing intensity as the dominative environmental factor along the transect, and that changes in grazing intensity were distinct at this study site. Analysis of the relationships between composition ratio by plant functional types and grazing intensity revealed that grazing intensity, together with palatability to livestock, affects the pattern of floristic composition. Furthermore, our results suggest that not only analyses of the quantitative aspects but also analyses of the qualitative aspects of vegetation, such as floristic composition and plant functional types, can be an important method of diagnosing grassland conditions with common criteria.

Acknowledgments

We thank the project members, especially Y. Shirato and H. Fujiwara, National Institute for Agro-Environmental Sciences, and M. Asano, the University of Tsukuba, for their kindness in helping with the field survey. The staff of the Laboratory of Landscape Ecology and Planning, the University of Tokyo—especially S. Okubo, S. Yamada, and A. Mori—provided valuable suggestions.

References

Crawley MJ (Ed.) (1997) Plant Ecology. Blackwell, p 717

Dregne H, Kaasas M, Rosanov B (1991) A new assessment of the world status of desertification. Desertification Control Bulletin 20 : 6-29

Fernandez-Gimenez M, Allen-Diaz B (2001) Vegetation change along gradients from water sources in three grazed

Mongolian ecosystems. Plant Ecology 157 : 101-118

Gunin PD, Vostokova EA, Dorefeyuk NI, Tarasov PE, Black CC (1999) Vegetation Dynamics of Mongolia. Kluwer Academic Publishers, p 238

Hill MO (1979a) DECORANA A FORTRAN program for detrended correspondence analysis and reciprocal averaging. Cornell University, Ithaca, New York

Hill MO (1979b) TWINSPAN A FORTRAN program for arranging multivariate data in an ordered two-way table by classification of individuals and attributes. Cornell University, Ithaca, New York

Jigjidsuren S, Johnson DA (2003) Forage Plants of Mongolia. Ulaanbaatar, p 563

Kenkel NC, Orloci L (1986) Applying metric and nonmetric multidimensional scaling to ecological studies, some new results. Ecology 67 : 919-928

Li Y (1989) Impact of grazing on *Aneurolepidium chinense* steppe and *Stipa grandis* steppe. Acta Oecologica 10 : 31-46

Li Y (1991) The current situation of steppe rangeland use in Inner Mongolia, relations between rangeland structures and grazing. Proceedings of 4th International Rangeland Congress, Montpellier, France, 340-345

Nakamura T, Go T, Li Y, Hayashi I (1998) Experimental study on the effects of grazing pressure on the floristic composition of grassland of Baiyinxile, Xilingole, Inner

Mongolia. Vegetation Science 15 :139-145

Nakamura T, Go T, Wuyunna, Hayashi I (2000) Effects of grazing on the floristic composition of grassland in Baiyinxile, Xilingole, Inner Mongolia. Grassland Science 45 : 342-350

Nemoto M, Ohkuro T, Xu B, Zhao H (1994) Grazing intensity effects of sheep on the growth of some plant species grown at the sandy land in semi-arid region, a case study in Inner Mongolia, China. Japanese Journal of Grassland Science 40 : 239-245*

Nemoto M, Ohkuro T, Xu B (1997) The role of weed invasion in controlling sand dune reactivation in abandoned fields in semi-arid Inner Mongolia, China. Ecological Research 12 : 325-336

Newsome AE, Noble IR (1986) Ecological and physiological characters of invading species. In : Ecology of Biological Invasions: an Australian Perspective (Eds. Groves RH, Burdon JJ). Australian Academy of Sciences, Canberra, p 1-20

Ohkuro T (1997) Studies on the influence of grazing on the land and vegetation degradation and restoration process in grassland regions in northeast China. Doctoral thesis of the University of Tokyo, Tokyo, p 189*

Ohsawa M (1984) Differentiation of vegetation zones and species strategies in the subalpine region of Mt. Fuji. Vegetatio 57 : 15-52

Ohtuka T, Sakura T, Ohsawa T (1993) Early herbaceous succession along a topographical gradient on forest clear-felling sites in mountainous terrain, central Japan. Ecological Research 8 : 329-340

Pettit NE, Froend RH, Ladd PG (1995) Grazing in remnant woodland vegetation, changes species composition and life form groups. Journal of Vegetation Science 6 : 121-130

UNEP (1992) World Atlas of Desertification. Edward Arnold, London, p 69

Yiruhan, Hayashi I, Nakamura T, Shiyomi M (2001) Changes in floristic composition of grasslands according to grazing intensity in Inner Mongolia, China. Grassland Science 47 : 362-369

Wang R, Ripley AE (1997) Effects of grazing on a *Leymus chinensis* grassland on the Songnen plain of north-eastern China. Journal of Arid Environments 36 : 307-318

Wuyunna, Nakamura T, Hayashi I (1999) Species diversity and phytomass production of the grassland in Inner Mongolia. Japanese Journal of Grassland Science 45 : 140-148*

*: In Japanese with English summary

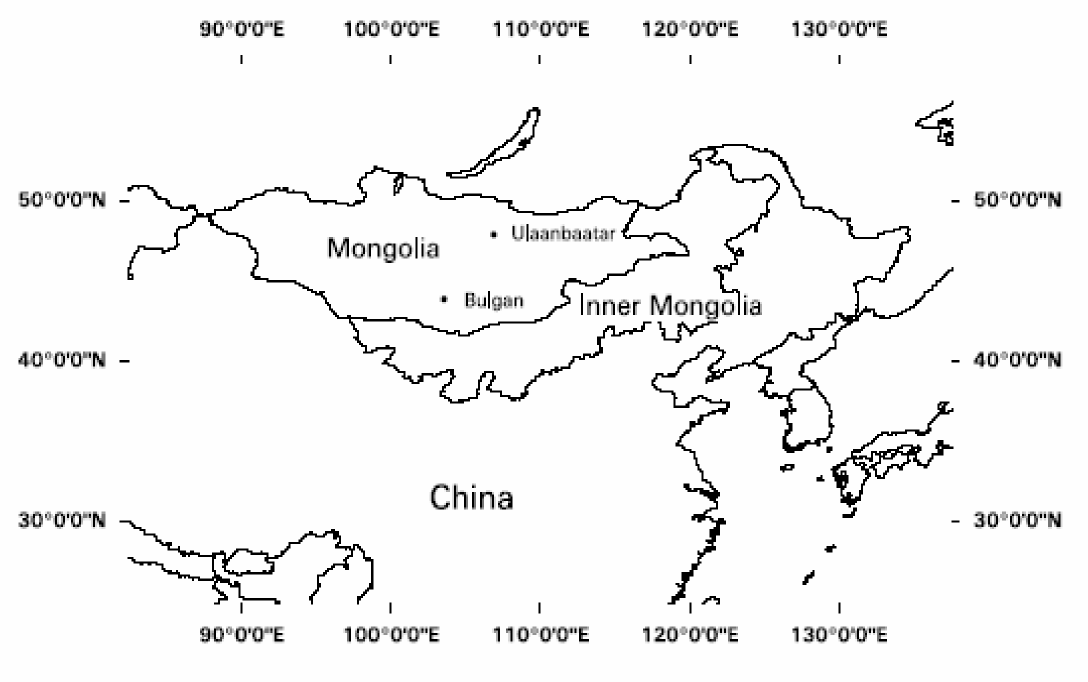

Fig. 1. Location of the study site in Bulgan, in the South Gobi of Mongolia.

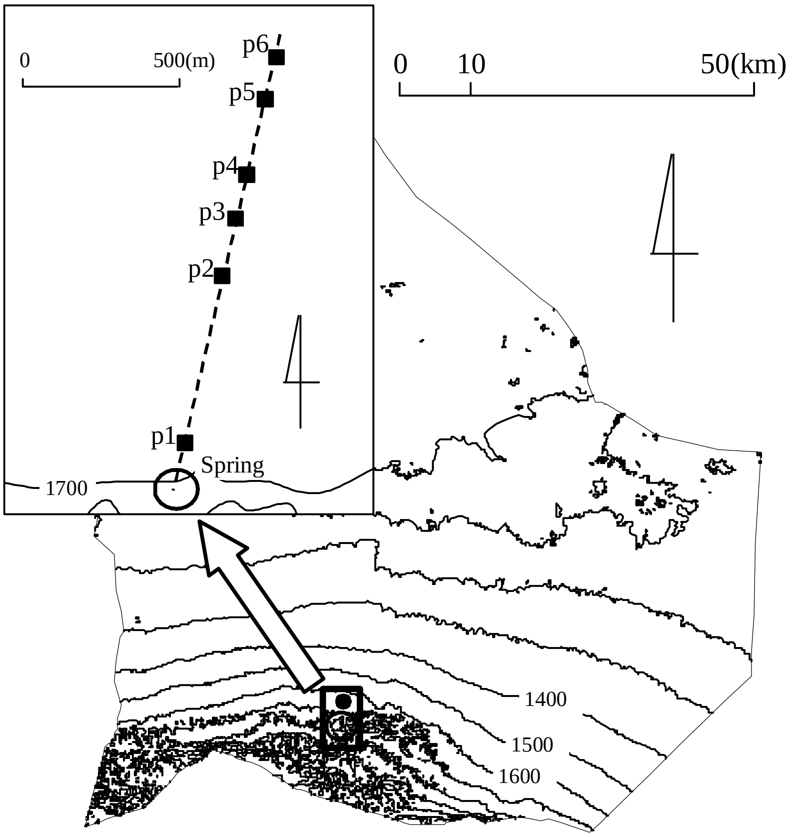

Fig. 2. Map of the study site. Contour lines are 100 m.
● : Study site ○ : Spring

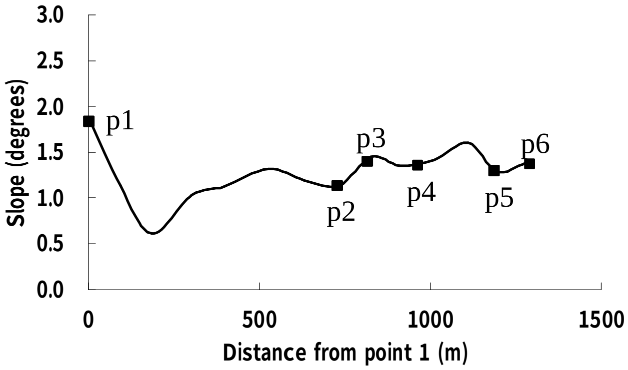

Fig. 3. Change of slope from point 1 to point 6.

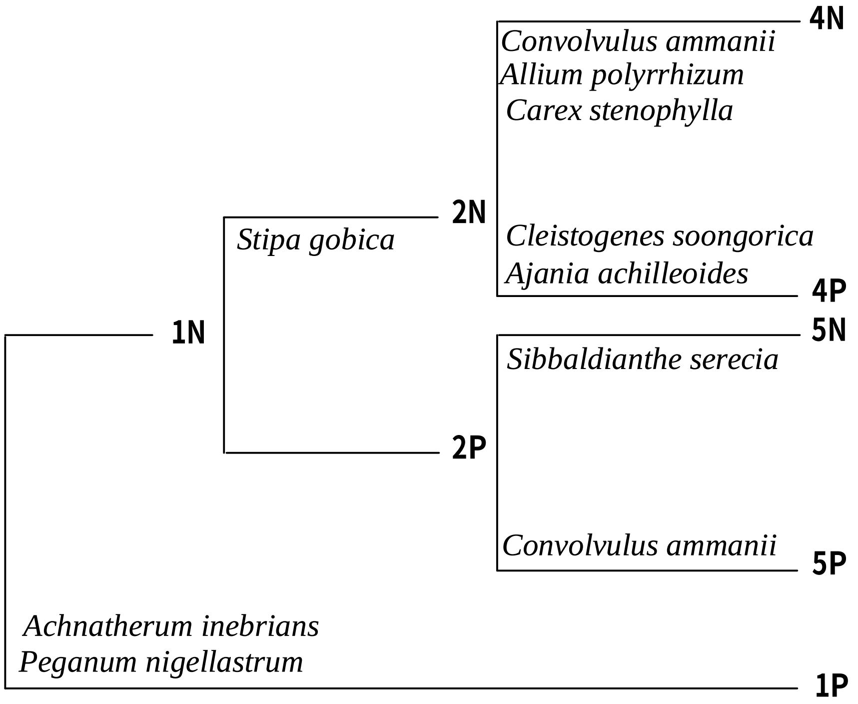

Fig. 4. Process of classification using TWINSPAN and pseudospecies. Pseudospecies are in italics.

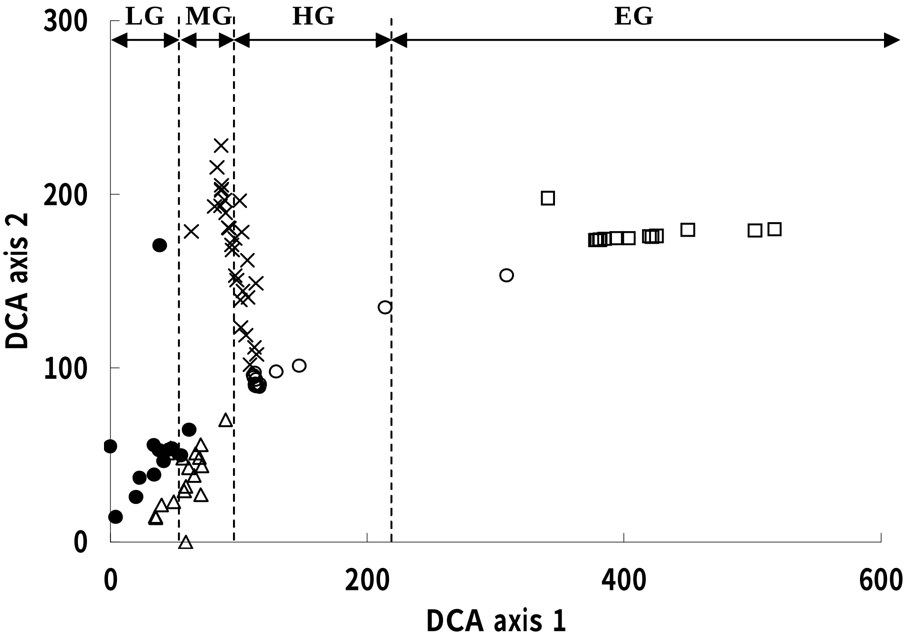

Fig. 5. Ordination of 90 quadrats by DECORANA (DCA) for five vegetation groups clustered by TWINSPAN.
☐ : 1P, ○ : 5P, × : 5N, △ : 4N, ● : 4P
EG: extremely grazed, HG: heavily grazed, MG: moderately grazed, LG: lightly grazed
The four stages (EG, HG, MG, and LG) were distinguished by considering the distribution, mean, and standard deviation of DCA scores at each point. Floristic composition changed dramatically in a lopsided stepwise-pattern along the DCA axis 1.

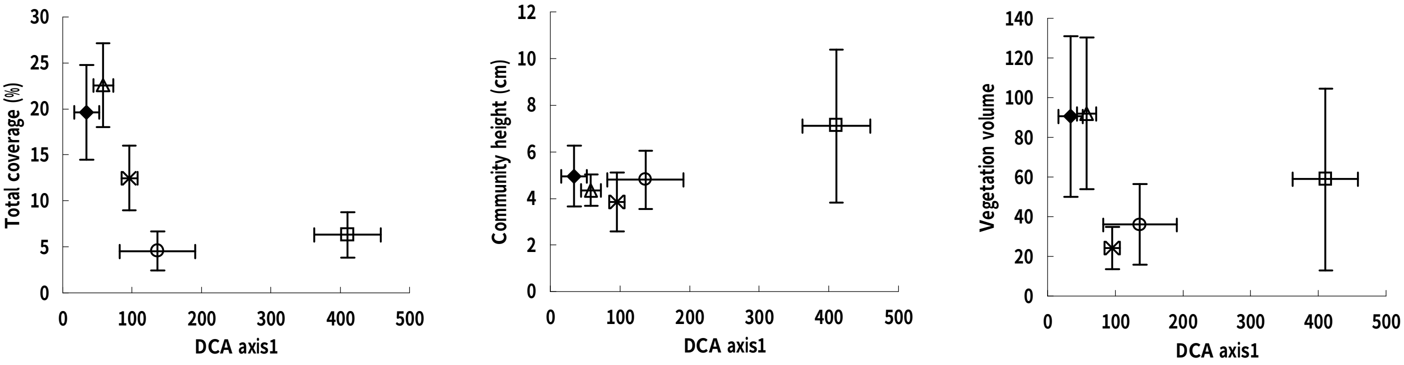

Fig. 6. Relationships between DCA axis1 and some community attributes for five vegetation groups clustered by TWINSPAN.
Horizontal and vertical bars indicate S.D..
☐ : 1P, ○ : 5P, × : 5N, △ : 4N, ● : 4P

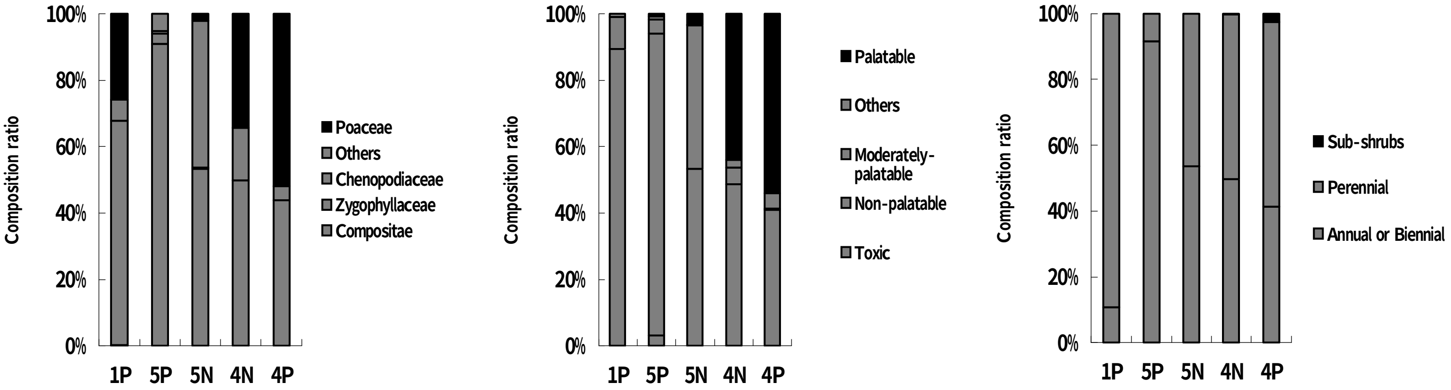

Fig. 7. a: Composition ratio by family; b: composition ratio by toxicity and palatability; c: composition ratio by life-form, for the five vegetation groups clustered by TWINSPAN.
Compositon ratio were caluculated using relative species dominance (RD).

Table 1. Characteristic of some community attributes and soil attributes at each point.

Survey point	p1	p2	p3	p4	p5	p6
Distance from the spring (m)	150	800	950	1050	1400	1500
Classification by TWINSPAN	1P	5P	5N[a)]	5N[a)]	4N[a)]	4P[a)]
Total coverage (%)	6.30±2.46[b)]	4.53±2.13	14.63±3.68	10.10±3.52	22.13±4.53	21.40±5.16
Community height (cm)	7.10±3.29	4.80±1.26	3.62±0.87	3.93±1.27	4.10±0.68	5.27±1.31
Vegetation volume[c)]	58.90±45.78	36.12±20.35	26.89±4.76	24.30±10.55	91.98±38.18	90.62±40.45
Soil hardness (mm)	19.67±1.84	21.00±3.29	23.00±2.25	22.50±2.01	19.30±1.84	20.05±2.09
Soil moisture (%)	13.40±0.84	14.60±1.82	15.60±1.82	15.00±1.22	14.80±1.30	15.40±1.14

[a)] The majority of the groups identified by TWINSPAN corresponded to quadrats at this point.

[b)] Mean with standard deviation.

[c)] Vegetation volume (×100cm^3/m^2) was the sum of height (cm) × coverage (%) of each plant species.

Table 2. Floristic composition at each point (dominant species are in italics).

species	Life form a)	Growth form b)	RD c) value in each survey point					
			p1 (n=15)	p2 (n=15)	p3 (n=15)	p4 (n=15)	p5 (n=15)	p6 (n=15)
Herbs								
Peganum nigellastrum	Per	e	*63.38*	3.14				
Achnatherum inebrians	Per	t	*25.82*					
Salsola collina	Ann	b	5.46	0.72	0.21	0.41		
Tribulus terrestris	Ann	p	4.07					
Chenopodium album	Ann	e	0.65					
Bassia dasyphylla	Ann	e	0.35					
Artemisia macrocephalla	Ann	e	0.27		0.25			
Artemisia pectinata	Ann,Bie	e		*90.89*	*48.35*	*58.03*	*51.24*	*43.11*
Sibbaldianthe sericea	Per	p		0.65	*43.89*	*34.85*		
Stipa gobica	Per	t			0.00	0.82	*26.53*	*42.45*
Allium polyrhizum	Per	t					11.38	2.28
Convolvulus ammanii	Per	p		3.77	5.76	1.78	6.16	1.07
Cleistogenes songorica	Per	t		0.00	0.25	3.29	3.19	6.99
Carex stenophylloides	Per	t		0.83	1.24	0.71	0.40	0.12
Gypsophylla desertrum	Per	e				0.03	0.54	1.51
Heteropappus altaicus	Bie	e					0.18	0.18
Haplophyllum dahuricum	Per	e					0.13	0.29
Iris bungei	Per	t					0.22	
Shrub(semi-shrub)								
Ajania achilleoides	—	b			0.05	0.07	0.04	1.78
Artemisia caespitosa	—	b						0.22

a) Life form: Per, perennial; Ann, annual; Bie, biennial.

b) Growth form: b, branched; e, erect; p, prostrate; t, tussock.

c) RD: relative species dominance.

Table 3. Results of one-way ANOVA[a].

	Sum of squares	d.f.	Mean squares	F value	P
Total coverage	4221.43	5	844.29	60.63	P＜0. 001
Community height	121.52	5	24.30	8.61	P＜0. 001
Vegetation volume	71117.61	5	14223.52	14.87	P＜0. 001
Soil hardness	234.56	5	46.91	9.17	P＜0. 001
Soil moisture	18.17	5	3.63	1.85	N.S.[b]

[a] Compared among the six points.

[b] N.S.; not significant.