Impacts of grazing on community structure and productivity in a *Stippa grandis* steppe of eastern Mongolia

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Abstract

During 2001-2003, we conducted vegetation surveys on four semi-arid *Stipa grandis* grassland sites that were subjected to different livestock grazing intensities in eastern Mongolia. The four sites, representing light-, moderate-, heavy-, and over-grazing were situated 1.5, 4.0, 6.5, and 10 km from the Kherlen River. Each of the four grasslands was surveyed by placing 40 quadrates (50 × 50 cm) along 80 m line transect. The main characteristics of vegetation such as vertical structure, species composition, vegetation cover and productivity were measured and analyzed in relation to different levels of grazing pressure. We found that the total biomass decreased and the proportion of woody plants increased with increasing grazing pressure, and the vegetation cover, productivity, and species richness and diversity were higher under moderate grazing compared with heavy and over-grazing. The lightly grazed grassland exhibited high heterogeneity, the highest species diversity and richness and a high productivity due to occurrence of *Stipa grandis*, whereas the overgrazed grassland exhibited low species diversity and a higher occurrence of *Artemisia adamsii* of poor feed quality. Based on study, we suggest immediate and full protection of the overly grazing grasslands until the vegetation was restored to a healthy state, and for the moderately and heavily grazed grasslands, it is necessary to implement a strategy of rotating between rests and moderate grazing to prevent the grasslands from further degradation.

Key words: Grassland, overgrazing, productivity, community, succession, semi-arid.

Introduction

Grasslands are estimated to cover 125 million hectares (ca 80%) of the total land area of Mongolia, and make up 2.6% of the global grassland vegetation (World Resources Institute, 2003). Currently about 122 million hectares of Mongolia is devoted to nomadic pastoralism, with 28% of which lying in the steppe zone. The climate on the regional arid and semiarid steppes is distinctly continental with a strong influence from the East Asia summer monsoon (Yatagai & Yasunari, 1995). Precipitation is highly variable both in time and space. Nomadic herding constitutes the major human activity in Mongolia, making grazing the dominant anthropogenic factor that affects steppe vegetation. Moreover, the arid and semiarid steppes are ecologically fragile and sensitive to seasonal and decadal changes in climate (Dennis, 1987). The intensified anthropogenic activities and climatic changes have both been concerned for contributing to degrading ecosystem productivity of the Mongolian grasslands.

Bunge, Krylov (1830-1831), Radde (1856) were the pioneer scientists documenting plant species in eastern Mongolia, who identified 489 species in the region. But the systematic scientific study of this region began under the central Asian surveys conducted by the Ceographycal Society of Russia (1870-1885) and Traytfetter (1872) was analyze the collected plants by Lomonosov and defined 529 species in the eastern Mongolia. From that time Russian scientists Potanin (1901), Komarov, Palibin, Kazacevich (1925) Pobedimova (1931), Unatov, Lavrenco, Grubov (1940-1954) made important contributions to grassland research and grassland science in Mongolia. (1974)

Since 1940, eastern steppe ecosystem of Mongolia was investigated in relation to rational use of natural vegetation cover and grasslands. Mongolian dry steppe vegetation and grassland had been studied by Dashnyam (1969) more than 30 years and he defined the steppe zone of eastern Mongolia within the Middle Khalkh, Mongolian daurian, eastern Mongolia and Khyangan botanical-geographycal provinces. Also he distinguished 1103 species belonging to 89 families and 412 genera and 21 vegetation types in the steppe zone of eastern Mongolia.

Since 1970, the vegetation dynamics and flora of Eastern Mongolia were studied by Joint Mongolian-Russian Biological Complex Expedition (Main pasture types in MPR, 1974) and played large role in grassland investigation of Mongolia. Most work on community productivity has been done by Mongolian researchers from the institute of Botany, Mongolian Academy of Sciences.

Also, at this time, the species composition of Eastern steppe was investigated careful by Dashnyam(1974), Ulziikhutag (1989) and they reported that the Eastern Mongolia botanical-geographycal province occupies area equal 8.94 per cent of total area of Mongolia.

Nachinshonkhor, Gargalsaihan, Tserendash and Khyroshy investigated the influence of climate and livestock on steppe vegetation and reported that species diversity in ungrazed and moderate grazed communities is the same not differences; but plant leaf surface index is high in the ungrazed steppe community than others.

Ariuntsetseg (2002) studied the influence of *Microtus Brandti* on steppe vegetation and reported that when steppe vegetation has a 30-40 per cent cover than here density of *Microtus Brandti* is high, namely, degraded grassland provide a good habitat for mice, which in turn eat the vegetation, when cover 60-70 per cent than habitat for *Microtus Brandti* is limited.

A primary cause of low and declining productivity is land degradation. Mongolian grasslands are partly overstocked, particularly in semiarid region of Mongolia. Heavy grazing of livestock has in many places, and led to changes in soil and vegetation. In order to prevent further degradation and rehabilitate degraded areas, it is necessary to study the impact of grazing on this grassland.

The present work (monitoring study) was done on the territory of Bayantumen Sumu in East Aimag Mongolia in 2001-2003 and were compared the dynamics of productivity, species composition and vertical structure in vegetation with different levels of grazing pressure.

Introduction of heavy grazing often initiates a regressive succession, including a decrease in biomass and structural complexity. Therefore, our hypotheses were that:

- Productivity of vegetation with heavy grazing would decrease.
- With increasing grazing the quality and productivity would be deteriorate due to decrease biomass of palatable species.
- Due to overgrazing the species richness and diversity would reduce.
- Total productivity and number of species is higher in the grassland on the moderate grazing.

Our objectives of the current monitoring study are to

a. investigate the main characteristics of vegetation such as species composition, cover, structure and productivity in vegetations with different levels of grazing pressure.
b. Based on above investigation to reveal the succession of *Stipa grandis* steppe vegetation in relation with grazing.
c. Quantitative criteria of grassland degradation have been discussed.

Materials and methods

Study area and sites

The research area situated at N48^{0}00'89", E114^{0}27'671" within the Kherlen river valley. The climate is temperate semiarid, with distinct continental characteristics. The annual mean temperature is 0.5^{0}C, annual precipitation 278 mm and approximately 80% of which is concentrated on the period of june-august. Chesnut and dark chestnut soils are the dominant types in the area.

We chose four grasslands in the Kherlen river valley for our monitoring study. Main criterions by which distinguished the vegetation into levels are: cover of dominated species in vegetation, mean height of plant, productivity and quality (ratio between the biomasses of palatable and unpalatable species).

a).*Artemisia adamsii* overgrazed grassland (S_4) is situated within the 1.5 km range from the Kherlen river at N 48^{0}00'89" E 114^{0}27'671" were altitude is 764 m, soil is dark chestnut. Plants are exposed to overgrazing and plant mean height is very low (approximately 6 cm. table 1), vegetation cover is 10.2% and very sparse, species richness is poor. Because there sheep and cattle concentrated during the growing season or year. There dominated by woody or unpalatable by livestock or steady to grazing species such as *Artemisia adamsii, A. frigida, A. scoparia*,and also annual and biennial species of *Chenopodiaceae* families.

b). *Cleistogenes squarrosa* heavy grazed grassland (S_3) is situated within the 4 km range from Kherlen river, were altitude is 782 m a.s.l. Soil is chestnut and there plants are exposed to heavy grazing and plant mean height is 11 cm and dominated by lower grass- Cleistogenes squarrosa, codominated Koeleria macrantha, Festuca lenensis and etc. Besides lower grasses here began to increase phytocenological role of unpalatable, woody and annual, biennial as degradation indicator species in grassland. Especially, began to play large role in vegetation Artemisia frigida, A. scoparia, Chenopodium album, Ch. acuminatum, Dontostemon integrifolius and ets which are becoming to dominate in further degradation of grazing.

c). *Forb-grass* moderate grazed grassland (S_2) is situated at the approximately 6.5 km range from the Kherlen river at N 47^0 49'259", E 114^{0}27'396"were plants are exposed to moderate level of grazing and plant mean height is approximately 19 cm. In vegetation dominated by grasses such as Agropyron cristatum, Festuca lenensis, Stipa krylovii, S. grandis,, Leymus chinensis and ets. By vegetation conditions (vegetation cover 45%, species richness is high), it is a moderate grazing community and comparatively remoted from Kherlen river.

d). *Stipa grandis* light grazed as control grassland (S_1) is situated at N $45^0$54'739", E $114^0$28'365"within 10 km range from the Kherlen river, were plants are exposed to very light grazing , plant mean height is 35 cm, vegetation cover 42%, species richness is very high and in vegetation are dominated by Stipa grandis, S.krylovii. The altitude is 930 m, distributed to stony soils.

Measurements

We used the line transect method. From the Kherlen river to remote direction randomly was taken 10 km's line transect in 160^0 south east (Buzzard, 1998). Along the transect within the 1.5 km range was choosen permanent study's first plot (S_4), on 4.0 km - second plot (S_3), on the 6.5 km-third plot (S_2) and on 10 km –fourth plot (S_1).

On each permanent plots we were studied comparatively the vegetation structure, species composition, and vegetation cover was documented in randomly placed quadrates of $1m^2$, 10 in each plot.

Sampling of above ground biomass was carried out from 1 m^2 in 10 times during the growing season. All species were cut at ground level and also was taken the litter -biomass. Samples were dried at 80^0C to content weight and weighted to the nearest 0.001g.

Canopy cover was recorded in percent for all species and measured their heights.

Data analysis

Biomass data were anylized for important species separately. The biomass components were sorted as groups of species: shrubs; grasses; legumes; sedges; warmwoods (Artemisia), forbs and litter. Above all the except litter sorted as palatable and unpalatable groups.

The all data were calculated by following formula:

1. $X = \sum_{(c)} /n;$ were n- number of replication; X- mathematical mean; c – 1.2.3…

2. $\mu(variance) = \sum (c-x)^2 / n-1;$

3. $m = \mu/n;$ were m-standard error of means. The standard error of the difference is used to access the difference between the means by the T and F tests.

4. $t_{1.2} = (X_1-X_2) / (m_1^2+m_2^2);$ were (X_1-X_2)- difference between the means

$(m_1^2+m_2^2)$-standard error of the difference.

5. $F_{1.2} = \mu_1/\mu_2;$

The level of significance is readily obtained from a table of T and F (Fisher and Yates, 1957). The significance of our study is a P=0.05 or 95%.

3. Results

Overview of the four grasslands

Table 1 shows general characteristics of the four grasslands surveyed in 2001-2003. The grassland most distant from Kherlen river experienced moderate and light levels of grazing, whereas the grassland closest to Kherlen river experienced the overgrazing. Plants under light grazing conditions grew taller than those overgrazing and heavy grazing conditions (plant height is a simple indicator of grazing intensity). The occurrence of *Stipa grandis* is a characteristic grass preferred by animals in this area, decreased with increasing grazing intensity.

Stand (vertical) structure

Each species in the vegetation communities should layer into height strata and vegetation vertical structure had been changed negatively to increase grazing pressure.

In full flourish, the maximum height in light grazed *Stipa grandis* community is a 70 cm, the minimum is 10 cm, then in overgrazed *Artemisia* community is a 10 and 3 cm, that vegetation vertical structure was shorten to 11.8 times with intensive grazing pressure.

Species composition

The total numbers of species recorded from grasslands with moderate grazing were higher than others, especially total number in overgrazing is lower.

The species composition of *Stipa grandis* community consists of 16 families, 28 genera, 45 species, whereas in the overgrazed *Artemisia* community was registered 15 species belonging to 13 families and 15 genera (Fig. 2).

The average number of species recorded per plot higher in *Stipa grandis* community (S_1) than in other, especially, in *Artemisia* community on overgrazing, were most likely related to the increase in cover and dominance of *Artemisia adamsii. A. scoparia*.

The families of more species are Gramineae, Compositae, Leguminosae, Rosaceae and Chenopodiaceae.

Synusia structures in the communities include seven kinds: bunch - grass; rhizome – grass; Sedge; forbs; annual-biennial herb and semi-shrub and shrub.

Also classified on ecological group of water requirement, of all species 46.9% species are xerophytes or eury-xerophytes, 40.8% species are meso-xerophytes, 8.2% species are xero-mesophytes, and only 4.1% species are annual-biennial plants.

Vegetation cover

The total cover of vegetation is higher about 4 times in light grazed *Stipa grandis* as control site than in overgrazed *Artemisia adamsii* community. A grazing induced in increase warmwood (*Artemisia*) plant species in vegetation following the reduction of herbaceous vegetation. (figure 3)

But, moderate grazing vegetation has a higher cover (45%) than in light grazing site, because rational use of vegetation under grazing led to intensive renewal in above ground parts of species.

Productivity

There was a tendency toward an increase in total productivity of vegetation with decrease grazing pressure. For example, in overgrazed community the total productivity is a 2.6 c/ha, of these: above ground biomass is a 2.3 c/ha. Litter biomass is a 0.3 c/ha, whereas total productivity in light grazed *Stipa grandis* community is a 22.9 c/ha, that increased about 8.8 times due to increase aboveground biomass and litter (figure 4; 5).

The above ground biomass sorted as groups: palatable and unpalatable and by their ratio we were assess the quality of productivity in each vegetation (figure 6).

In overgrazed *Artemisia* community the biomassa of palatable species lower than unpalatable species, because there are only dominated species of feed poor quality as *Artemisia adamsii*, *A. scoparia*, not palatable for domestic animals in growing season. There biomass of unpalatable species occupies 1.8c/ha or 78.3% of total biomass in vegetation, whereas of total biomass in light grazing community: – 92.2% palatable, 7.7%-unpalatable. Total productivity and above ground biomass higher in moderate grazing community than in other communities. It is a good condition.

Discussion

Grassland vegetation clearly changed according to the degree of degradation (intensity of use). In the heavy and overgrazed, degraded grassland, *Stipa grandis*, *S. krylovii* (Graminae) and some forbs (Leguminosae) have been seriously damaged by grazing and trampling. The number of species and species diversity on these degraded grasslands were lower, about 2.3 times, than those in the moderate and lightly grazed grasslands (Table 1). The average height of plants with increasing grazing pressure decreased about 6 times in relation to their palatability by livestock.

The lower species richness and diversity in overgrazed grassland were most likely related to the increase in cover and dominance *Artemisia adamsii*, *A. scoparia* and *A. frigida* and suggest increasing grazing had a facilitating effect through reduction of the perennial palatable species. The lightly grazed grasslands have high species diversity because of the vertically stratified community structure. The similar result reported by Zhang (1985).

With decreasing grazing total productivity of vegetation was increased, especially, biomass of palatable species. In overgrazed grassland biomass of unpalatable species occupies 1.8c/ha or 78.3% of total biomass in vegetation and their quality severely deteriorated due to increasing grazing intensity. In this case, the average height, cover and biomass of *Stipa grandis* decrease sharply, whereas undesirable plants of *Artemisia* and *Potentilla* species increase. Therefore, overgrazed community is unsuitable to grassland.

The forb-grass community on moderate grazing have greater species diversity, high quality and productivity and cover, so this grassland is in good condition. It was also reported by Li (1998). It related with rational use of vegetation under grazing and led to intensive renewal in above ground parts of species. Thus, based on these results of study we try to establish succession of *Stipa grandis* typical steppe under influence of grazing. (Figure 7).

In our opinion, the *Stipa grandis* steppe formation along the transect was changed through four associations: In Mongolia does not have ungrazed natural steppe grassland, so, Mongolia has a nomadic herdering, because in our present study lightly grazed *Stipa grandis* steppe community is as a control plot and here edificator plant is a *Stipa grandis*, dominants are other tall grasses: such as *Agropyron cristatum, Leymus chinensis, Stipa krylovii* and ets. Under influence of moderate grazing edificator plant of this community replaced by subdominant – tall grasses and was formed *forb-grass* community. Here dominance and cover of *Stipa grandis* decreased, grass dominance and cover increased due to grazing. Our study results were indicate that the vegetation on moderate grazing have a greater species diversity, and according to the analysis of composition and measurement of biomass have high quality and productivity, so the grassland is in good conditions. It is related with it rational use under grazing by livestock, therefore moderate level of grazing, it is a optimal condition for plant growth and development in vegetation, because inconstant cutting (graze) of plants led to intensive renewal of their dormant bud. Further with increasing grazing intensity the forb-grass community was heavy grazed and replaced by short grass *Cleistogenes squarrosa* dominated steppe, here tall grasses seriously damaged by livestock and trampling and began intensively grow woody plants as degradation indicators: *Artemisia, Potentilla* species and annual, biennial unpalatable by livestock species., especially at this level strong grew plants with vegetative generation such as *Gleistogenes squarrosa*, *Koeleria macrantha* and ets. Just exactly on this level of grazing severely deteroriated the quality and productivity, that was appear qualitative change in vegetation. Further, under overgrazing *Cleistogenes squarrosa* community replaced *Artemisia adamsii* dominated community. Here the grasses were eaten by livestock at the ground level, only unpalatable, woody and steady to grazing species, and especially annuals of Chenopodiaceae family were dominated. Also the community has a lot of bare ground. It is unsuitable to grassland.

From the differences among these four grasslands, we judged that to prevent further degradation, necessary to provide fencing and protection for each plots, for example, a). protect the vegetations on light, moderate and heavy grazing intensity from further degradation by different ways: to rest of grazing or to rotate (to alternate) to grazing, b). The vegetation on overgrazing necessary fence to exclusive from livestock for their restoration to original vegetation conditions of high species diversity, plant biomass and plant height.

Further our investigation is needed to answer how to restored degraded *Artemisia* overgrazed grassland and when restored will whether recover the *Stipa grandis* grassland again. (Figure 7).

Conclusion.

- The features of grassland community is closely related with the grazing pressure.
- The moderate grazing is a optimal condition for of plant develop and growth in vegetation.
- Under overgazing of livestock the *Stipa grandis* steppe community was replaced by *Artemisia adamsii* dominated community.
- Overgrazing leds to the reduction of productivity and it's quality.
- In order to prevent further degradation neseccary to improve the management for use grassland under grazing of livestock.
- To prevent further degradation necessary to rest and rotate the vegetations on the light and moderate grazing
- The vegetation on overgrazing necessary fence to exclusive from livestock for their restoration to original vegetation conditions

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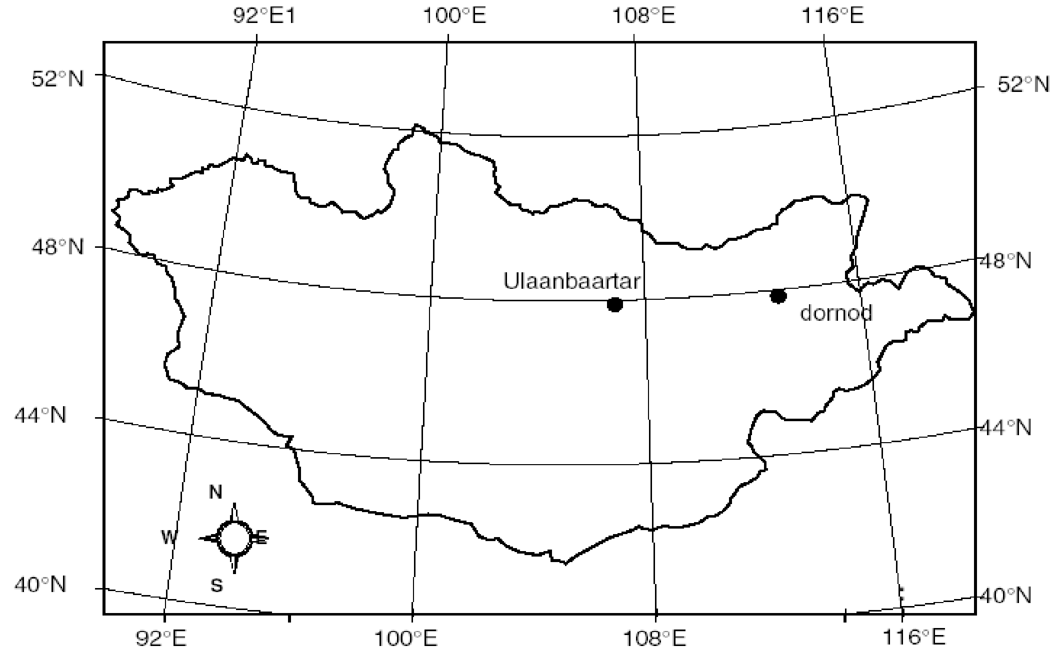

Figure 1. Map of Mongolia illustrating the location of study sites

Table 1.

The features of the communities on the different levels of grazing pressure.

The attributes of the community**.**	*Artemisia grassland (S_1)*	*Cleistogenes community (S_2)*	*Forb-grass grassland (S_3)*	*Stipa grandis grassland (S_4)*
Edificator	Artemisia adamsii	Cleistogenes squarrosa	Agropyron cristatum Leymus chinensis	Stipa grandis
Main dominant species	Caragana microphylla	Koeleria macrantha	Poa botryoides	S. sivirica
	Cleistogenes squarrosa	Festuca lenensis	Stipa krylovii	Stipa krylovii
	Potentilla acaulis	Agropyron cristatum	Caragana stenophylla	A.bidentatum
	Sibbaldianthe adpressa	Chenopodium acuminatum	Allium anisopodium	Serratula centauroides
	Salsola collina	Heteropappus hispidus	Potentilla tanacetifolia	Haplophyllum dahuricum
	Artemisia frigida	Salsola collina	P. bifurca	Allium anisopodium
Average number in 10 quadrats of $1m^2$	19	25	49	45
Cover (%) average of 10 quadrats.	10.2	28.2	55.6	52.1
Mean height of vegetation (cm)	6	11	19	35
Total productivity: (c/ha)	2.6	13.1	22.3	20.9
a. above ground bio-massa	2.3	12.0	17.5	19.3

b. Litter	0.3	1.1	1.8	2.6
Distance to Kherlen river (km)	1.5	4.0	6.5	10
Grazing pressure	overgrazing	Heavy grazing	Moderate grazing	Light grazing

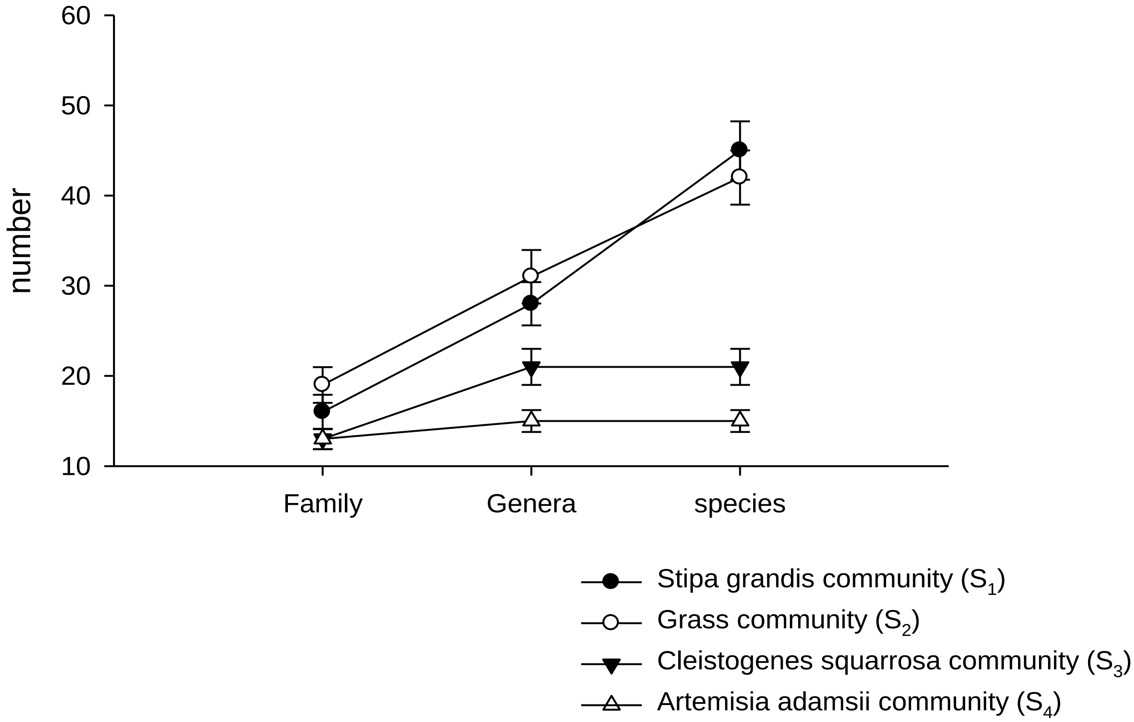

Figure 2. The species composition of vegetations in different levels of grazing

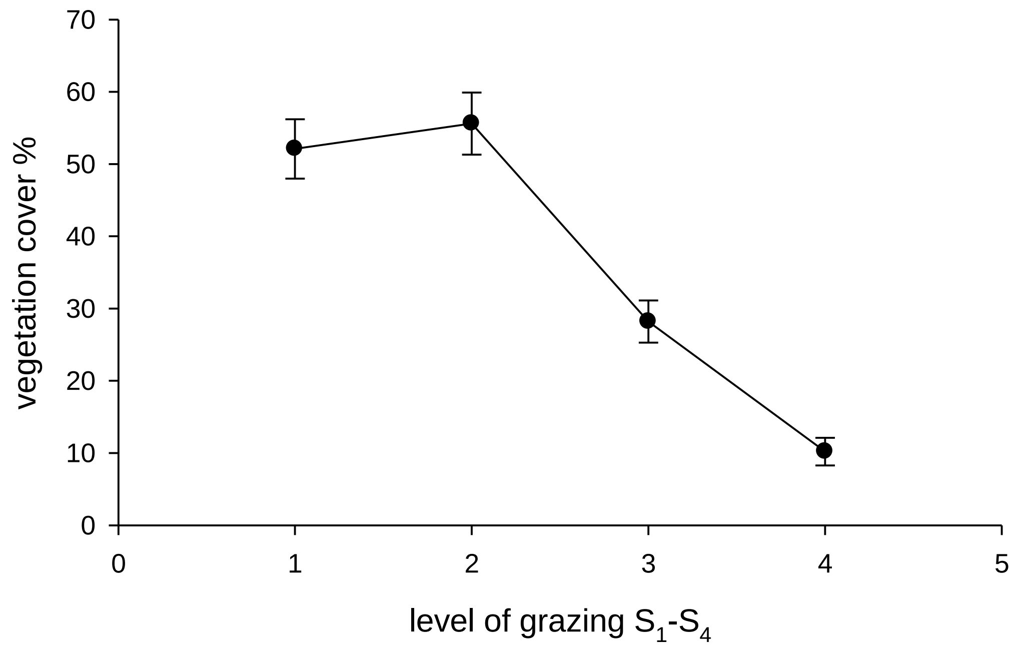

Figure 3. The vegetation cover on different gradients of grazing

S_1- Light grazing (*Stipa grandis* community); S_2- moderate grazing (*forb-grass* community);

S_3- heavy grazing (*Cleistogenes squarrosa* community); S_4-overgrazing (*Artemisia* community);

Figure 4. Total productivity of vegetation on different gradients of grazing.

S_1– Light grazing (Stipa grandis); S_2- moderate grazing (forb-grass); S_3- heavy grazing (Cleistogenes);

S_4 – overgrazing (Artemisia community);

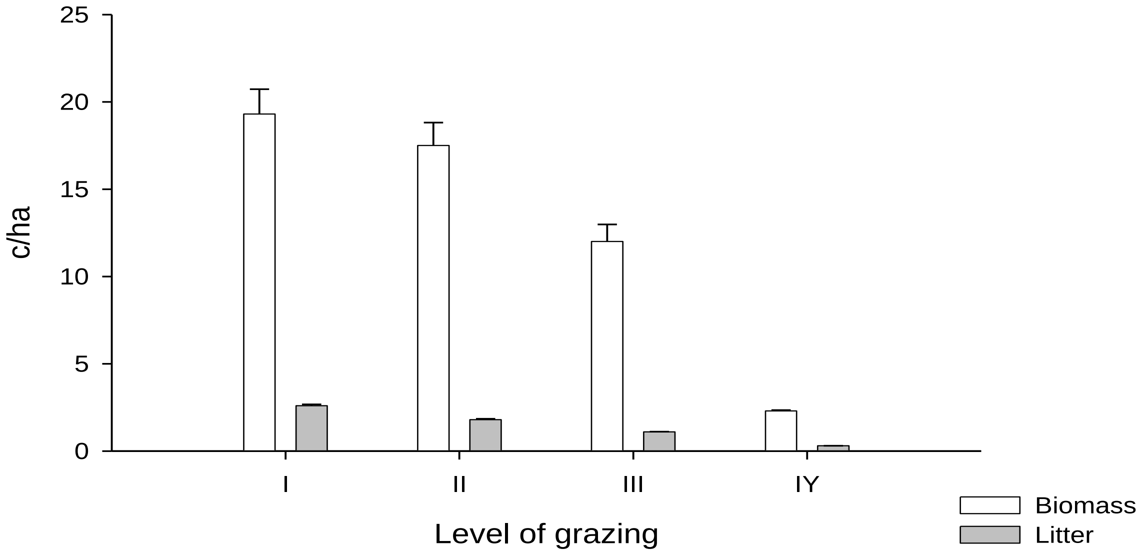

Figure 5. The proportion between the aboveground biomass and litter.

S_1– Light grazing (Stipa grandis community); S_2-moderate grazing (forb-grass community); S_3- heavy grazing (Cleistogenes squarrosa community); S_4 –overgrazing (Artemisia adamsii community);

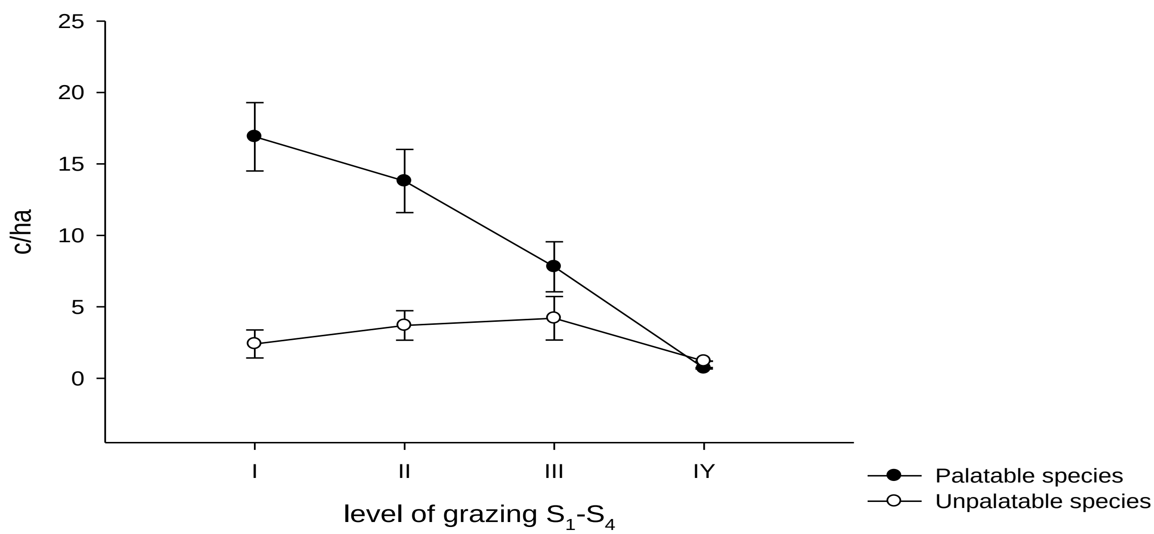

Figure 6. The proportion between the biomass of palatable and unpalatable species.

S_1– Light grazing (Stipa grandis community); S_2-moderate grazing (forb-grass community); S_3- heavy grazing (Cleistogenes squarrosa community); S_4 –overgrazing (Artemisia adamsii community);

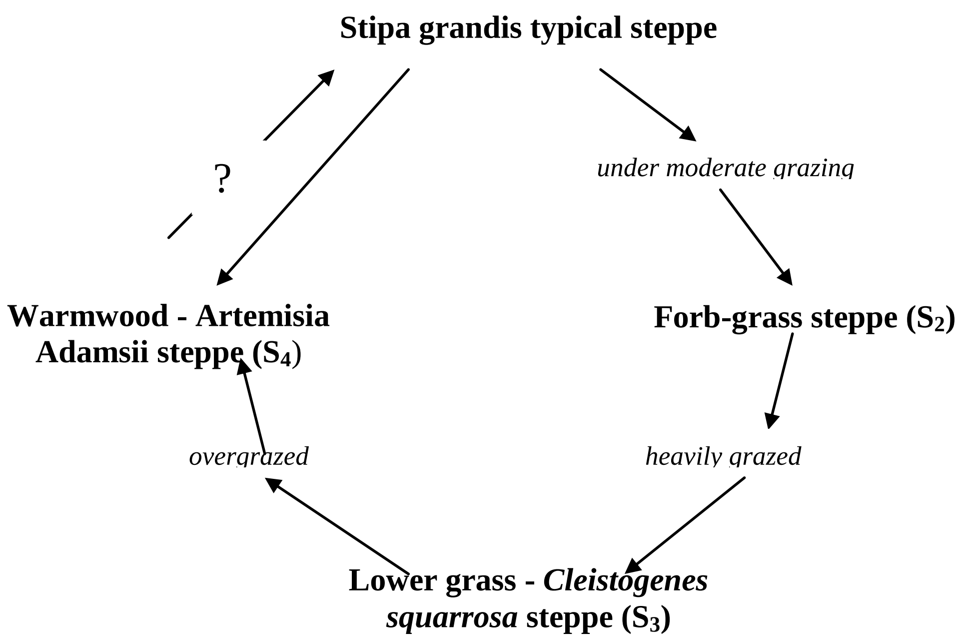

Figure 7. The scheme of succession in Stipa grandis steppe.

S_2 – moderate grazing; S_3- heavy grazing; S_4- overgrazing;