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Effects of Cutting and Grazing on Vegetation and Productivity of Shrub-steppe in the Loess Plateau, North-west China

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中国北西部の黄土高原におけるかん木ステップの植生と生産性におよぼす刈取りと放牧の影響

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ABSTRACT

The Loess Plateau, situated in north-west China, has been subjected to degradation of vegetation owing to overgrazing. In order to clarify the effects of grazing and cutting on vegetation and productivity of shrub-steppe, the study was carried out from May in 1989 to October in 1991 in the Pastoral Preserving Zone of Yunwu Mountain. The vegetation was monthly surveyed, and DM weights of dominant species were separately measured. Soil samples were taken at three selected sites and one overgrazed site and these chemical analysis were made.

Relative abundance of species was calculated on the base of the total frequency of 7835. *Gramineae* showed the highest value (26 %), followed by *Compositae* (24 %) and *Leguminosae* (12 %). During 3 experimental years, the significant increasers were *Trigonella ruthenica* and *Potentilla acaulis*, and the significant decreasers were *Poa sphondylodes*, *Agropyron cristatum*, *Potentilla bifurca* and *Heteropappus altaicus*. Species diversity was apparently lower in the cutting plots than in the other plots. According to the result of ordination by principal component analysis, *Trigonella ruthenica*, *Carex* spp., *Aneurolepidium dasystachys* and *Thermopsis lanceolata* were indicator species under natural recovery from overgrazed condition. *Artemisia frigida* and *Potentilla acaulis* were typical species in grazing plots. According to monthly aerial DM productions, *Stipa bungeana* showed excellent regrowth after cutting or grazing, and contributed to higher aerial DM production. *Stipa bungeana* showed significantly lower values of important nutritional elements and higher values of neutral detergent fiber than other species. The result of soil analysis suggests that total carbon and phosphorus contents may relate with the rate of the rehabilitation from overgrazed condition of steppes.

Key words: Loess Plateau, overgrazing, rehabilitation, shrub-steppe and *Stipa*.

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INTRODUCTION

Semi-arid steppes of north-west China have been subjected to increasingly severe overgrazing associated with the growing pressure of human population (Zhang 1992). Under continuous overgrazing, a grass-dominant steppe usually changes to *Artemisia*-dominant steppe with decreasing productivity by 30 to 50 % (Zhang 1984). The change in species composition is caused by light grazing (McNaughton 1976). At the first stage of vegetational degradation, species number and plant density decline, followed by a rapid decrease in plant coverage and biomass, resulting in desertified condition (Zhao and Zhou 1993). During this degradation process, the most common change is a loss of palatable species with a replacement of less palatable annual plants, thorny shrubs or poisonous plants (Grainger 1992; Ludwig and Tongway 1995; Wu and Loucks 1992). In the steppe, *Artemisia frigida* is said to be the most efficient indicator to the desertification (Li 1989).

The enclosure is reported to be most effective for the rehabilitation of overgrazed steppes because of increased coverage of perennial grasses, which are palatable and sensitive to grazing (Han 1996; Hongo et al. 1995). *Artemisia*-dominated steppes changed into improved steppes dominated by *Stipa* and *Agropyron* species as well as soil condition and forage production after the 6-year enclosure (Chen 1984; Ma 1985).

Thus, damaged steppes can be rehabilitated by the enclosure simply. At present, however, there are two inconsistent requirements for the steppes in the Loess Plateau. One is the rehabilitation of overgrazed steppe and another is the demand of grazing utilization of improved steppes for increased animal production by local farmers. Especially in less-rainfall season, which had been caused periodically in this area, improved steppes have been required for grazing utilization.

In the future, rehabilitated steppes will be grazed again according to the environmental changes. Therefore, a suitable management system of semi-arid steppes must be established (Zhang 1992). From a global point of view, the restoration program was commenced in the Loess Plateau in 1988 cooperatively by Japanese and Chinese scientists (Tamura 1991). This report is a part of results in this program.

METHODS

Study Site

This study was carried out in the Pastoral Preservation Zone of Yunwu Mountain (latitude 36° 13' - 19' north and longitude 106° 24' - 28' east) in Guyuan country, Ningxia Hui Autonomous Prefecture, situated in the west of the Loess Plateau (Fig. 1). The management method of the Preservation Zone was mentioned in the previous report (Hongo et al. 1995).

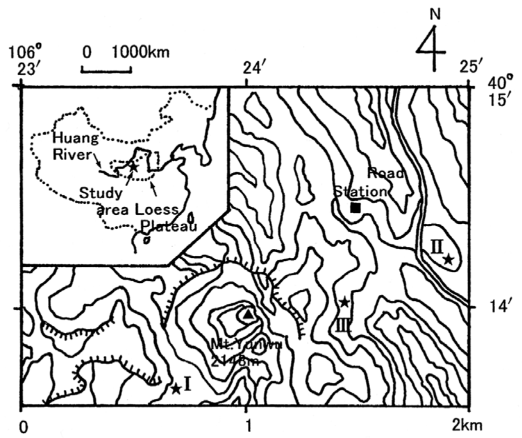

Fig.1.Three Study Sites on the Mt.Yunmu.Contour lines are placed at 40m intervals.
I :*Stipa* site, II :*Thymus* site, III:*Artemisia* site.

The climatic conditions in this area are estimated from observed data at the nearest meteorological station by using an altitudinal lapse. Mean annual air temperature is 5 - 6 ℃, frost-free period 120 - 150 days, and mean annual precipitation is 400 - 480 mm (Zou et al. 1986).

Methods

The study was carried out during the period from May in 1989 to October in 1991. Three sites on a north-west slope were selected according to dominant species in the result of preliminary survey. The dominant species were *Stipa bungeana* (*Gramineae*) at *Stipa* site, *Thymus mongolicus* (*Labiatae*) at *Thymus* site and *Artemisia sacrorum* (*Compositae*) at

Artemisia site. The mean inclination was 19 ± 2.2 (mean ± s.e.), 12 ± 0.7 and 20 ± 1.7 degrees, respectively, and an altitude was 1980, 2030 and 2040 m, respectively.

At each site, the area (200 m wide along a contour line x 50 m long) was enclosed rectangularly with a prickled wire. This area was divided into four plots (50 x 50 m), which were assigned to four experimental treatments (control, cutting, lightly grazing and heavily grazing plots). Each plot was also fenced with a prickled wire. In a cutting plot, aerial parts were cut in July and September at a height of 5 cm. Lightly grazing plot were grazed by sheep in May, July, September and October, and heavily grazing plot were grazed monthly from May to October. Each grazing treatment was done using 20 sheep for 3 days in 1989 and 100 sheep for one day in 1990 and 1991.

In every plots, the vegetations were monthly surveyed at five points distributed at random within each plot. At heavily grazing plot, the survey was done immediately before grazing. At each point selected, a 0.5 x 0.5 m square quadrate was laid down. The abundance of all vascular plants within a quadrate was recorded. Then, aerial parts of plants were cut at a 5-cm height. Weights of dominant species were separately measured. Plant samples were dried in a forced drought oven at 80℃ and dry matter weights were measured.

Soil samples were taken after a vegetational survey in August in 1991. At each point, the vertical patterns of physical characteristics in the soil profile were recorded down to a depth of 50 cm. Soil samples and soil cores (100 ml in 50 mm diameter) were taken from 10 cm scarified stratum. In addition, soil samples were taken at one overgrazed site outside of the preserving zone. The method of soil analysis was the same as the previous report (Hongo et al. 1995).

The ordination analysis was applied to vegetation data to interpret the main environmental gradients related to variation of vegetation. A principal component analysis (PCA) using abundance scores was carried out (Goodall 1970; Greig-Smith et al. 1967). Standardization of original data was done prior to PCA (Noy-Meir 1973). Since rare species were statistically inactive (Barkhan and Norris 1970), the species with greater than 10 % abundance were used for the analysis. As a criterion of the species diversity, or heterogeneity, the information content was calculated using abundance scores (Greig-Smith 1983; Clifford and Williams 1976).

RESULTS AND DISCUSSION

Abundance of plant families

Twenty-two families including 67 species were observed in this study. The total abundance of all vascular plants was 7835 including 3 years, 3 sites, 4 treatments and 5 months (Table 1).

Table 1 Total abundance scores (No. of quadrates) and species number observed at three experimental sites for three years.

Family name	Species No.	Total abundant scores	%
Gramineae	10	2022	25.8
Compositae	14	1856	23.7
Leguminosae	7	964	12.3
Labiatae	3	781	10.0
Rosaceae	6	685	8.7
Thymelaeaceae	1	341	4.4
Cyperaceae	2	314	4.0
Ranunculaceae	2	142	1.8
Rubiaceae	3	138	1.8
Primulaceae	1	99	1.3
Cruciferae	1	90	1.1
Liliaceae	2	77	1.0
Others	15	326	4.1
Total	67	7835	100
Annual or biennial	10	458	5.8

Gramineae showed the highest value of 25.8 %, followed by *Compositae* (23.7 %), *Leguminosae* (12.3 %), *Labiatae* (10.0 %) and *Rosaceae* (8.7 %). These 5 families, which were adaptable to grazing and drought stress, occupied 80.5 % of total abundances. Ten annual or biannual species occupied only 5.8 % of total abundances, and poisonous species such as *Stellera* and *Thermopsis* occupied 9.0 %.

The previous study recorded 51 families including 161 species, in the 3200 ha exclosure as a whole (Zou et al. 1986).

Abundance of species

Percentages of abundance of 24 species with more than 10 % of total abundances are shown in Table 2. The most dominant species were *Stipa bungeana* at *Stipa* site, *Thymus mongolicus* at *Thymus* site and *Artemisia sacrorum* at *Artemisia* site. These results coincided with the result of preliminary surveys. There were considerable variations in abundance patterns of many species among 3 experimental years. The species increased linearly were *Trigonella ruthenica*, *Potentilla acaulis*, *Consolida ajacis* and *Galium verum*. In contrast, the species decreased linearly were *Poa sphondylodes*, *Agropyron cristatum*, *Potentilla bifurca*, *Heteropappus altaicus*, *Viola yedoensis* and *Androsace erecta*.

Table 2 Percentages of abundance of main 24 species for three years studied.

No	Scientific name	Family name	Year 1st	Year 2nd	Year 3rd	sed	Significant
1	*Stipa bungeana*	*Gramineae*	89±2.9	89±2.7	97±1.2	4.2	*
2	*Thymus mongolicus*	*Labiatae*	91±2.4	86±2.6	95±1.1	3.7	**
3	*Artemisia sacrorum*	*Compositae*	86±3.2	80±3.2	92±1.7	4.9	*
4	*Trigonella ruthenica*	*Leguminosae*	59±4.4	66±2.9	90±2.0	5.7	**
5	*Artemisia frigida*	*Compositae*	49±5.2	50±4.4	53±4.8	8.4	ns
6	*Poa sphondylodes*	*Gramineae*	68±4.7	43±4.3	39±4.6	7.8	**
7	*Potentilla acaulis*	*Rosaceae*	28±4.5	50±3.8	57±4.7	7.5	**
8	*Stellera chamaejasme*	*Thymelaeaceae*	41±4.5	45±3.8	36±2.9	6.7	ns
9	*Carex* spp.	*Cyperaceae*	11±3.1	48±4.0	49±4.3	6.7	**
10	*Aneurolepidium dasystachys*	*Gramineae*	23±4.4	13±3.1	47±5.2	7.5	**
11	*Agropyron cristatum*	*Gramineae*	48±4.6	34±3.9	6±1.7	6.3	**
12	*Potentilla bifurca*	*Rosaceae*	52±4.6	26±3.1	8±1.7	5.8	**
13	*Leontopodium leontopodioides*	*Compositae*	16±3.7	23±3.8	25±3.8	6.6	ns
14	*Heteropappus altaicus*	*Compositae*	30±4.2	23±3.3	13±2.4	5.9	**
15	*Thermopsis lanceolata*	*Leguminosae*	tr	31±3.8	28±4.3	5.8	**
16	*Hierochloe odorata*	*Gramineae*	40±5.3	4±1.6	19±2.9	6.3	**
17	*Stipa grandis*	*Gramineae*	16±4.1	20±3.4	26±3.6	6.5	ns
18	*Consolida ajacis*	*Ranunculaceae*	4±2.4	15±2.6	29±3.8	5.2	**
19	*Artemisia scoparia*	*Compositae*	39±4.8	4±1.3	6±2.4	5.6	**
20	*Oxytropis bicolor*	*Leguminosae*	19±3.6	23±3.7	tr	5.2	**
21	*Viola yedoensis*	*Violaceae*	21±4.2	11±2.5	9±2.0	5.3	**
22	*Androsace erecta*	*Primulaceae*	24±4.2	12±2.6	1±0.6	5.0	**
23	*Galium verum*	*Rubiaceae*	tr	9±2.8	22±4.4	5.2	**
24	*Torularia humilis*	*Cruciferae*	9±2.9	6±2.1	16±3.4	5.0	ns

Figures show mean±s.e. tr; less than 0.4 %, ns; not significant, *; significant at p<0.05, **; significant at p<0.01.

The vegetation in this region was classified into shrub-steppe (Zhang 1992). Only one shrub species such as *Caragana jubata* was recorded at *Artemisia* site. No other shrub species was observed, although 3 *Caragana* species were recorded in the previous report (Zou et al. 1986). The original plant community might had included *Caragana* shrubs. These shrubs are now observed only on steep slopes where farmers and livestock can not reach them. A lack of shrub species is due to human impact over a long period before the commencement of the exclosure. It is said that most shrubs have been cut by local people for fuel over the last 2000 years at least (Zou et al. 1986).

Species diversity

Mean number of species recorded per 0.25 m^2 during three years were lower in the control plot (38-44) than in the other plots (41-51) as shown in Table 3. Information contents as a criterion of species diversity were apparently lower in the cutting plots than in the other plots. It was due to the decreased abundances of poisonous or unpalatable species such as *Compositae*, *Leguminosae* and *Thymelaeaceae* families.

Historically, this area had been grazed only in summer and never mown because of long distance far away from the nearest villages. Poisonous and unpalatable species could be maintained with high abundance scores under a few disturbances. The cutting treatment in this study may seriously affect the abundance of these poisonous or unpalatable species.

Table 3 Information contents and observed species number in parentheses in four treatments at three experimental sites for three years.

Site	Treatment				
	Control	Cutting	Light grazing	Heavy grazing	Pooled
Stipa	1075(44)	715(46)	1207(50)	1186(51)	4614(59)
Thymus	1008(39)	591(41)	1015(46)	1046(44)	4080(58)
Artemisia	972(38)	582(51)	1075(51)	1058(46)	4096(59)

*** Information contents were calculated from percent abundant scores.**

Ordination of 36 plots

The ordination diagram of 36 plots by principal component analysis is shown in Fig. 2. The first and second axes of the ordination accounted for 22.3 % and 11.4 % of the variance of the data, respectively. The trend represented by the first principal component corresponded to sampling years. Plots at the positive side along the first principal component were identified as many plots in 1989 and those at the negative side as many plots in 1991. On the contrary, environmental factors along the second principal component appeared to be related to the experimental sites. Many plots at the positive side along the second principal component were included in *Stipa* site, and those at the negative side were in *Thymus* and *Artemisia* sites. There was no tendency for the distribution of four experimental treatments with respect to the plot distribution, because of limited period of the experiment

Ordination of main 24 species

The species highly loaded at the positive end along the first principal component showed decreasing pattern of abundances with a progress in years (Fig. 3). These species were *Poa sphondylodes*, *Agropyron cristatum*, *Hierochloe odorata*, *Heteropappus altaicus*, *Artemisia scoparia*, *Potentilla bifurca*, *Viola yedoensis* and *Androsace erecta*. On the contrary, the species at the negative side were characterized by increasing abundances. Typical species were *Aneurolepidium dasystachys*, *Trigonella ruthenica*, *Thermopsis lanceolata*, *Carex* spp., *Consolida ajacis* and *Galium verum*. These species may increase under natural recovery from overgrazed condition. *Artemisia frigida*, *Potentilla acaulis* and *Oxytropis bicolor* at the negative end along the second principal component were indicator species of overgrazing with high abundances in grazing plots and low in the control plot.

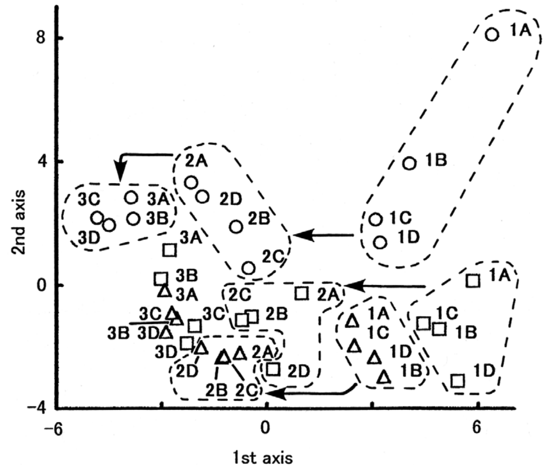

Fig.2.Ordination diagram of 4 treatments at 3 sites for 3 years by principal component analysis.Figures(1,2 and 3) show experimental years.A,B,C and D show 4 treatments(control,cutting,lightly grazing,respectivery).Dotted lines enclose 4 treatments in one year.

○:*Stipa* site,□:*Thymus* site,△:*Artemisia* site.

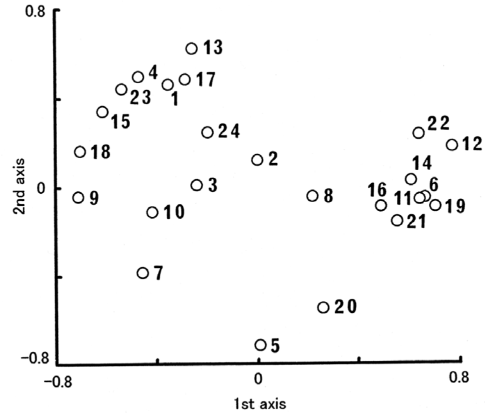

Fig.3.Ordination diagram of 24 main species by principal component analysis.

1:*Spita bungeana*	2:*Thymus mongolicus*
3:*Artemisia sacrorum*	4:*Trigonella ruthenica*
5:*Artemisia frigida*	6:*Poa shpondylodes*
7:*Potentillia acaulis*	8:*Stellera chamaejasme*
9:*Carex spp.*	10:*Aneurolepidium dasystachys*
11:*Agropyron cristatum*	12:*Potentillia bifurca*
13:*Leontopodium leontopodioides*	14:*Heteropappus altaicus*
15:*Thermopsis lanceolata*	16:*Hierochloe odorata*
17:*Stipa grandis*	18:*Consolida ajacis*
19:*Artemisia scoparia*	20:*Oxytropis bicolor*
21:*Viola yedoensis*	22:*Androsace erecta*
23:*Galium verum*	24:*Torularia humilis*

Percentage abundance of main 12 species

Twelve species showed significant differences of percentage abundances among 4 treatments (Fig. 4). The species with significantly higher values in the control plot and lower in grazing plots were *Poa sphondylodes*, *Agropyron cristatum*, *Potentilla bifurca* and *Stipa grandis*. The reverse tendency was observed in the species such as *Artemisia frigida* and *Aneurolepidium dasystachys*. *Artemisia frigida* seems to be the most efficient indicator to the grazing pressure (Li 1986; Li 1989).

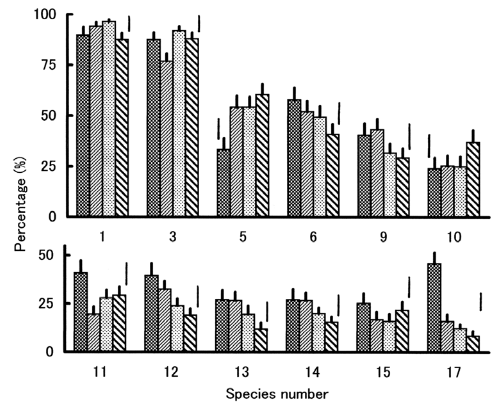

Fig.4.Percentages of abundances of main 12 species.Attached lines on bars show s.e. of mean and vertical lines show s.e.d. of the mean difference. :Control, :Cutting plot, :Lightly grazing plot, :Heavily grazing plot.

1:*Spita bungeana*	3:*Artemisia sacrorum*
5:*Artemisia frigida*	6:*Poa shpondylodes*
9:*Carex spp.*	10:*Aneurolepidium dasystachys*
11:*Agropyron cristatum*	12:*Potentillia bifurca*
13:*Leontopodium leontopodioides*	14:*Heteropappus altaicus*
15:*Thermopsis lanceolata*	17:*Stipa grandis*

Aerial DM production

Fig. 5 shows monthly aerial DM production averaged for 3 years. In all 4 treatments, *Stipa* site maintained higher values of aerial DM production than *Thymus* and *Artemisia* sites. In cutting plots of *Stipa* site, excellent regrowth after cutting was observed. Aerial DM production was remarkably affected by species composition, especially by dominant species.

Percentages of total DM production of 3 dominant species were shown in Fig. 6. calculated. As a grand mean of 4 treatments, *Stipa bungeana*, *Thymus mongolicus* and *Artemisia sacrorum* occupied 34±1.2, 16±1.3 and 21±1.5 % of total DM production in *Stipa* site, 8±1.0, 27±1.5 and 9±1.2 % in *Thymus* site, and

9±1.0, 10±1.1 and 29±1.6 % in *Artemisia* site, respectively. Higher percentages of *Stipa bungeana* contributed to high aerial DM production.

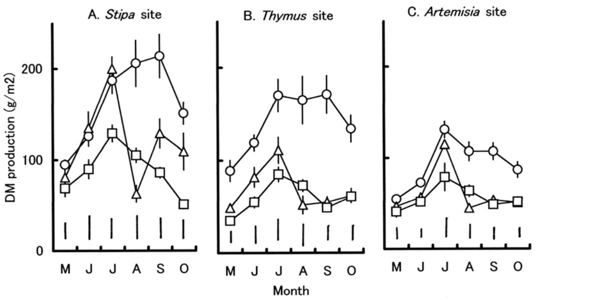

Fig.5.Monthly DM production at three sites.Arrow marks show each cutting time.Attached lines on symbols show S.E. of mean and vertical lines at lower side show s.e.d. of the mean differences. ○:Control plot,△:Cutting plot,□:Grazing plot.

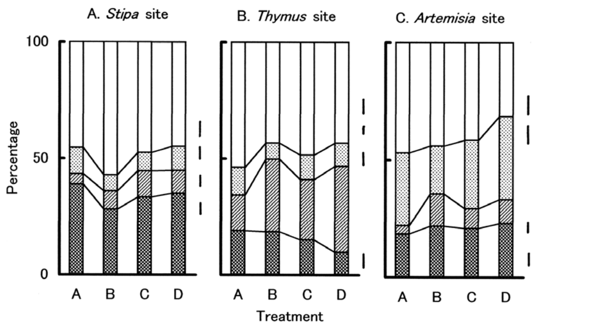

Fig.6.Percentages of produced DM of 3main species and other species in 4 treatments.Vertical lines show s.e.d. of the mean differences.
A:Control plot,B:Cutting plot,C:Lightly grazing plot,D:Heavily grazing plot.
□ :*Stipa bungeana*, ▒ :*thymus mongolicus*, ▨ :*Artemisia sacrorum*, ▩:Other species.

Potential DM production

Potential DM productions were compared among 4 treatments using the following parameters: the maximum values in the control plots, sum of two harvests in cutting plots, and 60 % (presumable intake rate of pasture) of sum of 6-month DM productions in grazing plots. There were no significant differences of any species and total production among 4 treatments (Fig. 7). The results suggest that this steppe vegetation will be able to be maintained with high capacity of potential DM production under cutting twice or grazing monthly during growing season. Therefore, the rehabilitation process and vegetational dynamics must be reexamined under cutting or grazing managements.

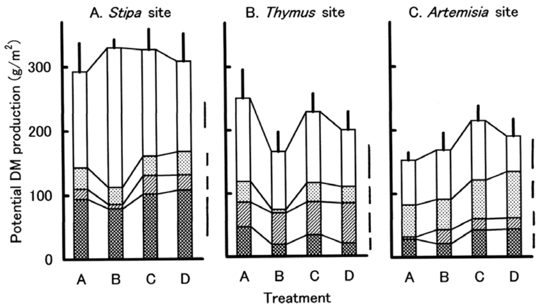

Fig.7.Potencial DM productions of 3 main species on 4 treatments.Attached lines on bars show s.e.d. of the mean differences.
A:Control plot,B:Cutting plot,C:Lightly grazing plot,D:Heavily grazing plot.
□ :*Stipa bungeana*, ▒ :*thymus mongolicus*, ▨ :*Artemisia sacrorum*, ▩:Other species.

Chemical properties of plant materials

Stipa bungeana showed significantly lower values of important nutritional elements such as organic cell content, total digestible nutrients, Ca, Mg, P and K than *Thymus mongolicus* and *Artemisia sacrorum*, and significantly higher values of neutral detergent fiber (cellulose, hemi-cellulose and lignin), as shown in Fig. 8. Thus, *Stipa bungeana* may adopt step vegetation with fibrous and low-nutrition characteristics, resulting in less grazing intake by animals.

Soil factor

Fig. 9 shows the result of chemical analysis of soils at 3 experimental sites and one overgrazed site. Soil moisture and pH increased and other properties decreased with increasing soil depths. Total carbon and phosphorus contents were significantly different among 4 sites. Total carbon contents were significantly higher in *Stipa* and *Artemisia* sites than *Thymus* and overgrazed sites, but phosphorus contents were significantly lower in overgrazed plots than other plots. The rate of the rehabilitation from overgrazing may be estimated from phosphorus contents (Harper and Climer 1985; Hongo et al. 1995; Qi et al. 1985; Yang et al. 1985).

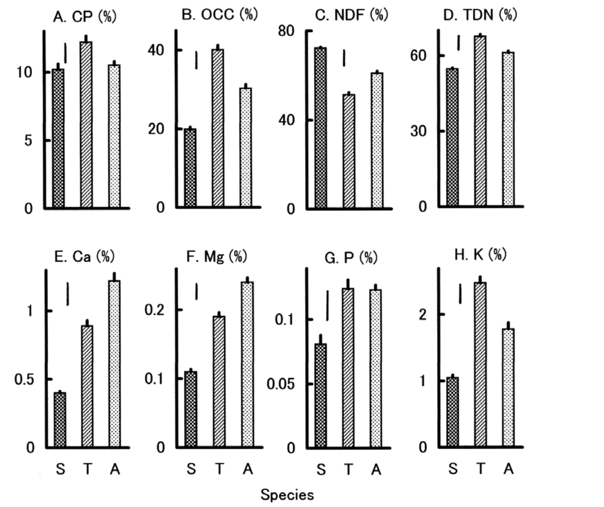

Fig.8.Digestible nutrients and mineral contents of 3dominant species.Attached lines on bars show s.e. and vertical lines show s.e.d. of the mean differences.CP:Crude protein,OCC:Organic cell content,NDF:Neutral detergent fiber,TDN:Total digestible nutrient,S:*Stipa bungeana*,T:*Thymus mongolicus*,A:*Artemisia sacrorum*.

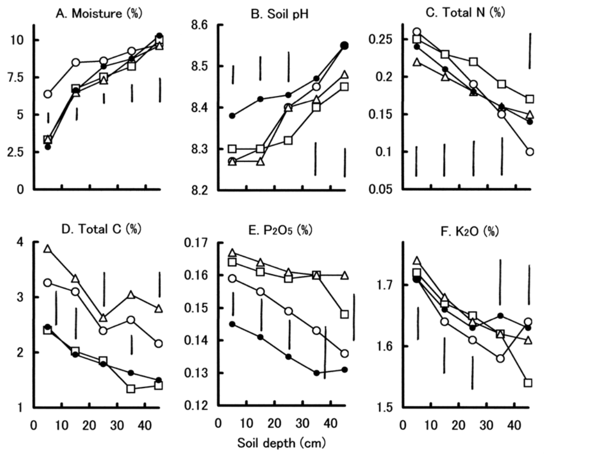

Fig.9.Vertical distribution of soil properties at three experimental sites and one overgrazed site.Vertical lines show s.e.d. of mean differences.

○:*Stipa* site,□:*Thymus* site,△:*Artemisia* site,●:Overgrazed site.

Methods of restoration

The mutual relationship between five types of steppe vegetations observed in this region is shown in Fig. 10. Potential vegetation, which does not exist in the natural condition, is estimated to be dominance of *Stipa bungeana*, *Stipa grandis* and *Caragana* species. Overgrazed steppes, which are dominated by *Artemisia frigida* and poisonous species, had been naturally restored into Stipa-dominant steppes after 5-year exclosure in this region (Zou et al. 1986). During this rehabilitation process, soil organic matter and phosphorus are considered to be the principal factor through the modification of soil moisture condition (Newbould 1989). Soil organic matter plays an important role in preventing crust formation at the surface, resulting in increasing water infiltration (Cheng 1986; Gee et al. 1988). Therefore, the artificial input of organic matter and phosphorus into soils seems to accelerate rehabilitation process from overgrazed steppes (Bradshaw 1988; Jordan 1988).

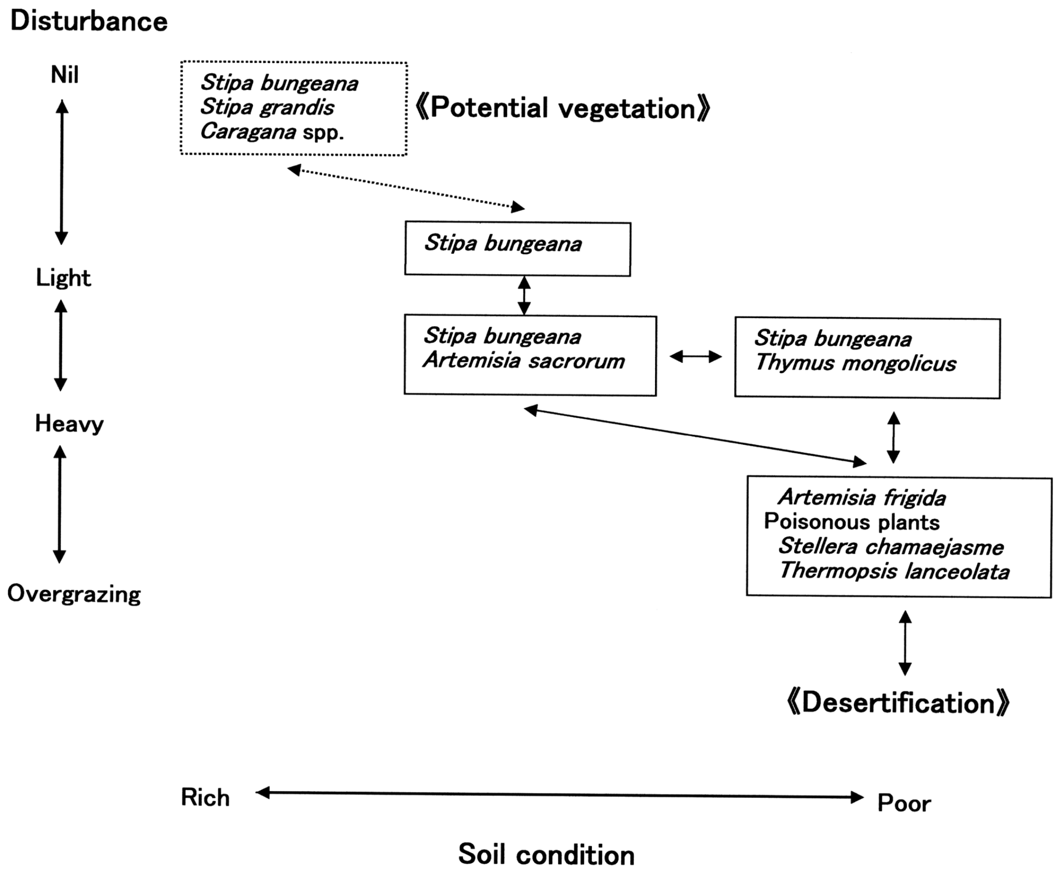

Fig.10.Model of rehabilitation process from overgrazed vegetation of shrub-steppe under different soil conditions and grazing intensities.

Under lightly grazing, the steppe vegetation showed high species diversity and high potential of DM production, suggesting that growth of dominant species is suppressed and more resources are made available for small, less competitive plants (Grime 1973; Milchunas et al. 1995). It will be possible to rehabilitate overgrazed steppe vegetation and to improve animal production by the improved grazing management with optimal intensity of animals.

Once destroyed or damaged, steppe vegetations are very slow to re-establish themselves (Richard and Vaughan 1988). In order to shorten restoration period in damaged vegetation, artificial reseeding may be effective (Coupland 1992). Introduced species are expected to have a greater capacity to produce herbage and control of water and nutrients, and regaining its energy capture efficiency (Beedlow et al. 1988). In the Loess Plateau, three native grasses such as *Stipa bungeana*, *Agropyron cristatum* and *Poa sphondylodes*, which widely distribute, may be advantage over other plants in term of adaptability, small seed size, quick germination, capacity to prevent soil erosion, and agricultural usage as a feed (Huang and Li 1985). Further studies are needed on the methods of establishment and management of these grasses.

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要　約

中国北西部に位置する黄土高原は過放牧のためにその植生が荒廃しつつある。そこで,かん木ステップの植生と生産性におよぼす刈取りと放牧の影響を明らかにするために,1989 年 5 月から 1991 年 10 月までの間，雲霧山草原保護区において研究を実施した。毎月,植生を調査し,優先種の DM 重を種別に測定した。また,土壌を 3 試験地と過放牧地から採取して,化学分析を行った。
植物の総出現頻度は 7835 個であり,この結果について種の相対出現頻度を求めた。イネ科がもっとも多く(26%), 次いでキク科(24%)とマメ科(12%)が多かった。実験を行った 3 年間で,有意に増加した種は *Trigonella ruthenica* と *Potentilla acaulis* であり,有意に減少した種は *Poa sphondylodes*, *Agropyron cristatum*, *Potentilla bifurca*, *Heteropappus altaicus* であった。種の多様性は他の処理区より刈取り区で明らかに低かった。主成分分析による座標付けの結果では,*Trigonella ruthenica*, カヤツリグサ類, *Aneurolepidium dasystachys*, *Thermopsis lanceolata* は過放牧の状態から自然に回復する時の指標種であった。*Artemisia frigida* と *Potentilla acaulis* は放牧区において顕著な種であった。月ごとの地上部 DM 生産量について，*Stipa bungeana* は刈取りや放牧の後に非常に良好な再生力を示し,その結果として高い地上部 DM 生産量を達成していた。また,*Stipa bungeana* は他の種と比べて主要な栄養素が有意に低く,逆に繊維成分は有意に高かった。土壌分析の結果から,総炭素とリンの濃度は,過放牧の状態からの回復の程度と関連していることが示唆された。

キーワード：黄土高原，過放牧，リハビリ，かん木ステップ，ハネガヤ.