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Degradation of Grassland in Keerqin Sandland, Inner Mongolia, China

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Synopsis

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A vegetation survey has been completed for gathering information and diagnosis of degradated vegetation in Wulanaodu, Western Keerqin Sandland, Inner Mongolia, China. Serious desertification of pastures occurred there after 1950s. On the sandland and sand dunes areas the non-degraded vegetation is *Caragana microphylla-Cleistogenes squarrosa*, which is a shrub and perennial caespitose grass dominant community. The most degraded vegetation is dominated by such annuals as *Setaria viridis* and the psammophyte *Corispermum telegium* and others. On the lowland meadow soil, the non-degraded vegetation consists mostly of perennial grass such as *Hemarthria japonica*. The lightly degraded vegetation is dominated by *Calamagrostis epigeios*, and the heavily degraded one by such annuals as *Setaria viridis*. In the lowland areas with saline-alkali soil, the non-degraded vegetation is dominated by *Aneurolepidium chinense*, a rhizomatous grass with broad adaptation. Lightly degraded vegetation is dominated by *Hordium brevisublatum*, while the degraded vegetation is mostly *Suaeda corniculata*, a halophyte. These results indicate that degraded pastures are dominated by sand loving annuals or halophytes on the saline-alkali lowlands.

Key words : Desertification, Grassland degradation, Halophyte, Indicator species, Inner Mongolian grassland.

Introduction

Desertfication (vegetation degradation, alkalization and sand drifting) seriously threatens grasslands in the Wulanaodu region because of high winds and human activities. This resulted in the decrease of productivity. Production of above ground biomass has decreased from 2.2-3.0 t/ha in the 1950s, to 0.75-1.50 t/ha in the 1980s (NAN Y. unpublished data). Several authors[2,3,9] reported that vegetation in the lowland meadow steppe is seriously degraded because of soil alkalization and that grazed pastures were utilized intensively and degraded more than the hay-making pasture.

The landscape of grazing lands is extremely heterogeneous. For instance, a pasture of 60 ha, is consists of sand dune and lowland. The ratio of the former area to the latter is 10 to 4. Forty% of the sand dune area is covered with vegetation of *Caragana microphylla* while remaining 60% is bare ground. The lowland vegetation is dominated by annuals. Thus, there are a lot of land types and vegetation types in one grazing land, and it is assumed that vegetation types correspond to the land types.

On stages of degradation following results have been reported. Vegetation degradation is a process of retrogressive succession and is a phenomenon of desertification, which includes deterioration of environment and vegetation. In the region overgrazing has caused deterioration of soil and vegetation. Vegetation degradation appears in the reduction of soil cover, less biomass, and change of dominant plants. The life-form and the growth-form of dominant species change as degradation continues. In the progressive succsession for 15-20 years on protected areas in degraded pastures in the sandland

and dune areas, dominant or conspicuous species replaced each other in the following sequence: *Setaria viridis* and *Pappophorum boreale* (annual or biannual stage) - *Pennisetum flaccidum* and *Aneurolepidium chinense* (perennial rhizomatous grass stage) - *Cleistogenes squarrosa* (perennial caespitose grass stage) - *Caragana microphylla* and *Salix* spp. (shrub stage)[5].

RI, P., *et al.*[8] reported a similar successional sequence of stages related to life-forms and growth-form of the species in the abandoned fields of the steppe region. The major species of the respective stage were as follows ; *Setaria* spp. (annual stage), *Aneurolepidium* spp. (rhizomatous grass stage), *Cleistogenes* spp. (caespitose grass stage), *Prunus* spp. (tree stage). The caespitose or bunch grasses such as *Cleistogenes squarrosa*, which have growing points at ground level receive more damage by intensive grazing than the rhizomatous or turf grasses such as *Pennisetum flaccidum* and *Aneurolepidium chinense*. The annual plants, *Setaria viridis* and *Pappophorum boreale* regenerate from seeds receive the least damage.

These facts suggest that the most degenerated communities are dominated by the annuals, the least degenerated communities by caespitose grasses, and that the communities dominated by the rhizomatous grasses are intermediate. Therefore, the process of degradation appears to be the revers order of the progressive succession, from the caespitose grasses to rhizomatous grasses and finally the annual plants.

The objective of this study was diagnosis of vegetation degradation on three characteristic land types in the region by applying these ecological principles.

Study region and Survey methods

The study area was the same as in former studies[2-4] in the Wulanaodu region, western Keerqin Sandland, Inner Mongolia, long. 118°38′-120°43′ E. and lat. 42°47′-43°25′ N. A continental, temperate semi-arid climate characterizes the region. Mean year temperature ranges about 6.7°C and annual rainfall between 300-350 mm, mostly in summer according to recent 25 years observations.

Strong winds prevail with mean speed in a year of 4 m/second and maximum speed 31 m/second, which cause serious erosion.

The land types in the region are classified as : 1) the level sandland with a cover of sand and the sand dune of movable, semi-movable and fixed, with a cover of blown sand ; 2) the lowland meadow soil ; and 3) the lowland with saline-alkaline soil. The ground water level in the sandlands and sand dune lies more than 2 m below the surface. In the lowland it is less than 1 m. The land utilization of the former is continuous grazing whereas the latter is dual utilization ; hay-making once in summer/autumn, and grazing on the aftermass in winter. Pastures on five privately owned farms were surveyed. An average farm formerly contained about 60 ha of grazing pastures and about 7 ha of hay-making pastures. Vegetation analysis followed the methods of BRAUN-BLANQUET[1] namely dominance ratio (coverage) and sociability of species. The combined estimate of coverage is as follows. 5 ; Covering more than 3/4 of the area, 4 ; Any number of individuals covering 1/2 to 3/4 of the area, 3 ; Any number of individuals covering 1/4 to 1/2 of the area, 2 ; Very numerous, or covering at least 1/20 of the area, 1 ; Plentiful, but of small cover vlue, + ; Sparsely or very sparsely present, cover very small. The scale of sociability is as follows. 5 ; Plants occurring in great crowds (pure populations), 4 ; Plants in small colonies, in extensive patches, or forming carpets, 3 ; Plants in troups, small patches or cushions, 2 ; Plants grouped or tufted, 1 ; Plants growing in one place, singly.

Survey has been carried out on 2-3 plots at the typical communities selected by vegetation type in each pastures an area of 1-2 m^2 on August 1995.

Results and Discussion

Surveyed plots forty in all are classified by the land and soil types and arranged for Tables 1-3.

1. Vegetation on the sandland the simi-move able and fixed sand dunes

Table 1 shows the major species in the vegetation on the sandland and sand dunes. Communities are arranged left to right from least degraded to the most degraded. The dominant species have the highest coverage values. The principal life-forms of dominant species are tall trees (communities 1-3), shrub (Nos. 4-9), perennial rhizomatous grasses (10), and annual/biannual grasses and herbs (Nos. 11-15).

Species of the herb layer suffer more by excessive grazing than do shrubs and trees, therefore degradation first occurs in the herbaceous plants. Based on the herb layer, the least degenerated communities are No. 10, dominated by *Cleistogenes* and No. 1 with perennial species and medium coverage values. Community No. 5, dominated by *Pennisetum*, is slightly degenerated. The other 12 communities all dominated by the annuals are in the serious stage of deterioration.

Annual grasses such as *Setaria viridis*, *Pappophorum boreale*, *Aristida adscensionis* and *Digitaria sanguinalis* in the herb layer of communities 4 and 6-9 also occur under the shrub *Caragana microphylla*. Annual psammophytes, such as *Corispermum thelegium*, *Chenopodium acuminatum*, *Bassia dasyphylla*, and *Agriophyllum arenarium*, are

Table 1. Dominance and sociability of vegetation in the sandland and sand dune areas (for 15 communities).

Species	Life form[1]	Trees dominant			Shrubs dominant						Rhizomatous	Annuals dominant				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ulmus pumila	Ph	1・1[2]	1・1	1・1												
Caragana microphilla	Ph	2・2	2・2	1・1	3・2	3・2	2・2	2・2	2・2	2・2						
Cleistogenes squarrosa	H	2・2		1・1				1・1	+	1・1	4・3					
Koeleria crista	H	2・2									2・2				1・1	1・1
Carex duriuscula	H	2・2														
Agropyron cristatum	G	2・2	2・2								2・2					
Pennisetum flaccidum	G	1・1				3・2					1・1				3・2	
Aneurolepidium chinense	G										1・1					
Cynanchum sibiricum	G	+	+			1・1	1・1	+	1・1	+	1・1	+	+	+	+	+
Setaria viridis	Th	+	3・2	5・5	3・2		3・2	1・1	1・1	2・2	1・1	5・5	4・3	3・2	1・1	1・1
Pappophorum boreale	Th		1・1	3・2				5・5	2・2	2・2	1・1	1・1		1・1	4・3	2・2
Digitaria sanguinalis	Th		+	1・1					5・5	1・1	+	1・1		1・1	2・2	5・5
Tragus berteronianus	Th		1・1	3・2				1・1			+	2・2		2・2		
Aristida adsensionis	Th		3・2	2・2				1・1	1・1	5・5	+	1・1			2・2	2・2
Agriophyllum arenarium	Th		+				1・1	+	+	+		+				+
Corispermum thelegium	Th		+	+	1・1	2・2	3・2	+	1・1	+		1・1			1・1	1・1
Chenopodium acuminatum	Th	+	+		1・1		+	+	+	+	1・1	1・1			1・1	1・1
Bassia dasyphylla	Th		+	1・1	1・1	1・1		+	+	+		+	1・1			
Chloris virgata	Th		+	2・2							+					+
Artemisia scoparia	Th	+														

[1] Ph : Phanerophyte (tree), H : Hemicriptophyte (herbaceous plant with bud lies soil level), G : Geophyte (herbaceous plant with bud lies below soil level), Th : Therophyte (annual)

[2] Two figures indicate the classes of coverage and sociability, respectively according to the scales of Braun-Blanquet.

Table 2. Dominance and sociability of vegetation in the lowland meadows (for 18 communities).

Species	Life form[1]	Rhizomatous dominant																Annuals dominant	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Arundinella hirta	G	5・5			2・2														
Spodiopogen sibiricus	G	2・2			2・2														
Aneurolepidium chinense	G	2・2	5・5	5・5	1・1														
Artemisia scoparia	Th		1・1		1・1				1・1									1・1	
Artemisia japonica	H	1・1			+														
Setaria viridis	Th		1・1	1・1														4・3	4・3
Amarantus retroflexus	Th				+		2・2											+	+
Stellera chamaejasme	H	1・1			2・2														
Chloris virgata	Th																	1・1	+
Plantago asiatica	H															2・2		+	+
Hemarthria japonica	G	2・2			5・5														
Calamagrostis epigeios	G	+	1・1	1・1	1・1	4・3	4・3	4・3	4・3	3・2	4・3	3・2	3・2						
Potentilla anserina	H	1・1			1・1														
Inula britannica	H	+		1・1	1・1											1・1			
Echinochloa crus-gali	Th				+		1・1											+	+
Arthraxon hispidus	Th	+			+	2・2	2・2									3・2			
Glycine ussurensis	G		+		+	2・2							2・2	3・2					
Agrostis alba	G											4・3	4・3	4・3	3・2				
Phragmities communis	G							1・1			1・1			2・2	2・2	4・3	4・3	1・1	+

[1] and [2] refer to Table 1.

associates with the shrubs, on fixed sand dunes.

Communities Nos. 12 and 13 with very dispersed annual species characterize the semi-moving sand dunes.

2. Vegetation on the lowland meadow soil

Table 2 presents data on vegetation of the lowland with meadows. Communities are arranged left to the right from the least degraded to the most degraded. Species are arranged top to down from the least tolerant for the high soil moisture to the most tolerant. Some species of the low coverage and the low frequency are excluded.

Dominant species of communities Nos. 1-4 are *Arundinella hirta*, *Aneurolepidium chinense*, and *Hemarthria japonica*. These are the most productive grasses with excellent quality forage in the pastures of the region. Communities Nos. 5-10, Nos. 11-13 and Nos. 15, 16 are dominated by *Calamagrostis epigeios*, *Agrostis alba*, and *Phragmites communis*, respectively. These grasses are rhizomatous and indicate little degradation, although a few annual species, such as *Arthraxon hispidus*, may be present. *Setaria viridis* and other annual species dominate in communities 17-18 and indicate severe degradation. Nevertheless, in the lowland soils with meadow vegetation are in better condition than vegetation on sandland and sand dune.

3. Vegetation degradation on the saline-alkali soils

Table 3 shows vegetation in the lowland with saline-alkali soils. Communities are arranged left to right from the least degraded to the most degraded. The dominant species of communities 1-3 is *Aneurolepidium chinense*, the wide spread rhizomatous grass of other non-degraded communities. It is productive, and of excellent quality. Community 4-7 are principally alkali-tolerant species, such as *Hordeum brevisublatum*, *Puccinellia tenuiflora*, *Artemisia anethifolia*, *Suaeda corniculata*, and *Kochia sieversiana*. The later two species are strict halohytes, the most tolerant of saline-alkali soil, and they indicate severely degraded vegetation.

The distribution of the above species is closely correlated with low to high salt content of the soil, as shown by Xu and NAN[9] in the following sequence : in the *Aneurolepidium chinense*, *Hordeum brevisblatum*, *Puccinellia tenuiflora*, *Artemisia anethifolia*, *Kochia sieversiana*, and *Suaeda corniculata*.

4. Indicator species of vegetation degradation

Table 4 shows indicator species of degradation. On the sandlands and dunes the vegetation degradation caused by overgrazing tends to occur as follows : the perennial caespitose grasses such as *Cleistogenes squarrosa* decrease and the rhizomatous grasses including *Pennisetum flaccidum* increase. The incomplete plant cover does not protect the soil against wind and water erosion. When soil and vegetation are more severely destroyed, the rhizomatous grasses also desappear and annual plants such as *Agriophyllum arenarium* replace them.

Thus, the fixed sand dune changes gradually to semi-moving sand dunes, and eventually to moving sand dunes. Species occupying these sand dunes in the final stage are psammophytes such as *Agriophyllum arenarium*, *Corispermum macrocarpum*, *Salsola ruthenica*, *S. collina* and *Bassia dasyphylla*, etc. These psammophyte withstand arid and high temperature of the habitat and are indicators of degradation.

On the low meadow soil, vegetation is little degraded in the surveyed area. However, NAN *et al.*[7] reported that in areas where soil becomes dry, vege-

Table 3. Dominance and sociability of vegetation on the lowland saline-alkali soils (for 7 communities).

Species	Life form[1]	Rhizomatous dominant				Annuals dominant		
		1	2	3	4	5	6	7
Artemisia mongolica	H	1・1						
Artemisia japonica	H	1・1						
Artemisia laciniata	H	+						
Sanguisorba officinalis	H	1・1						
Aneurolepidium chinense	G	4・3	4・3	4・3				
Hordium brevisublatum	G	1・1		+	3・2			
Puccinellia tenuiflora	H			1・1	2・2			
Plantago salsa	H				+	+		
Artemisia anethifolia	Th		1・1			3・2		
Polygonum sibiricum	G				+		+	1・1
Suaeda corniculata	Th			+	+	2・2	4・3	4・3
Kochia sieversiana	Th						3・2	

[1] and [2] refer Table 1.

Table 4. Indicator species of non-degraded and degraded pastures in Keerqin Sandland, Inner Mongolia, China.

1. Indicators on flat sand areas and sand dunes
   1) Non-degraded pastures
      Caragana microphylla, Lespedeza dahurica, L. hedysaroidis*, Cleistogenes squarrosa, Agropyron cristatum, Pennisetum flaccidum, Koeleria crista*
   2) Degraded pastures (psamophytes)
      Corispermum macrocarpum, C. sibiricum*, C. thelegium*, Setaria viridis, Salsola ruthenica*, S. collina*, Bassia dasyphylla, Agriophyllum arenarium, Aristida pictinata*, A. scoparia, Pappophorum boreol, Aristida adcensionis, Tragus berteronianus, Chenopodium acuminatum*

2. Indicators on the lowland meadow soils
   1) Non-degraded pastures
      Hemarthria japonica, Arundinella hirta, Aneurolepidium chinense
   2) Degraded pastures
      Potentilla ancerina, Taraxacum mongolicum, Swaisona salsula*, Plantago asiatica, Artemisia mongolica*, Stellera chamaejasme, Artemisia manshurica*, A. scoparia, Setaria viridis*

3. Indicators on the lowland saline-alkali soils
   1) Non-degraded pastures
      Aneurolepidum chinense
   2) Slightly degraded pastures (halophytes)
      Puccinellia tenuiflora, Hordium brevisubratum
   3) Heavily degraded pastures (strict halophyte)
      Artemisia anethifolia, Suaeda corniculata, Polygonum sibiricum, Kochia sieversiana

Note : *These species are not appear in the survey but put into the table with reference to previous papers[6,7].

tation is invaded by drought tolerant plants like *Potentilla anserina, Stellera chamaejasume, Artemisia scoparia.* Therefore, these species indicate degradation on the lowland meadow soils. Lowland with saline-alkali soil shows the most severe degradation, where little forage production could be expected. When plant cover is destroyed by intensive cutting and grazing large areas become denuded and active evaporation takes place from ground surface. Consequently, salt accumulates on the soil, on which only halophytes survive. Thus, the presence of intermediate halophytes, *Puccinellia tenuiflora* and *Hordium brevisubratum*, indicates lightly degraded condition. The strict halophytes such as *Artemisia anethifolia, Kochia sieversiana* and *Suaeda corniculata* indicate severely degraded condition. NAN *et al*[7] reported that area of the halohyte communities in the region occupied 15% in the 1970s, and had increased to 30% by the 1990's.

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要　　旨

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中国内蒙古のケルチン沙地は，過度の放牧，採草利用等により最近の 40 年間に沙漠化が著しく進行している。植生退化診断の資料を得る目的で，Wulanaodu 村の各種草地の植生を調査した。指標として注目したのは，優占種の生活型（一年生または多年生），生育型（叢生型または根茎型）である。沙地・沙丘地は退化前は，アオムレスズメ（*Caragana microphylla*）が低木層を占め，草本層を多年生の *Cleistogenes squarrosa* などが優占している。著しく退化した場合には，アオムレスズメがなく，一年生のエノコログサ（*Setaria viridis*）などが優占し，*Corispermum thelegium* など多くの沙生植物が侵入してくる。低地の非塩基性土壌の草地では，退化前はトダシバ（*Arundinella hirta*）などが優占している。退化した場合には湿潤地を好むヨシ（*Phragmites communis*）やエノコログサが優占した。低地の塩基性土壌の草地では，退化前はシバムギモドキ（*Aneurolepidium chinense*）が優占種で，退化した場合には *Artemisia anetifolia, Suaeda corniculata* など多くの塩生植物が優占した。これらの結果と文献から草地退化の指標植物を考察した。

キーワード：内蒙古草地，塩生植物，塩類土壌，草地退化，退化指標.