Chapter 10
Degradation of Mongolian Grassland Vegetation Under Overgrazing by Livestock and Its Recovery by Protection from Livestock Grazing

Indree Tuvshintogtokh and Dorjgotov Ariungerel

Keywords Degradation • Dominant species • Protection of grazing • Steppe vegetation • Succession

10.1 Introduction

In Mongolia, the largest biome is steppe, covering 83.4% of the total land area of the country, which corresponds to roughly 2.6% of the global grassland vegetation (World Resources Institute 2003). Mongolia has 126.0 million hectares of pasture area, including 6.2 million hectares of bluffs and gullies that are not valuable for pasture area and 3.0 million hectares of sand-covered areas, and saline soil areas of extra-arid desert occupy 20.5 million hectares. According to this estimation, only 76.5%, or 96.8 million hectares (ha), of total pasture area is currently used for grazing purposes. Approximately 70% of pastureland area has been degraded environmentally: around 40% is degraded ecologically, 20% is moderately degraded, 5% is severely degraded, and 2–3% is classified as very severely degraded (Awaadorj and Badrakh 2007).

The main reasons of this degradation are overgrazing and climate changes. In the period between 1940 and 2004, the mean annual temperature of Mongolia increased by 1.9°C, which is comparatively higher than that cited in earlier research

I. Tuvshintogtokh (✉)
Institute of Botany, Mongolian Academy of Sciences, Ulaanbaatar, Mongolia
e-mail: tuvshintogtokh@yahoo.com

D. Ariungerel
MercyCorps, Gobi Forage Project, Ulaanbaatar, Mongolia

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papers (1.56°C). The total annual precipitation has decreased by 2% during those 65 years, which is considered insignificant in light of the current global changes. The sum of effective precipitation during the vegetative growth period is decreased by 13.8 mm, or 7.2%. In Eastern Mongolia, the sum of effective precipitation during the vegetative growth period is increased by 2.7–9.5%. In the central and Gobi parts of the country, it is decreased by more than 10% (Natsagdorj and Gomboluudev 2005).

Anthropogenic factors such as the nomadic herding system have the most important impact for changing the steppe vegetation cover. The most recent changes in the socioeconomic status have forced new changes in pastoral management because of the relaxation of central government control and implementation of a more “free-enterprise” system. Livestock numbers increased to 43 million from 25.8 million between 1990 and 2009. The carrying capacity of Mongolian pastureland can support only 60 million sheep units during the winter–spring seasons, but right now our livestock population is 65 million sheep units. The grazing pressure is increasing year by year in Mongolia because of overgrazing and degradation of the rangeland ecosystem. Introduction of heavy grazing often initiates a regressive succession, including a decrease in biomass and in structural complexity. Grazing intensity has altered the species composition of the grasslands. The extent of grassland degradation can be assessed by investigating the floristic composition of the plant community, and the floristic composition has been demonstrated to be an accurate indicator of grassland condition (Clements 1928; Dyksterhuis 1949; Nakamura et al. 2000). The floristic composition of the steppe is decreased such that mesophytes and unpalatable species have increased to 50–70%, and xerophytes have increased through increased grazing, as shown by results of the investigations by Mongol and neighbors Ovor Baigal and Inner Mongolia (Chognii 2001; Tong et al. 2004).

On the other hand, protection of grazing often leads to a progressive succession with changes in floristic composition (Clements 1916; Chognii 2001). The effect of protection of grazing varies with, for example, floristic composition and physiognomy, soil conditions, and precipitation, and grazing history may lead to changes in the phenology of species and to increases in canopy cover and standing biomass (Browns and Bagley 1986; Smith and Rushton 1994). Depending on whether the dominant species are palatable, the direct influence of grazing may lead to either an increase or a decrease in species diversity. It is generally assumed that the highest species richness is found at intermediate levels of disturbance (Collins and Barber 1985; Maarel 1993) and under conditions of moderate grazing (Helle and Aspi 1983).

Objectives of our survey are these:

1. Define succession, as affected by a long-term change on the vegetation communities of the steppe, dry steppe, desert steppe, and desert of Mongolia resulting from grazing pressure and climate changes.
2. Define pasture restoration after giving up grazing. Our study is focused on the following characteristics: (a) floristic composition and species richness, (b) vegetation coverage, and (c) dominant and subdominant species of community.

10.2 Materials and Methods

The geobotanical survey was conducted in the east, southeast, and south parts of Mongolia (Dornod, Sukhbaatar, Dornogobi, Dundgobi, and Umnugobi aimags) between 2001 and 2009. The typical steppe, dry steppe, desert steppe, and desert cover the territories of these aimags. We determined the floristic composition, height, phenological stage, and species coverage in quadrats of 10 m^2. All covered points are shown in (Fig. 10.1). In all, 291 geobotanical releves were analyzed, then compared with 1:1,500,000 scale vegetation maps from 1975 compiled for previous research purposes. We also defined succession stages in the two dominant vegetation communities of Eastern Mongolia through grazing.

We were studied nine fenced plots (Fig. 10.2). When designing our surveys, we made use of the right-of-way zone through the Ulaanbaatar to the Zamiin Uud. The width of the right of way, which is fenced off, is normally about 25–30 m, and in some places up to 1–1.5 km. The period of stringent isolation from grazing exceeded more than 50 years. We also used field research plots of the Institute of Botany, MAS (fenced for 6–10 years) (Table 10.1). We compared the vegetation community in pastures that were moderately or heavily grazed and those where grazing has been abandoned. Seven of our nine sampling sites are located in desert steppe, one is in typical steppe, and one is in the mountain steppe belt.

At each sampling site, 20 quadrats (10 are inside and 10 are outside the fenced plots) were sampled along the transect, using a frame of 1×1 m^2 in the grassland and 10×10 m^2 in the shrublands, for collecting data of floristic composition,

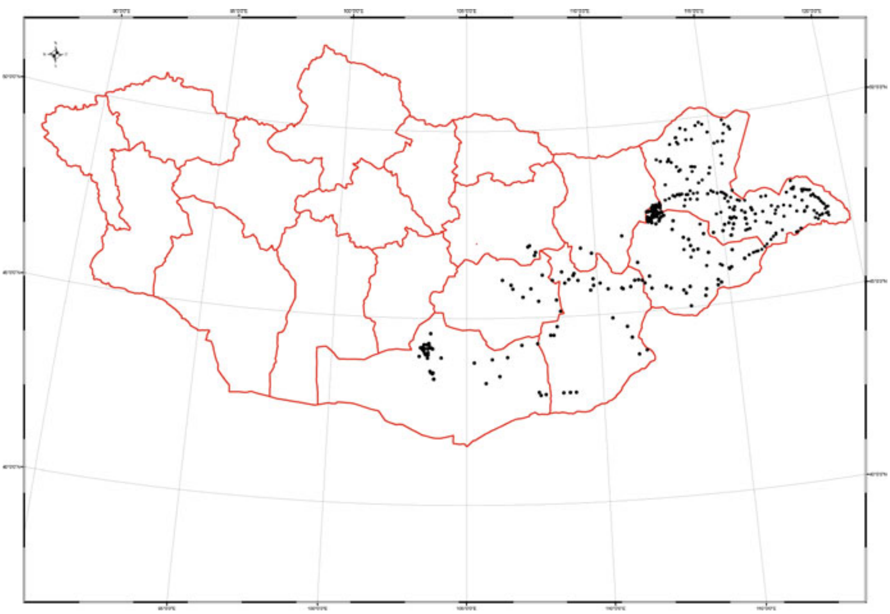

Fig. 10.1 Points of geobotanical releves

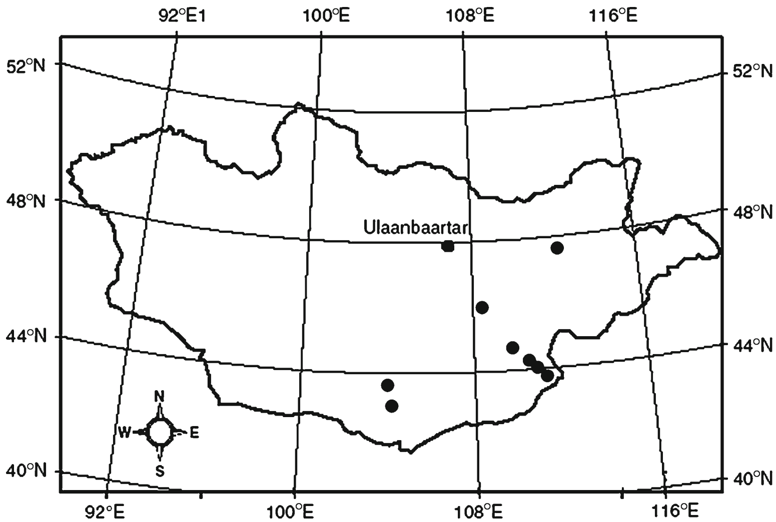

Fig. 10.2 Location fenced from livestock grazing

Table 10.1 Characteristics of sites fenced from livestock grazing

No.	Site name	Longitude	Latitude	Elevation (m)	Vegetation	Grazing level	Years fenced	Fenced site
04-1	Tumentsogt	47,79	112,51	985	Typical steppe	Moderate	6	Research site of Institute of Botany, MAS
01-1	Dalanjargalan	46,04	109,05	1,107	Desert steppe	Moderate	>50	Along the railway
01-2	Urgun-West	44,89	110,51	942	Desert steppe	Moderate	>50	Along the railway
01-3	Urgun-East	44,63	111,03	1,032	Desert steppe	Moderate	>50	Along the railway
03-1	Gurvan Saikhan	43,58	103,65	1,936	Mountain steppe	Moderate	7	Research site of SPA "Gurvan Saikhan"
02-1	Bulgan-North	44,18	103,73	1,312	Desert steppe	Heavy	20	Research site of Agricultural Institute
02-2	Bulgan-South	44,11	103,41	1,302	Desert steppe	Heavy	10	Research site of Institute of Botany, MAS
02-3	Erdene-North	44,29	111,48	1,012	Desert steppe	Heavy	>50	Along the railway
02-4	Erdene-South	44,03	111,66	991	Desert steppe	Moderate	>50	Along the railway

coverage, abundance, height, and phenological stage of species. All dominant species were classified into C3 and C4 plants through photosynthetic pathways (Wang and Yin 1997; Wang 2002, 2003; Pyankov et al. 2000).

Similarity between plant communities is defined by Jaccarda's formula (ISj) (Mueller-Dombois and Ellenberg 1974) as $ISj = c/(A + B - c) \times 100\%$, where A is the number of species of the fenced site, B is the number of species outside the fence, and c is the number of similar species of both sites.

10.3 Results

Dominant species display more abundance and greater coverage than other species and play a main role in composing the vegetation community and changes of pasture quality; these species act to confer environmental conditions. Therefore, changes of dominant species can express changes of the vegetation community and environmental conditions. We can identify changes of the dominant species for the years 1975–2009 (Table 10.2).

The vegetation of typical steppe, dry steppe, desert steppe, and desert in the vegetation map of Mongolia with scale 1:1,500,000 (1975) was compared with our research results between 2001 and 2009, as follows.

Our research points involved 32 contours of the vegetation map, and the dominant species of all contours changed. In eight contours, all dominant species were changed.

Table 10.2 Comparison of dominant species and vegetation subtype, 1975–2009

Number of map contours	Dominant species		Vegetation subtype	
	Remaining (1975–2009)	Current (2009)	Previous (1975)	Current (2009)
35a	–	*Cleistogenes squarrosa*, *Allium polyrrhizum*, *Stipa krylovii*, *S.gobica*	Typical steppe	Dry steppe Desert steppe
35a	–	*Stipa gobica*, *Allium polyrrhizum*, *Cleistogenes squarrosa*, *C. songorica*	Dry steppe	Desert steppe
38a	*Stipa grandis*, *S. baicalensis*	*Filifolium sibiricum*, *Leymus chinensis*, *Cleistogenes squarrosa*	Typical steppe	Typical steppe
38a	*Caragana leucophloea*	*Cleistogenes squarrosa*, *Allium polyrrhizum*, *Artemisia frigida*, *Reaumuria soongorica*	Dry steppe	Dry steppe Desert steppe
39a	*Stipa klemenzii*	*Allium polyrrhizum*	Dry steppe	Dry steppe
40a	*Stipa baicalensis*	*Leymus chinensis*, *Cleistogenes squarrosa*, *Artemisia frigida*, *Poa attenuata*	Typical steppe	Typical steppe Dry steppe
40a	–	*Stipa grandis*, *Cleistogenes squarrosa*, *Leymus chinensis*	Typical steppe	Typical steppe

(continued)

Table 10.2 (continued)

Number of map contours	Dominant species		Vegetation subtype	
	Remaining (1975–2009)	Current (2009)	Previous (1975)	Current (2009)
41	*Stipa krylovii*, *Cleistogenes squarrosa*, *Leymus chinensis*	*Allium polyrrhizum, Reaumuria soongorica*	Dry steppe	Dry steppe Desert steppe
42a	*Caragana microphylla*	*Stipa krylovii*, *Cleistogenes squarrosa*, *Leymus chinensis*, *Carex duriuscula*, *Allium polyrrhizum*, *Artemisia adamsii*	Typical steppe	Dry steppe
42a	*Caragana microphylla*	–	Typical steppe	Dry steppe
42a	*Caragana microphylla*	*Allium polyrrhizum*, *Stipa gobica*, *Cleistogenes squarrosa*, *Artemisia frigida*, *Reaumuria soongorica*, *Salsola passerina*	Dry steppe	Dry steppe Desert steppe
46	–	*Reaumuria soongorica*	Dry steppe	Desert steppe
47	*Stipa krylovii*	*Allium polyrrhizum*, *Cleistognes squarrosa*, *Artemisia pectinata*	Dry steppe	Dry steppe
48a	*Stipa klemenzii*, *Artemisia frigida*	*Stipa gobica*, *Allium polyrrhizum*, *Cleistogenes songorica*	Dry steppe	Desert steppe
49a	*Stipa gobica*	*Achnatherum splendens Ajania trifida*	Desert steppe	Desert steppe
49a	*Stipa gobica*, *Artemisia xerophytica*	*Allium polyrrhizum*, *Eurotia ceratoides*, *Caragana korshinskii*, *Anabasis brevifolia*, *Achnatherum splendens*	Desert steppe	Desert steppe
51	*Stipa gobica*, *Cleistogenes songorica*	*Caragna korshinskii*, *Allium polyrrhizum*	Desert steppe	Desert steppe
52a	*Stipa gobica*	*Allium polyrrhizum*, *Cleistogenes squarrosa*, *Caragana korshinskii*, *C. pygmaea*	Desert steppe	Desert steppe
54	*Allium polyrrhizum*, *Stipa gobica*	*Cleistogenes songorica*, *Allium mongolicum*	Desert steppe	Desert steppe
55	*Stipa glareosa*, *Anabasis brevifolia*, *Allium polyrrhizum*	*Artemisia frigida*, *Cleistogenes songorica*	Desert steppe	Desert steppe

(continued)

Table 10.2 (continued)

Number of map contours	Dominant species		Vegetation subtype	
	Remaining (1975–2009)	Current (2009)	Previous (1975)	Current (2009)
58a	*Stipa gobica, S.glareosa, Anabasis brevifolia, Caragana leucophloea*	*Allium polyrrhizum, Cleistogenes songorica, Haloxylon ammodendron*	Desert steppe	Desert steppe Desert
59a	*Stipa gobica, Caragana pygmaea*	*Allium polyrrhizum, Artemisia frigida, Cleistogenes squarrosa, C. songorica, Ajania achilleoides, Convolvulus ammanii, Reaumuria soongorica*	Desert steppe	Desert steppe
60a	–	*Caragana korshinskii, Stipa gobica, Cleistogenes songorica*	Sandy vegetation	Desert steppe
62	*Stipa glareosa*	*Allium polyrrhizum, Cleistogenes squarrosa, Caragana leucophloea, Convolvulus ammanii*	Desert steppe	Desert steppe
63	*Anabasis brevifolia*	*Salsola passerina*	Desert	Desert
64	–	*Anabasis brevifolia*	Desert	Desert
71	*Haloxylon ammodendron*	*Ajania achilleoides, Stipa gobica, Artemisia xerophytica, Convolvulus ammanii*	Desert	Desert Desert steppe
79	*Allium polyrrhizum*	*Cleistogenes songorica, C. squarrosa, Stipa gobica, Artemisia frigida*	Desert steppe	Desert steppe
80	–	*Kalidium gracile*	Desert steppe	Solonchak
82	*Reaumuria soongorica*	*Brachanthemum gobicum, Anabasis brevifolia*	Desert	Desert
83	–	*Artemisia pectinata, Chenopodium acuminatum, Artemisia frigida*	Solonchak	Dry steppe
84	*Haloxylon ammodendron*	–	Desert	Desert

The remaining 37 dominant species consist of 46% *Stipa* species (*Stipa gobica*, *S. glareosa*, *S. klemenzii*, *S. krylovii*, *S. baicalensis*, *S. grandis*), 16% *Caragana* species (*Caragana microphylla*, *C. leucophloea*, *C. pygmaea*), and 8.1% of *Allium polyrrhizum* and *Salsola passerina*.

Of the new 94 (overlapped) dominant plant species, there were 21 *Cleistogenes squarrosa*, *C. songorica*, 16 *Allium polyrrhizum*, 10 *Stipa*, 7 *Artemisia frigida*,

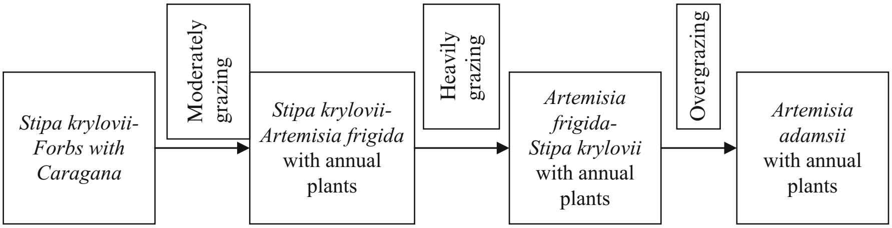

Fig. 10.3 Degradation pathways of the *Stipa krylovii* community

5 *Reaumuria soongorica*, 6 *Caragana* (*Caragana korshinskii* 4, *C. pygmaea* 1, *C. leucophloea* 1), 4 *Leymus chinensis*, 3 *Convolvulus ammanii*, and 3 *Anabasis brevifolia* registered.

Our study has shown that in the first stage, forbs and mesophyte plants disappeared because of the steppe degradation. The typical steppe is changed to dry and desert steppe, and dry steppe is changed to desert steppe; desert steppe and desert plant species are comparatively stable.

Nowadays, *Cleistogenes squarrosa*, *Stipa krylovii*, *Artemisia frigida*, and *Leymus chinensis* are the main dominants in the dry steppe, and *Allium polyrrhizum*, *Stipa gobica*, *Reaumuria soongorica*, *Cleistogenes songorica*, *Caragana korshinskii*, *Anabasis brevifolia*, and *Convolvulus ammanii* are dominant in the desert steppe.

We considered how floristic composition, vegetation coverage, and dominant species changed in the slightly, moderately, or heavily degraded community with *Stipa krylovii* widely scattered over the whole dry steppe zone of Mongolia. As seen from our results, the *Stipa krylovii-forbs-Caragana* community is changed to *Stipa krylovii–Artemisia frigida* with annual plants through moderate grazing and to *Artemisia frigida–Stipa krylovii* with annual plants community through heavy grazing, and to the *Artemisia adamsii* with annual palants community in the overgrazed condition (Fig. 10.3).

The total vegetation coverage of the community was not changed, but species diversity decreased from 44 species to 7 species, and *Stipa krylovii* coverage decreased to 2% from 15%; also, coverage of annuals increased to 87% from 14% (Table 10.3).

Our study was carried out in the *Stipa grandis* steppe, which can represent the typical steppe of Eastern Mongolia. In particular, the aforementioned principle is frequent in this community. Consequently, succession is going through changes in dominant species in response to the increased grazing effect (Fig. 10.4).

In this case, general coverage was not changed, but species diversity was reduced to seven species from 35 plant species whereas the coverage of *Stipa grandis* is decreased to 15% from 35%. In the overgrazed area with colony of Brandt's, *Stipa grandis* disappeared, and annuals such as *Ephedra sinica* are increased to 65% from 9% (Table 10.4).

The climax steppe is changed by the degraded community with unpalatable species and has five- to sixfold reduced species diversity.

In our results, when grazing ceases and the pasture is fenced, community structure and floristic composition are changed (Table 10.5). The coverage of community was increased by 1.5- to 2.5-fold, and the height of the community was also increased, by 1.4- to 2.4-fold.

Table 10.3 Change in vegetation community of *Stipa krylovii* through grazing level

Vegetation community	Total vegetation coverage (%)	Species numbers	Dominant plants: Species	Dominant plants: Coverage (%)	Annual plants	Annual percent for the plant community (%)
Stipa krylovii-Forbs-Caragana	50	44	*Stipa krylovii*	15	*Chenopodium viride*	14
			Caragana microphylla	2	*Salsola collina*	
			Caragana stenophylla	5		
			Serratula centauroides	4		
			Filifolium sibiricum	4		
			Potentilla acaulis	2		
Stipa krylovii-Artemisia frigida with annual plants	52	23	*Stipa krylovii*	7	*Chenopodium viride*	67
			Artemisia frigida	5	*Salsola collina*	
					Axyris amaranthoides	
Artemisia frigida-Stipa krylovii-with annual plants	54	22	*Artemisia frigida*	10	*Chenopodium viride*	74
			Stipa krylovii	3	*Salsola collina*	
Artemisia adamsii with annual plants	47	7	*Artemisia adamsii*	10	*Chenopodium viride*	87
			Stipa krylovii	2	*Salsola collina*	
					Chenopodium aristatum	

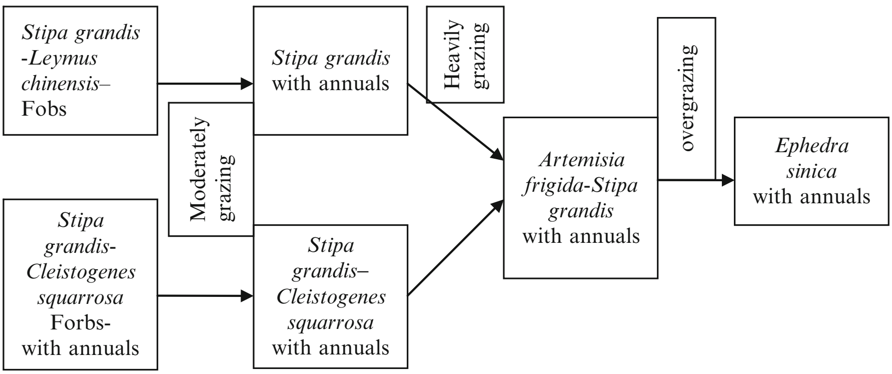

Fig. 10.4 Degradation pathways of the *Stipa grandis* community

Also, species richness is increased in the seven fenced sites, and floristic composition is very different between grazed and ungrazed pastures. Although the number of species has not changed in some sites, such as "Urgun-East" and "Gurvan Saikhan," the floristic composition is different. ISj has higher value in the site 1 "Tumentsogt" when protected from grazing for a few years and lower value in sites "Bulgan-North" and "Bulgan-South" with heavy grazing.

The coverage of dominant and subdominant species is recovering through the long-term abandonment of grazing (Tables 10.5 and 10.6). Although the dominant

Table 10.4 Changes in vegetation community of *Stipa grandis* through grazing level

Vegetation community	Total vegetation coverage (%)	Species number	Dominant plants: Species	Dominant plants: Coverage (%)	Annual plants	Annual percent for the plant community (%)
Stipa grandis-Leymus chinensis-Pulsatilla turczaninovii	66	35	*Stipa grandis*	30	*Chenopodium aristatum*	9
			Leymus chinensis	8		
			Pulsatilla turczaninovii	5		
Stipa grandis with annual plants	45	25	*Stipa grandis*	25	*Chenopodium viride*	22
			Leymus chinensis	2		
			Caragana microphylla	2		
			Kochia prostrata	2		
Stipa grandis-Cleistogenes squarrosa-Serratula centauroides with annual plants	60	35	*Stipa grandis*	20	*Chenopodium viride*	33
			Cleistogenes squarrosa	5		
			Serratula centauroides	3		
Stipa grandis-Cleistogenes squarrosa with annual plants	64	29	*Stipa grandis*	16	*Chenopodium viride*	54
			Cleistogenes squarrosa	5	*Salsola collina*	
Artemisia frigida- Stipa grandis with annual plants	60	12	*Artemisia frigida*	20	*Chenopodium viride*	21
			Stipa grandis	15	*Salsola collina*	
Ephedra sinica with annual plants	70	7	*Ephedra sinica*	15	*Chenopodium viride*	65
			Potentilla bifurca	5	*Chenopodium acuminatum*	
			Carex duriuscula	2	*Salsola collina*	

Table 10.5 Vegetation treatment of research sites comparing ungrazed and grazed pastures

Site	Vegetation coverage, %		Average height, cm		Species richness		IS_j (%)	Dominant species	
	In	Out	In	Out	In	Out		Ungrazed	Grazed
Tumentsogt	46.1	30.3	18.6	12.3	30	28	75.8	*Stipa grandis –Polygonum divaricatum*	*Stipa grandis*
Dalanjargalan	62	34	30	15	31	21	62.5	*Stipa gobica +Allium polyrrhizum*	*Stipa gobica +Allium polyrrhizum*
Urgun-West	41	22	28.5	16	25	19	57.1	*Artemisia anethifolia +Artemisia xerophytica +Eurotia ceratoides*	*Artemisia anethifolia +Artemisia xerophytica +Eurotia ceratoides*
Urgun-East	20	15	15.9	9.7	20	20	53.8	*Stipa glareosa +Cleistogenes songorica*	*Stipa glareosa +Cleistogenes songorica*
Gurvan Saikhan	64	30.5	15.8	8.6	11	11	57.1	*Agropyron cristatum + Artemisia frigida +Allium polyrrhizum*	*Allium polyrrhizum +Artemisia frigida +Convolvulus ammanii*
Bulgan-North	10.5	6.8	4.5	2	16	10	50,0	*Stipa gobica +Convolvulus ammanii +Artemisia frigida*	*Stipa gobica +Artemisia frigida +Cleistogenes songorica*
Bulgan-South	18	7.2	7.5	5.4	24	13	48.0	*Salsola collina +Stipa gobica +Eurotia ceratoides*	*Stipa gobica +Cleistogenes songorica +Allium polyrrhizum*
Erdene-North	17.3	11.8	14.1	5.8	19	15	57.1	*Cleistogenes songorica +Allium polyrrhizum +Bassia dasyphylla +Salsola collina +Stipa glareosa*	*Allium polyrrhizum +Stipa glareosa*
Erdene-South	45.4	25.1	15.1	10.8	20	19	62.5	*Salsola pestifera +Stipa glareosa +Cleistogenes songorica*	*Stipa glareosa +Cleistogenes songorica*

Table 10.6 Comparison of the coverage of dominant species in fenced sites

Site	Dominant species	Coverage (%)		C3/C4
		Ungrazed	Grazed	
Tumentsogt	*Stipa grandis* P. Smirn.	16	13	C3
	Polygonum divaricatum L.	5	1	C3
	Serratula centauroides L.	2.5	1.3	C3
Dalanjargalan	*Stipa gobica* Roshev.	35	13	C3
	Allium polyrrhizum Turcz.	20	10	C3
	Artemisia pectinata Pall. Polsak.	1	5	C3
Urgun-West	*Artemisia anethifolia* Weber	15	15	C3
	Artemisia xerophytica Krasch.	12	4	C3
	Eurotia ceratoides (L.) C.A. Mey	10	2	C3
Urgun-East	*Stipa glareosa* P. Smirn.	8	5	C3
	Cleistogenens songorica (Roshev.) Ohwi.	4	4	C4
Gurvan Saikhan	*Agropyron cristatum* (L.) Gaertn.	22	4	C3
	Allium polyrrhizum Turcz.	15	15	C3
	Artemisia frigida Willd.	17	8	C3
	Stipa krylovii Roshev.	4	1.5	C3
	Convolvulus ammanii Desr.	1.5	5.5	C3
Bulgan-North	*Stipa gobica* Roshev.	5.6	3.1	C3
	Convolvulus ammanii Desr.	1.7	0.1	C3
	Artemisia frigida Willd.	1.3	1.6	C3
	Cleistogenes songorica (Roshev.) Ohwi.	0.4	1	C4
Bulgan-South	*Stipa gobica* Roshev.	3.5	4	C3
	Eurotia ceratoides (L.) C.A. Mey	3	0.2	C3
	Allium polyrrhizum Turcz.	1.5	1.6	C3
	Cleistogenes songorica (Roshev.) Ohwi.	0.6	2.2	C4
	Salsola collina Pall.	5	0.1	C4
Erdene-North	*Salsola pestifera* A. Nelson	16	3.5	C4
	Stipa glareosa P. Smirn.	13	7.5	C3
	Cleistogenes songorica (Roshev.) Ohwi.	3.5	3.5	C4
	Allium mongolicum Regel.	3	1.3	C3
Erdene-South	*Allium polyrrhizum* Tuzcz.	3.5	5.6	C3
	Cleistogenes songorica (Roshev.) Ohwi.	4	0.3	C4
	Bassia dasyphylla (Fisch.) O. Kuntze	3.5	–	C4
	Stipa glareosa P. Smirn.	1.6	2.5	C3
	Salsola collina Pall.	2	0.1	C4

species were not changed in "Dalanjargalan" and "Urgun-West" sites, their coverage is different. According to our study, the coverage of bunchgrass such as *Stipa grandis*, *Stipa krylovii*, and *Agropyron cristatum* and taproot forbs such as *Polygonum divaricatum* and *Serratula centauroides* in the typical steppe is being dramatically increased through being protected from grazing for the long term.

As for desert steppe, the coverage of bunchgrass such as *Stipa gobica* and *Stipa glareosa*, and of semi-shrubs, namely *Artemisia xerophytica* and *Eurotia ceratoides*, is increased. There is high coverage of some annuals in both the ungrazed and grazed areas in the desert steppe where are found *Salsola collina*, *Salsola pestifera*, and *Bassia dasyphylla* (C4 plants). However, for annuals including *Artemisia pectinata* (C3) and *A. anethifolia* (C3), no results could be determined.

Grazing does not strongly influence some plants such as *Allium polyrrhizum*, *Cleistogenes songorica*, and *Convolvulus ammanii.*

Sand coverage of "Bulgan-South" sites was increased to 72% from 28% through giving up grazing, and senescence of year-round stands accumulated as well. A 5-cm sand layer covered the bare ground, and a 10-cm sand layer appeared around the bunchgrass and shrubs. Grass and forbs such as *Stipa gobica*, *Cleistogenes songorica*, and *Allium polyrrhizum* do not like to grow in the sand, but shrubs increased in the sand area (Table 10.6).

10.4 Discussion

If annual mean temperature is increased by 1°C, natural zones can be moved as much as 200–300 km backward and forward, and zonal elevation changes by 100–200 m upward and downward as that principle is expressed (IPCC 1996). This progression can be influenced by increased overgrazing with dry climate changes. Our study has determined that a typical steppe changed to desert steppe and dry steppe to desert, as well as plants of the desert steppe and desert, will move to the north, notably *Reaumuria soongorica*, *Caragana korshinskii*, *C. pygmaea*, *C. leucophloea*, *Convolvulus ammanii*, *Anabasis brevifolia*, and *Salsola passerina*.

Those two factors strongly influence the vegetation community, particularly reduction of species diversity and change of the dominant species (Ichiroku et al. 2008; Kawada et al. 2008). At the beginning stage of degradation, forbs and mesophytes disappear, and in the next stage, only grass such as a drought-tolerant and grazing-resistant species can readily spread, for example, *Cleistogenes squarrosa*, *Allium polyrrhizum*, and *Ephedra sinica*. *Cleistogenes* occurs in 21 and *Allium polyrrhizum* in 16 of the 32 investigation contours on the vegetation map of Mongolia.

Scientists hypothesized that *Cleistogenes squarrosa* would increase through warming (Sanjid 2002). Studies have shown that *Cleistogenes squarrosa* is increased through grazing at light and moderate levels (Chognii 2001; Gunin et al. 2002), as well as after a steppe fire (Tuvshintogtokh and Urgamal 2007). Those results are ratified by our study. These results are dependent on the biomorphological characteristics of the *Cleistogenes squarrosa*, a C4 species, which has many buds and can regrow one or two times per year.

Allium polyrrhizum is widely distributed in the dry and desert steppe and covers 15 geobotanical regions of Mongolia. *Allium polyrrhizum* is scattered in Central Asia but is a rare species in the north of Mongolia because this is registered in the

"Red Book" of Russia and Kazakstan. Expansion of *Allium polyrrhizum* has occurred in past years (Tuvshintogtokh and Ariunbold 2007).

Allium polyrrhizum is fibrous rooted, a perennial of height 10–25 cm. This species has protein, but the part above ground would be dry in the autumn because it is not fodder for winter. It can be dormant for a long time, and after rain, it can quickly grow. It is tolerant of trampling and can grow from seeds and vegetative shoots.

Finally, *Ephedra* is extending its growing area. *Ephedra sinica* covers the center part of Mongolia, as noted by several studies (in Center and Dundgobi aimags) (Gunin 2001; Gunin et al. 2002). *Ephedra* is scattered in the pastures with *Stipa grandis* as noted in a study conducted in the Dornod aimag. The *Ephedra* communities can be scattered as spot- and point forming, and its growing area is in the Center region rather than Dornod. The lesser growing area of *Ephedra* is dependent on light and carrying capacity and climate factors such as lower temperature and high percipitation.

Total coverage of the plant community does not decrease, although species diversity can be changed, through overgrazing in Eastern Mongolia, but a palatable species can occur in place of annuals that is more related to current climate conditions. The summer pasture was good between 2008 and 2009, the year the study was conducted. Consquently, in rainy years pioneer speceis can cover all bare ground while palatable species are reduced. In drought years, soil erosion and degradation will increase because of reduced yield, coverage of the community, and fewer annuals. It seems that *Cleistogenes squarrosa*, *Allium ployrrhizum*, *Epdedra sinica*, and annuals can dramatically adapt to the dry and overgrazed steppe areas in Mongolia.

If pasture is not be used for a long time, it can support increasing species diversity and lead to change in dominant species for secondary succession. Cession of grazing in arid and semiarid steppes in Mongolia leads to changes in floristic composition and dominants and increases species diversity, vegetation cover, and community height. Canopy cover increase through the abandonment of grazing is reported by Browns and Bagley (1986), Smith and Rushton (1994), Zhang (1998), and Chognii (2001).

Differences in the vegetation in grazed and ungrazed areas is very clear, and protection from grazing directly influences changes in species composition, as reported by Zhang (1998) and Chognii (2001). Canopy cover and height of the plant community will increase through long-term cessation of grazing, leading to increased community biomass.

Consequently, species composition and dominant species were changed, which is expressed by progressive and regressive succession. Both types of succession consist of an old climax community (after passing through a variety of stages) and another climax community (after grazing is stopped).

After long-term protection from grazing in the overgrazed meadow and typical steppe (13 years), pasture recovered in three successional stages: (1) domination by perennial rhizome grasses (2–3 years); (2) domination by low bunchgrass and forbs (4–5 years); and (3) domination by high bunchgrass and forbs (6–10 years). Overgrazed pasture recovered through resting for more than 10 years (Chognii 2001).

After ending grazing in the desert steppe, changes occurred in community standing biomass and the environment of the "Bulgan-South" site (e.g., sand cover). If sand cover continues to increase, grass-dominated vegetation is replaced by a shrub-dominated community. The same result was reported by Zhang (1998), in that *Artemisia halodendron* is increased through protection of grazing for 5 years.

Annual C4 plants such as *Salsola collina*, *Salsola pestifera*, and *Bassia dasyphylla* were increased through the abandonment of grazing, which may be related to the C4 species, for example, *Chenopodaceae* and *Amaranthaceae*. However, annual grass and pioneer species can grow in disturbed and cultivated soil at early succession stages. C4 species have greater tolerance to environmental stress (Wang and Yin 1997), especially to dry and poor soil (Wang 2002).

Grazing was not a strong influence on some plants such as *Allium polyrrhizum*, *Cleistogenes songorica* (C4), and *Ephedra sinica*. It may be hypothesized that these species replaced the dominant species *Stipa gobica* and *S. glareosa* through heavy and moderate grazing in the desert steppe.

10.5 Conclusions

1. Within the past three or four decades, the steppe vegetation of Mongolia has become drier. In particular, a typical steppe is changed to dry steppe, and both steppe can change to desert steppe. However, the vegetation of desert steppe and desert is comparatively stable.
2. Degradation of the steppe and climate changes strongly influence the vegetation community by such factors as reduction of species diversity and change of the dominant species. Some species such as *Cleistogenes squarrosa*, *Allium polyrrhizum*, and *Ephedra sinica* have readily spread, and their area is expanding.
3. There is progressive succession as a result of the increased species diversity and coverage; as well, dominant species have recovered through the abandonment of grazing. Therefore, we consider that overgrazing can have a greater influence than climate change on degradation. We are considering, as a common and cheap approach, the rest-and-rotation system for pastures of Mongolia. The traditional style of nomadism is a better way to restore a degraded pasture.

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