Chapter 13
Vegetation Interactions for the Better Understanding of a Mongolian Ecosystem Network

Noboru Fujita, Narantsetsegiin Amartuvshin, and Erdenegerel Ariunbold

Keywords Forest and steppe distribution • Grazing tolerance • Precipitation and pasture production • Shrub and herb production • Soil alkalization

13.1 Introduction

An ecosystem network is composed of inorganic, organic, and human nodes, which interact directly and indirectly. Ecologically, important nodes in Mongolia include the atmosphere, vegetation, stock farming (livestock and herders), and a social system (Fig. 13.1). To better understand the Mongolian ecosystem network, we considered important interactions between adjacent nodes. In this network, vegetation interactions have important implications: the causes of forest mosaics, the effects of precipitation and temperature on primary production in pastures, the relationship between grazing-tolerant plant domination in pastures and soil alkalization, the recovery of edible pasture plant species diversity after disturbance removal, herbs and shrub leaves as a livestock food source, taproot depth of shrubs, the cause of shrub species distribution and that of shrub absence in pastureland, the relationship between shrub degradation and wind erosion, and the different grazing effects of goats and sheep on shrubs and herbs. We examined these subjects because they are important in elucidating the Mongolian ecosystem network. The nomenclature follows Grubov (2001), except for *Leymus chinensis*, which is based on Gubanov (1996).

N. Fujita (✉)
Research Institute for Humanity and Nature, Kyoto, Japan
e-mail: fujita@chikyu.ac.jp

N. Amartuvshin
Institute of Botany, Mongolian Academy of Sciences, Ulaanbaatar, Mongolia

E. Ariunbold
Institute of Geoecology, Mongolian Academy of Sciences, Ulaanbaatar, Mongolia

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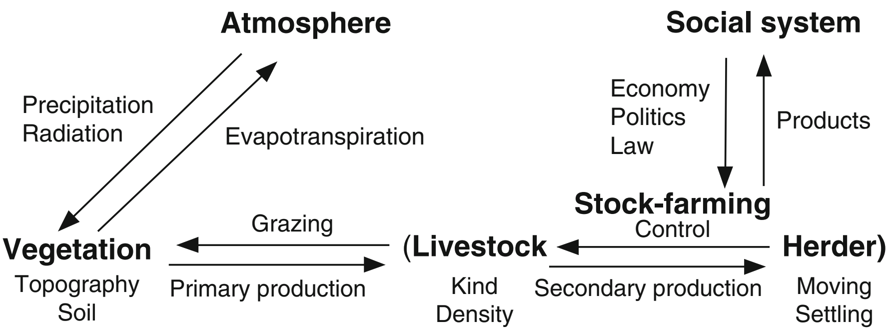

Fig. 13.1 The main nodes, actions, and flows of inorganic elements and organisms in the Mongolian ecosystem network

We used Tukey's honestly significant difference test to compare means. The statistical analysis was performed using JMP for Macintosh, ver. 5.1.2 (SAS Institute, Cary, NC, USA).

13.2 Forest Presence Versus Slope Orientation and Location on the Slope

Forest is distributed discontinuously in the forest-steppe zone. We investigated forest distribution on the slopes of ridges on Bogd Khan Mountain located south of Ulan Bator from field surveys on the site with auxiliary use of satellite photographs by Landsat. For each slope, we determined the slope direction and checked for the presence of forest, distinguishing between the upper and lower slopes.

Figure 13.2 shows forest frequency on upper and lower slopes with different slope directions. On the upper slope, forest was distributed on all north-facing, northeast-facing, and west-facing slopes, whereas it was limited on other slope directions. On south-facing slopes, it exhibited the least frequency. On lower slopes, forest frequency decreased in all slope directions.

What is the reason why the frequency of forest existence differed among different slope directions? Forest distribution in the forest-steppe zone may depend on soil moisture and human activity. Atmospheric processes that affect soil moisture include precipitation, which supplies water to the soil, and solar radiation, which supplies light energy for photosynthesis and removes water from the soil directly via heat energy and indirectly via evapotranspiration. Slope direction affects the quantity of precipitation and radiation that reaches the ground. In the Northern Hemisphere, radiation is greater on south-facing slopes than on north-facing slopes, and this difference increases with latitude. Precipitation is greater on windward slopes than leeward slopes between high mountain ranges. For example, the forests around Lake Baikal are richer on the north-facing slope than the south-facing slope

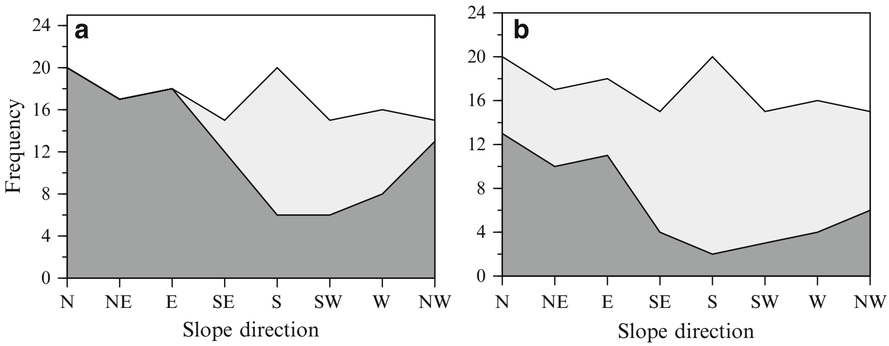

Fig. 13.2 Frequency of the presence and absence of forest on the upper and lower slopes facing different directions on Bogd Khan Mountain, south of Ulan Bator: upper (**a**) and lower (**b**) slopes. *Shaded area*, forested area; *light area*, no forest

on the east and west shores and are distributed more on the leeward east shore slope than the windward west shore slope, possibly because of the prevailing northerly winds (Fujita 1997). In Mongolia, the prevailing wind blows from the northwest, and between the north-facing and south-facing slopes of large mountains such as Khangai and Altai, this difference is observed. However, among closely spaced slopes of the same mountain facing different directions, differences in precipitation must be small. Then, differences in the presence of forests between the north-facing and south-facing slopes in the Bogdkhan Mountains is caused by other factors. Between adjacent north-facing and south-facing slopes with the same precipitation in Gachuurt, soil moisture after precipitation clearly remains higher on the north-facing slope (see Ishii and Fujita, this volume, Chap. 6). The deciduous conifer *Larix sibirica* Ledeb. dominates the east side of the Bogd Khan Mountain, whereas the evergreen conifers *Picea obovata* Ledeb. and *Pinus sibirica* Du Tour are abundant on the west side. These evergreen conifers grow in habitats with higher soil moisture than those occupied by *L. sibirica* (Fujita 1997). There is a possibility that precipitation is greater on the west side on the large scale of the Bogd Khan Mountains, as the prevailing wind blows from the northwest.

Forest occurred on the upper east-facing slopes, whereas it was restricted on the upper west-facing slopes. Differences in solar radiation and precipitation do not explain this difference. Insolation does not differ on east-facing slopes in the morning and west-facing slopes in the afternoon. It can be explained by differences in evapotranspiration rates on the east-facing and west-facing slopes. Although solar radiation does not differ, air temperature and soil surface temperature are likely higher on the west-facing slope before dusk than on the east-facing slopes after dawn. Therefore, evapotranspiration may be greater on the west-facing slopes.

Several possible explanations exist as to why forests occur mainly on the north-facing slopes in the forest-steppe zone. The distribution of forest and steppe, differing between slope directions, was thought to be natural (Gunin et al. 1999; Dulamsuren et al. 2005). Conversely, Hilbig (2000) concluded that it was the result of centuries of human activity, including logging and pasture use. When comparing the upper and lower slopes, forest is dominantly distributed on the upper slope in all directions (Fig. 13.2). Soil moisture is usually higher on the lower slopes (Yanagisawa and Fujita 1999) because the water in soil percolates downward via gravity. Therefore, this finding implies that the forests on the lower slopes were degraded by historical human and livestock activities (Sankey et al. 2006). At present, forest rarely occurs on south-facing slopes in the forest-steppe zone but is distributed on the south-facing slope of Bogd Khan Mountain where forests have been well protected from the past. The forest could previously have been distributed throughout the forest-steppe zone, including the flat valley and south-facing slope. Permafrost occurs beneath the north-facing forests, but not beneath the south-facing pastures (Ishikawa et al. 2005). Permafrost can contribute to soil moisture, but the degradation of forests could have damaged the permafrost, leading to its disappearance on south-facing pastures.

13.3 Pasture Production Versus Precipitation and Air Temperature

Primary production increases with the mean annual precipitation in Inner Mongolia, China, and Mongolia (Li et al. 2005; Bai et al. 2008). To investigate the effects of precipitation and air temperature on pasture plant production in different vegetational zones in Mongolia, we compared pasture production with precipitation and air temperature data from nearby meteorological stations at Gachuurt, east of Ulan Bator, Mandalgobi, and Dalanzadgad located in forest-steppe, steppe, and desert-steppe zones, respectively. At each site of Gachuurt (48°01′27″ N, 107°10′49″ E), Mandalgobi (45°43′44″ N, 106°16′16″ E), and Dalanzadgad (43°34′55″ N, 104°25′40″ E), we mowed pasture plants to 3 cm twice monthly in five 1-m^2 quadrats in an exclosure excluding livestock from May to September during 2006–2009. Annual precipitation of the three sites from 2006 to 2009 and their normal years are listed in Table 13.1. During the 4 years, the annual precipitation was never more than that of the normal year in Mandalgobi. We selected areas covered with herb vegetation without main shrub patches for the quadrats. After mowing, we dried the samples at 80°C and measured the dry weight as a measure of production during the half-month. We calculated the total precipitation and mean air temperature during the 15 days before each mowing. To determine the spatial variation of precipitation in the short term, we measured precipitation continuously at 16 points arranged in a netlike fashion at 5-km distances in Bayan-Unjuul from May to September in 2009. The northeast corner of the mesh was 46°58′19″ N, 105°52′44″ E. Despite human and bird disturbances, we were able to obtain perfect data from 13 points.

The relationships between total precipitation and mean air temperature and pasture plant production during a half-month for each measurement at all sites from 2006 to 2009 are shown in Fig. 13.3. The relationships between annual precipitation and annual production and pasture plant biomass in August at all sites are shown in

Table 13.1 Annual precipitation (mm) from 2006 to 2009. Measured durations of normal year are Ulan Bator (1969–2007), Mandalgobi (1944–2007), and Dalanzadgad (1937–2007)

	Gachuurt	Mandalgobi	Dalanzadgad
Normal	293.2	170.6	130.8
2006	264.1	98.6	89.0
2007	266.8	70.5	142.6
2008	352.0	107.0	135.0
2009	204.0	84.6	47.8

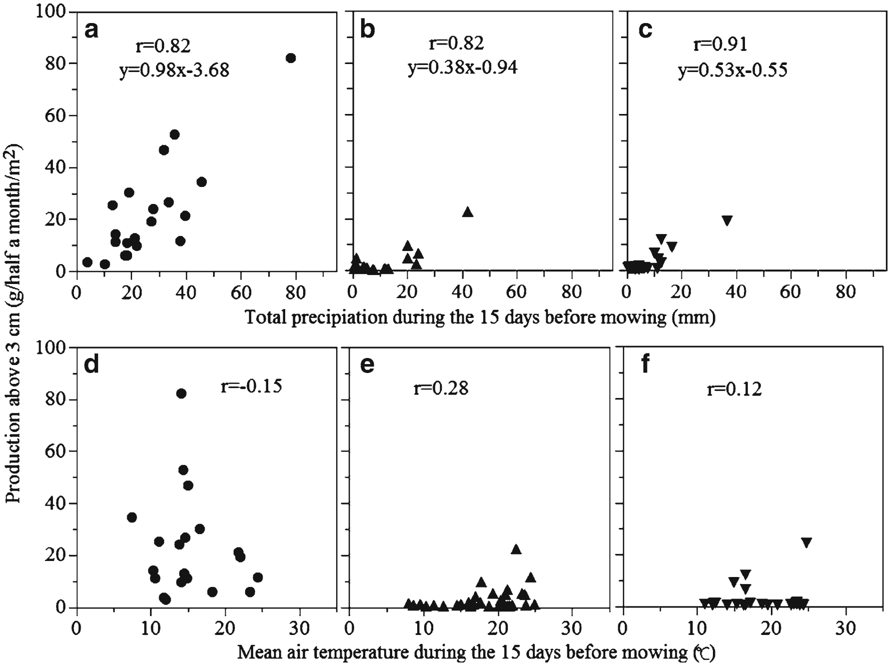

Fig. 13.3 Relationship between total precipitation and average air temperature and pasture plant growth over a half-month during the growing season from 2006 to 2009 in Gachuurt (**a**, **d**), Mandalgobi (**b**, **e**), and Dalanzadgad (**c**, **f**). *r* correlation coefficient, *y* regression line

Fig. 13.4. A significant correlation was observed between precipitation and pasture production over a half-month at all sites without reaching a ceiling of production, but air temperature was not correlated with pasture production. In the dry steppe and desert-steppe climates and the moist forest-steppe climate also, precipitation was the main factor determining pasture production during a half-month. Good pasture production, more than 20 g/half-month/m^2 resulting from high precipitation was very

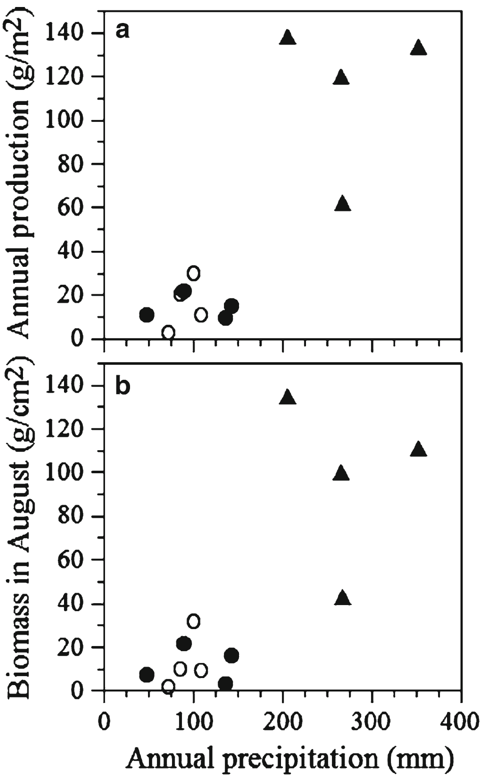

Fig. 13.4 Relationships among annual precipitation, annual production, and pasture plant biomass growth in August from 2006 to 2009. *Black triangles*, Gachuurt; *white-filled circles*, Mandalgobi; *black circles*, Dalanzadgad

rare, occurring only once during the 4 years from 2006 to 2009 in both Mandalgobi and Dalanzadgad. Total precipitation less than 10 mm for the half-month before mowing had little effect on pasture production at Mandalgobi and Dalanzadgad because it could not maintain soil moisture resulting from rapid water loss to the dry atmosphere. It was reported that the threshold precipitation becomes 25 mm in the Mojave Desert (Beatley 1974). At Dalanzadgad, a threshold of 10 mm is not clear compared with Mandalgobi, because small shrubs, such as *Youngia tenuicaulis* (Babc. et Stebbins) Czer. and *Ajania achilleoides* (Turcz.) Tzvel., are mixed more with herbs at Dalanzadgad than at Mandalgobi. These shrubs can produce some leaves in the growing season under drought conditions. At Gachuurt, even low precipitation had an effect, possibly because evapotranspiration was low as a result of low air temperature and wind velocity. A short, heavy rain may be more beneficial for pasture production than prolonged, low-intensity rain. During the growing season when the air temperature exceeded the threshold value of plant growth, air temperature was independent of pasture production with little precipitation.

Annual precipitation did not correlate with the annual or August pasture plant biomass production at any site from 2006 to 2009, but a correlation was observed when compared through all sites (Fig. 13.4). In a regional comparison along a large

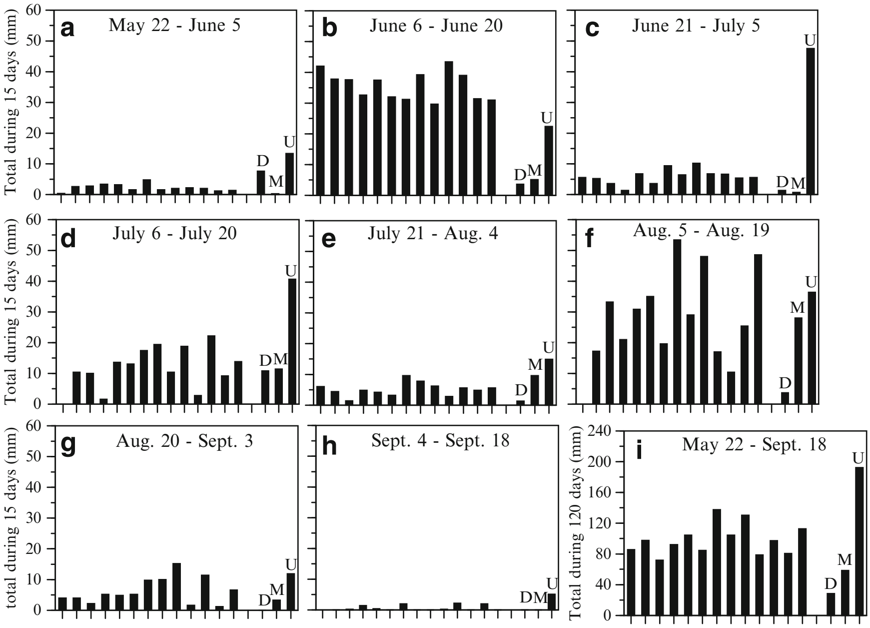

Fig. 13.5 Temporal changes of total precipitation during 15 days in 2009 at 13 points in Bayan-Unjuul and at Ulan Bator (*U*), Mandalgobi (*M*), and Dalanzadgad (*D*). Duration is given in each figure. Total precipitation throughout these durations is shown in (**f**)

climatic gradient, annual precipitation correlated with annual production. However, total annual precipitation cannot explain the yearly variation of annual production at each site because a heavy rainfall at a limited, critical time, for example, 10 mm during a half-month, is necessary for plant production, especially for the growth of herbs, which absorb water from the surface soil (see Satoh et al., this volume, Chap. 5). The effective precipitation timing for plant growth depends on the quantity of precipitation, weather after precipitation, specific vegetation, and soil texture. We used total precipitation during the 15 days before mowing, but this term was expedient, not absolute. The effect of precipitation on soil moisture after rainfall continues longer with increased mass of precipitation.

Temporal and spatial variation of precipitation at short range in Bayan-Unjuul in summer 2009 is shown in Fig. 13.5. Temporal variation in this area was very large, and precipitation was below the threshold (10 mm during 15 days) for more than half of this period. Spatial variation changed according to the time. The spatial variation among points was large in middle July (Fig. 13.5d), early August (Fig. 13.5f), and late August (Fig. 13.5g), and especially high and low differences between the threshold during their terms were serious among points for pasture production. All points showed high precipitation in middle June (Fig. 13.5b) and did not reach the threshold in late May (Fig. 13.5a), late July (Fig. 13.5e), and early

September (Fig. 13.5h). Temporal variations at Ulan Bator, Mandalgobi, and Dalanzadgad and spatial variations in a wide area from Ulan Bator to Dalanzadgad were large in 2009. As a result of seasonal and annual precipitation variation, pasture production over a half-month fluctuated greatly in all three sites (Fig. 13.3). This fluctuation shows the importance of abiotic factors such as precipitation for pasture production, even at Gachuurt, located in the forest-steppe zone. The instability of pasture carrying capacity makes nomadic livestock farming difficult unless herds can be moved from one pasture to another. Measures to overcome low-production seasons include moving to relatively higher production pastures and keeping livestock density below the carrying capacity of the pasture.

13.4 Edible Versus Grazing-Tolerant Plants in Pastures

Livestock prefer to graze certain edible plants and avoid other plants; therefore, the grazing-tolerant plants often remain without being eaten after livestock grazing. To understand the effects of the remaining grazing-tolerant plants on the recovery of edible plants after grazing is stopped, we conducted a selective mowing experiment. The study site was the same as that described in Fujita et al. (2009) in Gachuurt, east of Ulan Bator. In autumn 2003, five 4-m^2 exclosures were assembled at two sites, one on the upper slope, at an altitude of 1,615 m, and one in the flat valley bottom, at an altitude of 1,548 m. We made the exclosures from pillars and rectangular lumber to avoid creating shade. We used four mowing treatments to compare the annual production of edible plants among treatments: mowing edible and grazing-tolerant plants to 3 cm, mowing only edible plants to 3 cm, mowing edible and grazing-tolerant plants to 5 cm, and mowing only edible plants to 5 cm. We arbitrarily placed a 1-m^2 quadrat for each treatment in each exclosure. In total, we used five 1-m^2 quadrats for the duplicate of each mowing treatment in the five exclosures at each site. We mowed monthly from early June to early September 2004. After each mowing, we transported the mowed material to the laboratory where we dried the samples at 80°C for 2 days and measured the dry weight. The annual production for each treatment was the sum of the biomass after mowing four times.

The annual production of edible plants for each treatment at the two sites is shown in Fig. 13.6. When the treatments with only edible plants cut were compared to the treatments with all plants mown, the annual production of edible plants was higher in the 5-cm mowing of both types of plants in the flat valley bottom and in the 3-cm mowing of both plants on the upper slope. No significant difference was observed between the two other treatments. In the flat valley bottom, the unmown grazing-tolerant plants likely put the edible plants at a disadvantage, as the edible plants remained low after mowing because of light competition with grazing-tolerant plants. Conversely, on the upper slope, the annual production of edible plants increased in the quadrat with only edible plants mown to 3 cm where grazing-tolerant plants remained without mowing. Little competition for light likely occurred because of the lower height and mass of pasture plants in the quadrats; however, this does not

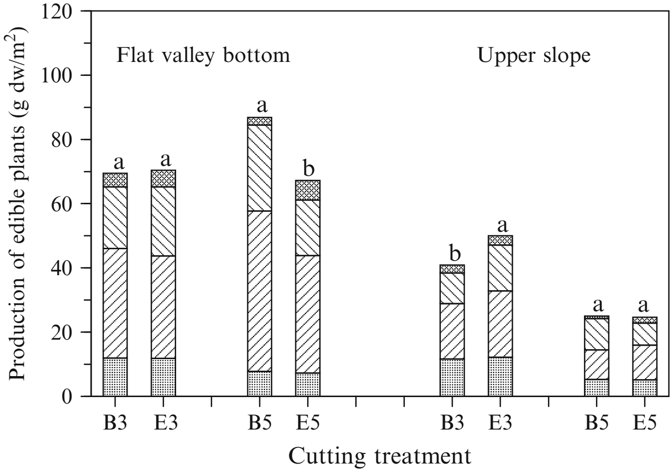

Fig. 13.6 Annual production of edible pasture plants after mowing to 3 or 5 cm with or without mowing the grazing-tolerant plants at the bottom of the flat valley and on the upper slope. *B3* mowing to 3 cm, including the grazing-tolerant plants, *E3* mowing only edible plants to 3 cm, *B5* mowing to 5 cm, including the grazing-tolerant plants, *E5* mowing only edible plants to 5 cm. Each *bar with a different pattern* in the annual production shows the monthly mowing in early June, July, August, and September from the base. *a*, *b* statistical significance at $P<0.01$

fully explain the reversed trend in annual production. One explanation is the difference in soil moisture. When measured in mid-July 2004, the soil moisture was 16.1% and 13.6% for the quadrats mown to 3 cm on the upper slope with grazing-tolerant plants remaining and quadrats with all plants mown, respectively. Soil moisture was higher in the quadrat in which the grazing-tolerant plants were unmown. Although rich vegetation transports more water from the ground to the atmosphere via evapotranspiration than does poor vegetation (Baldocchi et al. 2004), the surface soil temperature could have been lower in the quadrat with grazing-tolerant plants as a result of greater ground coverage after mowing. Moreover, edible plants mixed with unmown grazing-tolerant plants were not disadvantaged in terms of production in the drier habitat.

13.5 Grazing-Tolerant Plants and Soil pH

Several types of grazing-tolerant plants dominate Mongolian pastureland, and these plants have physical, chemical, and habitual defenses against livestock grazing. Grazing-tolerant plants with physical and chemical defenses can grow tall because livestock actively avoid grazing them. Grazing-tolerant plants with habitual defenses remain low to avoid livestock grazing. Overgrazing allows these plants to dominate pastures and increases soil pH (Hiernaux et al. 1999). We placed 1-m^2 quadrats at

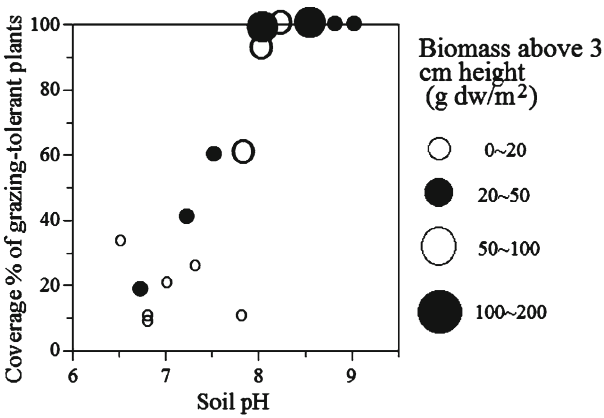

Fig. 13.7 Relationship between soil pH and weight percentage of grazing-tolerant plants versus all pasture plants in 1 m^2 using biomass greater than 3 cm

different pastureland sites in the forest-steppe zone around Ulan Bator in July 2005. We measured the surface soil pH and plant species coverage in each quadrat to determine the coverage domination between grazing-tolerant plants and all plants and mowed all pasture plants to 3 cm. After mowing, we dried the plants at 80°C for 2 days and measured their dry weight. To determine surface soil pH, we mixed surface soil with deionized water in a small bottle and measured the pH of the clear top layer of water. We used the average pH of three points in each quadrat. We calculated the total coverage separating edible and grazing-tolerant plants and compared them.

Figure 13.7 shows the relationship between soil pH and percent coverage of grazing-tolerant plants versus total coverage with the biomass of plants above 3 cm. A strong positive correlation was observed between the percent coverage of grazing-tolerant plants and soil pH, indicating that domination by grazing-tolerant plants in pasture coincides with soil alkalization. In northeast Thailand and southern Queensland, Australia, with high precipitation, land degradation caused soil acidification (Noble et al. 2000), but, in Mongolia, with little precipitation, pasture degradation is accompanied by soil alkalization and domination by grazing-tolerant plants. Plant biomass in good pasture dominated by edible plants for livestock becomes low as a result of grazing by livestock, whereas in degraded pasture it becomes relatively high because of the domination of grazing-tolerant plants that are little grazed by livestock. This difference makes it difficult to judge the degree of pasture degradation from the biomass of pasture plants, especially in the forest-steppe zone.

13.6 Pasture Plant Species Diversity Recovery After Disturbance Versus Soil pH

Plant species diversity declines greatly with heavy overgrazing in pastures and plowing in agricultural land. When the disturbance is removed, such as when herders move their livestock or abandon cultivation, plant species diversity should begin to recover. To determine the effects of disturbance history on the diversity recovery of plant species, we compared recovery after short- and long-term disturbances.

For the short-term disturbance, in 2001, we selected pasture near a winter shed moved annually in west Ih-Tamir, North Khangai Province. For the long-term disturbance, in 2005, we used agricultural land abandoned after more than 20 years of cultivation in the west of Ulan Bator. In the pasture, the herder yearly moved the winter shed to one side, so we could track its location up to 4 years previously. For the agricultural land, we determined the year of abandonment of each area by questioning people. We found sites abandoned for 1, 4, and 8 years in the west of Ulan Bator and for 20 years in the south of Ulan Bator. These sites had been farmed for more than 20 years before being abandoned. We set five 1-m^2 quadrats at and around each site and measured the number of pasture plants species and the surface soil pH in each quadrat.

Figure 13.8 shows the average number of pasture plant species from the five quadrats at each site for the length of abandonment and the surface soil pH, including the number of pasture plant species and surface soil pH in the surrounding pasture. Pasture plant species diversity recovered quickly where soil was not alkalized over 4 years after moving the site of the winter shed used for one winter, while it recovered slowly as the high soil alkalinity decreased after the agricultural land was abandoned. After deforestation, 10–15 years were necessary for soil pH to recover from alkalinization (Sangha et al. 2005). Soil alkalization progress depends on disturbance intensity and duration. Pasture plant species diversity recovers quickly after short-time disturbances because little soil alkalization occurs and also possibly

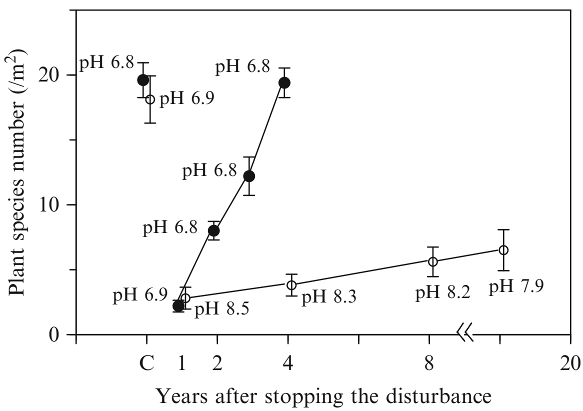

Fig. 13.8 Yearly recovery of plant species diversity and soil pH after removing the disturbance. *Black circles*, previous site of winter shed; *white-filled circles*, abandoned plowed land; *C* (*x*-axis), pastures around winter shed and abandoned plowed land

because root structures survive. Conversely, the slow recovery of pasture plants after a long-time disturbance occurs because high soil alkalinity prevents the invasion of pasture plants, especially edible plants. Soil alkalization causes a regime shift or positive feedback. In abandoned plowed land with very alkaline surface soil, the specialized grazing-tolerant species *Artemisia macrocephala* Jacq. dominates exclusively. This species is biennial, and its flowers cause pollinosis.

Once pasture soil becomes strongly alkaline, it cannot be used for breeding livestock for years because soil pH and edible plant diversity recover slowly. Short disturbances are inevitable with nomadism because livestock, especially sheep and goats, must be rounded up nightly near the residence. However, the seasonal and annual migration of traditional nomads avoids the soil alkalization associated with long-term disturbances.

13.7 Herb Versus Shrub Leaf Production

In the steppe and desert-steppe zones, both shrubs and herbs often grow in pastures. Dominant shrubs form patches of different sizes and densities. We measured the production and grazed mass of herbs and shrub leaves near Mandalgobi in 2009 to determine shrub edibility and their contribution to the livestock diet. We set ten 1-m^2 quadrats in the pasture exclosure (45°49′12″ N, 106°17′43″ E) to measure the seasonal production and grazed herb quantity. We mowed pasture plants to 3 cm at half-month intervals in five quadrats to determine herb production. We measured the height of herbs at ten points outside the exclosure monthly and mowed pasture plants at the mean height outside the exclosure in the other five quadrats in the exclosure to determine the grazed herb quantity outside the exclosure. Inside and outside the exclosure, *Caragana microphylla* (Pall.) Lam. was the dominant shrub, comprising about 20% of the canopy coverage. We used it for shrub measurement, although *Caragana leucophloea* Pojark. was mixed sparsely with it. We collected five duplicates of new leaves from a 20-cm^2 area of leaf canopy of each shrub patch in early June, July, and August in the exclosure. Then, we measured the dry weight per area of leaf canopy to determine shrub leaf production. We measured the leaf canopy size of five shrub patches inside and outside the exclosure by approximating ellipses in early May, June, July, and August. We calculated the monthly grazed mass of shrub leaves from the sum of the decreased leaf canopy outside the exclosure and the increased leaf canopy inside the exclosure. Some leaves at the patch canopy center had been grazed by livestock; however, this amount was not included in the measured mass because of the added difficulty in measurement. We measured the leaf canopy size of all shrub patches in the 1-ha exclosure and calculated the area percentage of shrub leaf canopy to land in early July and found that the canopy covered about 20% of the land. Based on the area percentage of the leaf canopy, we calculated the production and grazed mass of shrub leaves for 1 month.

Daily precipitation, herb production over a half-month, grazed herb mass, shrub leaf production, and monthly grazed shrub leaf mass are shown in Fig. 13.9. Daily

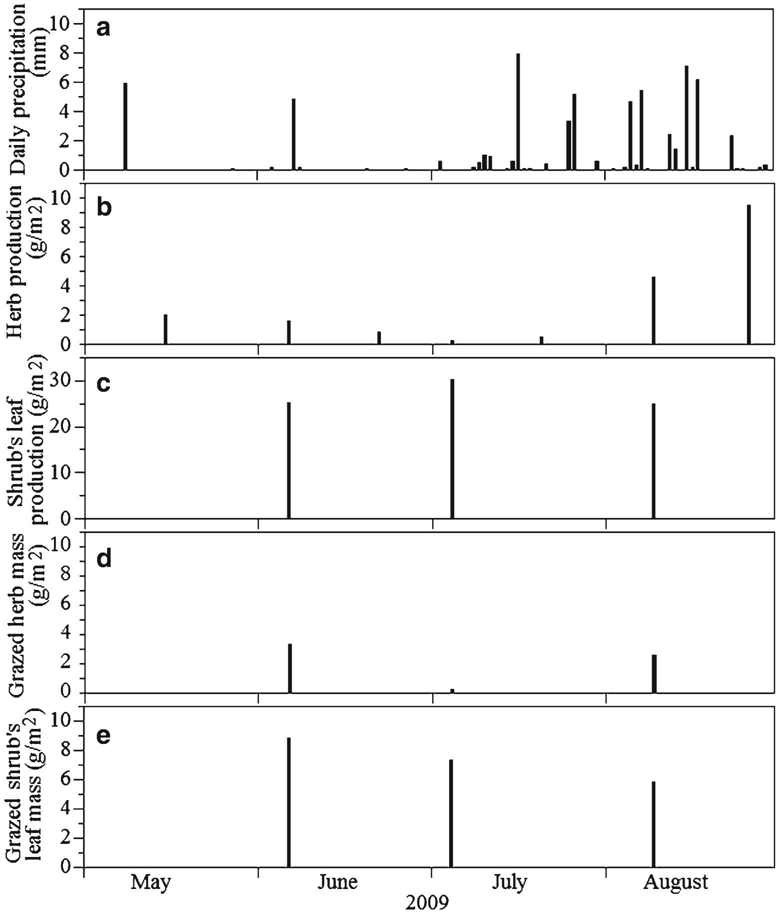

Fig. 13.9 Precipitation, and production and grazed mass of herbs and shrubs, during the growing season in Mandalgobi from May to August 2009: daily precipitation (**a**); herb production higher than 3 cm over a half-month (**b**); *Caragana microphylla* leaf production during 1 month (**c**); herb mass grazed by livestock during 1 month (**d**); *Caragana microphylla* leaf mass grazed by livestock over 1 month (**e**)

precipitation did not exceed 10 mm throughout the season in 2009. Precipitation was rare for the first half of the season; the total amount during a 15-day period was less than 10 mm. Herb production was low until July. After mid-July, the total precipitation for a 15-day period increased to more than 15 mm, despite daily precipitation of less than 10 mm, and herb production was high in August. Conversely, *C. microphylla* leaf production was high throughout the season. The grazed herb mass was also lower than grazed *C. microphylla* leaves.

In pasture with high shrub density, shrubs produced leaves better than herbs, and the shrub leaves were a good food source for livestock. *Caragana* belongs to

Fabaceae, which fix nitrogen gas; therefore, *Caragana* leaves and flowers are nutritious with good protein and fiber content (Jigjidsuren and Johnson 2003). If there is little precipitation in spring, herbs do not create leaves in spring, even if the temperature becomes warm enough for leafing. On the other hand, *Caragana* can produce leaves in spring regardless of precipitation, as reported by Yamada et al. (2009). Furthermore, when drought continues for a long time during the growing season, the aboveground parts that herbs have produced after heavy rains wither, but *Caragana* still keeps its leaves. Therefore, *Caragana* leaves are a valuable food for livestock in spring and the dry season. *Caragana* sprouts leaves in the dry season because it can absorb water deep in the soil. In *C. microphylla* habitat in Dalanzadgad, the surface soil is sandy and the deep soil layer holds water that percolates down during heavy rains (see Satoh et al., this volume, Chap. 5). Water use by shrubs and herbs at different soil depths has been reported on other steppes (Sala et al. 1989).

13.8 Distribution and Root Depth of Shrub Versus Soil-Particle Distribution

In central Mongolia, three shrub types dominate steppe and desert-steppe pastures (see Fujita and Amartuvshin, this volume, Chap. 3). In the steppe between Ulan Bator and Mandalgobi, *C. microphylla* is dominant. In the desert steppe between Mandalgobi and Dalanzadgad, two shrub types occur: *Caragana stenophylla* Pojark., and a mixture of *Kalidium foliatum* (Pall.) Moq. and *Reaumuria soongorica* (Pall.) Maxim. Two soil types occur in these zones: sandy and silty or clayey. *C. stenophylla* appeared to occur mainly in the sandy soil and *R. soongorica* also in the clayey soil (Grubov 2001). We collected 100 ml surface soil, removing fine roots, at a depth of 10 cm at five sites in the habitat of each shrub type (*C. microphylla*: 47°03′43″ N, 105°44′44″ E; 45°49′12″ N, 106°17′43″ E; 46°21′10″ N, 106°27′26″ E; 47°05′30″ N, 106°35′48″ E; 47°12″30″ N, 106°38′14″ E; *C. stenophylla*: 45°13′33″ N, 105°49′18″ E; 44°52′28″ N, 105°37′52″; 44°52′42″ N, 105°27′57″ E; 44°12′08″ N, 105°04′26″ E; 43°34′55″ N, 104°25′40″ E; mixture of *K. foliatum* and *R. soongorica*: 45°12′06″ N, 105°47′01″ E; 44°18′41″ N, 105°13′02″ E; 44°11′58″ N, 105°04′19″ E; 43°38′51″ N, 104°32′32″ E; 43°46′29″ N, 104°30′04″) in middle October, 2010. At the same time, we collected a taproot of each shrub species at 10-cm-depth intervals. At Mandalgobi (45°49′12″ N, 106°17′43″ E), we collected *C. leucophloea* Pojark. At Huld (44°52′42″ N, 105°27′57″ E), we gathered *C. stenophylla*. At the north of Dalanzadgad (43°38′51″ N, 104°32′32″ E), we collected *K. foliatum*, *R. soongorica*, *Kalidium gracile* Fenzl, and *Anabasis brevifolia* C.A. Mey. After drying the soil and the taproot at 90°C and 70°C, respectively, for 3 days, we sorted the soil and measured the dry weight of the taproot. We used 2-, 1-, 0.5-, 0.25-, 0.106-, and 0.053-mm-diameter sieves for soil sorting with a shaking apparatus for 15 min. We weighed the soil in successive sieves and determined the coarse sand, fine sand, and silt content of the soil from the particle diameters of 2–0.25, 0.25–0.053, and <0.053 mm, respectively.

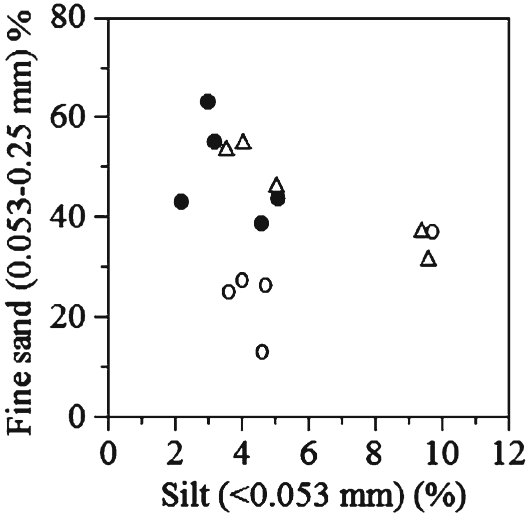

Fig. 13.10 Weight percentage of silt with diameter <0.053 mm and fine sand with diameter 0.053–0.25 mm at depth of 10 cm. Remainder is weight percentage of coarse sand with diameter 0.25–2 mm. *White triangle*, *Caragana microphylla* site; *white circle*, *Caragana stenophylla* site; *black circle*, *Kalidium-Reaumuria* site

The weight percentages of fine sand and silt at each site are shown in Fig. 13.10. The soil composition of the *C. stenophylla* sites was >38% fine sand and <5% silt (fine sand type), whereas the soil composition from the mixed *K. foliatum* and *R. soongorica* sites was <24% fine sand and <5% silt (coarse sand type) or >9% silt (silt type). *C. microphylla* had soil composition of the fine sand type and silt type. *C. microphylla* that grows in the soil of the fine sand type can absorb water from deep soil with the deep taproot for a long time, while herbs with shallow roots absorb water from shallow soil only just after precipitation in Mandalgobi with the fine sand type (see Satoh et al., this volume, Chap. 5). *C. stenophylla* and *C. leucophloea*, which occur in the soil of the fine sand type, have a deep taproot similar to *C. microphylla*, whereas *K. foliatum*, *R. soongorica*, *K. gracile*, and *A. brevifolia* that grow on the silty soil type have a shallow tap root (Fig. 13.10). *C. stenophylla* extends a taproot horizontally at 40-cm depth to penetrate deeply through the hard calcium carbonate layer with heavier root weight at the 40–50 cm depth (Fig. 13.11a). *C. stenophylla* and *C. leucophloea* might be able to absorb water from the deep soil under soil conditions similar to *C. microphylla*. On the other hand, *K. foliatum*, *R. soongorica*, *K. gracile*, and *A. brevifolia* seem not to try to obtain water from the deep soil. Near Mandalgobi, very little percolation of precipitation occurred to soil depths greater than 20 cm in 2001 (Yamanaka et al. 2007) However, after much precipitation, water percolates to the deep soil layer, and shrubs that have deep taproots, such as *Caragana* sp., suck water from the deep soil layer (see Satoh et al., this volume, Chap. 5). On the other hand, shrubs that have shallow taproots, such as *K. foliatum*, *R. soongorica*, *K. gracile*, and *A. brevifolia*, and herbs absorb water only from the shallow soil layer. To maintain much precipitation in the deep soil layer for a long time, it is necessary for much precipitation to penetrate deeply into the soil, with little being drawn up or down in the soil column.

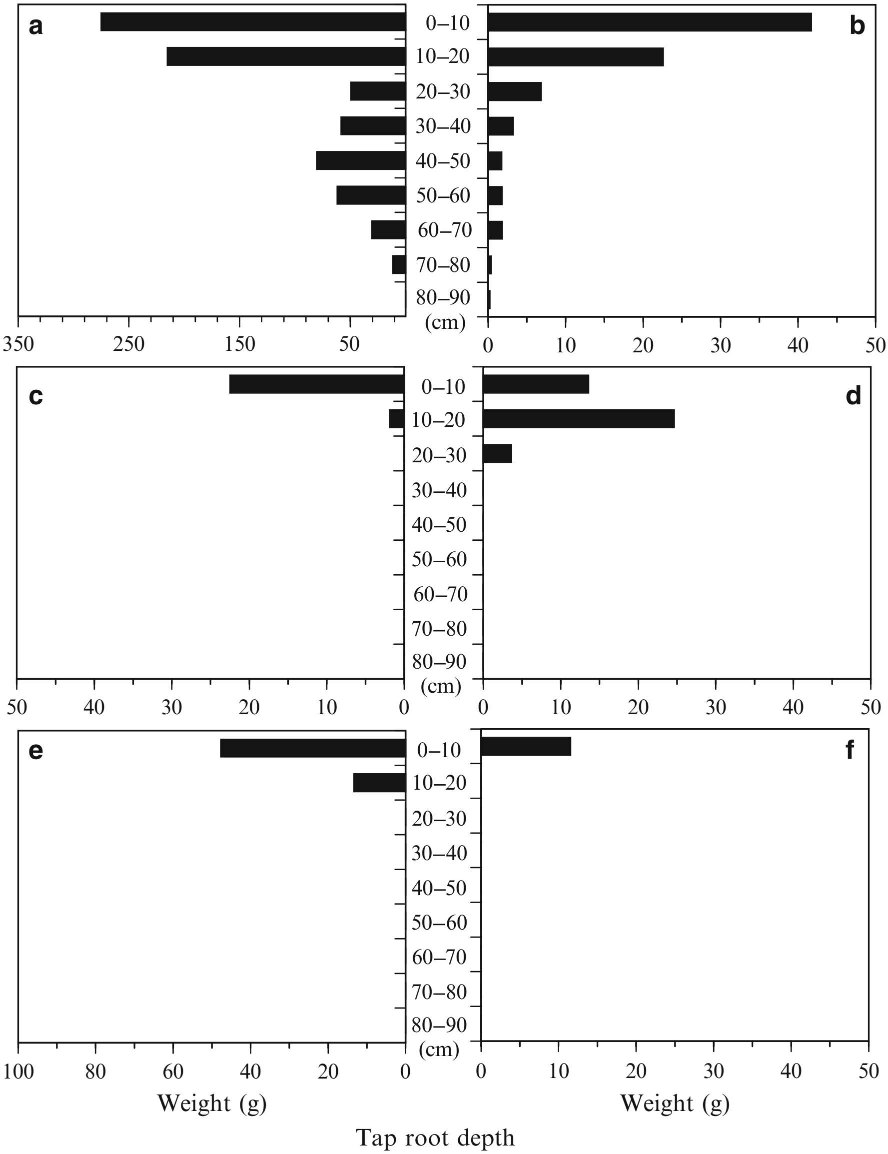

Fig. 13.11 Vertical taproot distribution of shrubs at intervals of 10-cm depth in the soil for *Caragana stenophylla* (**a**); *Caragana leucophloea* (**b**); *Kalidium foliatum* (**c**); *Reaumuria soongorica* (**d**); *Kalidium gracile* (**e**); *Anabasis brevifolia* (**f**)

The difference in the soil-particle distribution in the surface soil layer might be related to water percolation to the deep soil and water suction up to the soil surface. Shrubs with a shallow taproot must have drought tolerance because they are exposed to drought after when there is little precipitation, which is supported by the fact that *K. foliatum* and *A. brevifolia* are C4 shrubs (Pyankov et al. 2000).

13.9 Pasture Domination by Shrubs Versus the Effects of Human Activity

Shrub density varied in the pastures. To determine the distribution of shrub density and its relationship to human activity, we observed shrub density by driving a car along a road in August 2008. We classified shrub density into four levels: high, low, poor, and none, roughly equal to shrub patch coverages of >10%, 1–10%, <1%, and 0%, respectively. As we drove, when we observed a change in the shrub density level, we recorded the point using a global positioning system (GPS). We also recorded positions of herders' summer residences and winter sheds by GPS, noting the species present and the shrub density level. We calculated the distances between successive density change points. From Ulan Bator to Mandalgobi in the steppe zone, the main shrub was *C. microphylla*. From Mandalgobi to Dalanzadgad, the dominant species were *C. stenophylla*, *K. foliatum*, and *R. soongorica*, in different soil habitats (Fig. 13.10), with some other shrub species. *C. stenophylla* grew in sandy soil, while *K. foliatum* and *R. soongorica* were distributed, often together, in silty soil. We observed shrub density separately between *C. stenophylla* and the mixed *K. foliatum* and *R. soongorica* in the desert-steppe zone. The shrub type for areas where no shrubs grew was based on the shrub types growing on either side of the area. In all cases, the shrub types on both sides coincided.

The total distance for each shrub type level is shown in Fig. 13.12. The distribution patterns of the three shrub types differed. For *C. microphylla*, high density accounted for one-third of the distance from Ulan Bator to Mandalgobi, which was not observed in *C. stenophylla*. High-density patches accounted for more than half the distance of the mixed *K. foliatum* and *R. soongorica*. For all shrub types, shrub density decreased as the density of herders' summer residences and winter sheds increased. It is a question whether, with overgrazing by livestock, shrub density has increased or, conversely, has decreased. The density change of shrubs under overgrazing conditions depends on the palatability of shrubs (see Fujita and Amartuvshin, this volume, Chap. 3). These shrubs are all edible to greater or lesser degrees. Then, shrubs might have grown densely throughout the pastures in the past, but the low shrub densities observed could have been caused by degradation over long-term nomadic use. For example, *Caragana*, found in lower densities than *K. foliatum* and *R. soongorica*, is a better livestock food source. Comparing the two *Caragana* species, most *C. stenophylla* was strongly degraded and *C. microphylla* was partially degraded. In the desert-steppe zone where *C. stenophylla* grows, pasture production must be small because of lower precipitation compared with the steppe zone. Therefore, *C. stenophylla* had been degraded more often and more severely than *C. microphylla* in the steppe zone. *C. stenophylla* is a dry type of shrub with thin leaves and spines, similar to *C. leucophloea*. *C. microphylla* and *C. leucophloea* often grow together, and *C. leucophloea* is grazed more heavily by livestock. In addition to being a good food source, its weaker spines, a physical grazing-tolerance defense, is another reason for heavy *C. stenophylla* grazing by livestock. In mid-July 2009, Huld was very dry and *C. stenophylla* lost all their leaves. With *Caragana*

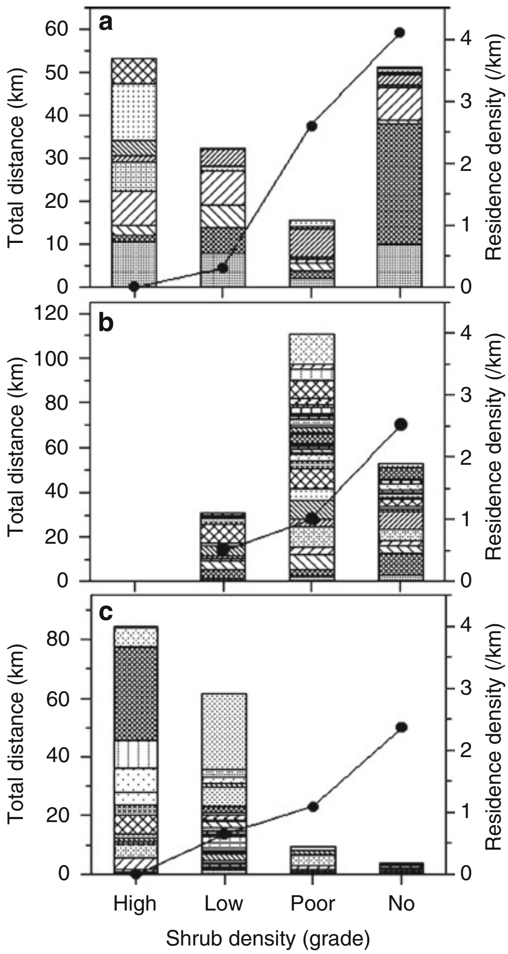

Fig. 13.12 Distribution of shrub density levels and density of summer residences and winter sheds at each level in August 2008. *Bar*, total distance of each shrub density level; *line*, density of nomad summer residences and winter sheds at each shrub density level. (**a**) *Caragana microphylla* between Ulan Bator and Mandalgobi; (**b**) *Caragana stenophylla* between Mandalgobi and Dalanzadgad; (**c**) mixed *Kalidium foliatum* and *Reaumuria soongorica* between Mandalgobi and Dalanzadgad. *High* shrub patch with greater than about 10% land coverage, *Low* about 1–10% land coverage, *Poor* coverage <1%, *No* no coverage. The patterned sections in the bars indicate the continuous units of each level

degradation, herb species also change. For example, *Allium mongolicum* Rgl. and *Stipa glareosa* P. Smirn. change to *Allium polyrrhizum* Turcz. ex Rgl. and *Stipa gobica* Roshev., respectively. According to Jigjidsuren and Johnson (2003), *A. mongolicum* has higher fiber content than *A. polyrrhizum*, and *S. glareosa* is highly nutritious. Therefore, *Caragana* degradation is accompanied by decline of nutrient value in herbs.

Decreasing shrub density is a major problem in the steppe and desert-steppe zones for sustainable nomadism. In semiarid and arid zones similar to the desert-steppe zone in Mongolia, it was reported that abiotic factors such as precipitation have stronger effects on vegetation than biotic factors such as herbivore grazing (Ellis and Swift 1988; Fernandez-Gimenez and Allen-Diaz 1999; Illius and O'Connor 1999; Wesche and Retzer 2005). Climate exerts short-term effects on vegetation, whereas herbivore grazing has long-term effects (Fuhlendorf et al. 2001). Actually, species diversity, coverage, biomass, and production of pasture plants change largely depending on the spatial, seasonal, and yearly fluctuation of precipitation (Figs. 13.3 and 13.4). However, pasture degradation is not caused by fluctuation in precipitation, because pasture plants have drought tolerance. Pasture vegetation damaged by a drought year nearly recovered after a following normal precipitation year (Shinoda et al. 2010). On the other hand, effects of herbivore grazing depend on the pressure and duration of grazing. Long-term hard grazing by livestock near the summer residences of nomads and the winter sheds that have been used through many years has brought pasture degradation such as shrub extinction to the steppe and desert-steppe zones in Mongolia.

Shrub preservation and recovery is an urgent issue in Mongolia, and *C. stenophylla* is especially at risk. For some shrubs, regeneration is sufficient to induce pasture succession (Vieira et al. 1994). In Inner Mongolia and China, *Caragana* can be grown by seed-spraying of pastures. However, we have not observed natural *C. microphylla* and *C. stenophylla* regeneration in these pastures. For *Caragana* to recover, individuals might have to be cultivated and grown to full size. Furthermore, a problem exists with planting fast-growing trees such as *Populus* in the steppe and desert-steppe zones where they do not normally grow, because they waste soil water, advancing drought, and are useless for nomads. *Caragana* species are best planted in the sandy soil of the steppe and desert-steppe zones.

13.10 Wind Erosion Versus Shrub Patch Degradation

Wind erosion is a problem in Mongolia, especially in the spring, because the prevailing westerlies carry soil eastward, sometimes as far as Japan. Shrub patches accumulate airborne soil and form mounds. When the shrub patches degrade, the soil mounds are eroded. To determine the wind erosion occurring on and around shrub patches at different levels of degradation, we measured the vertical change in soil surface through one windy season on and around normal and degraded shrub patches in the *C. microphylla* sites near Mandalgobi and the *C. stenophylla* sites in Huld. The average shrub patch coverage was almost 21% at the *C. microphylla* site and 5% at the *C. stenophylla* site. In early October 2009, we inserted seven thin iron rods in the soil so that their tops were flush with the soil surface, one on top, two on the shoulders, and two on the edges of the soil mound, as well as two in the flat ground 1 m from the edges along the axis of the prevailing wind (Fig. 13.13). We used shrub patches >1.5 m in diameter along the major axis of the prevailing wind. We distinguished normal and degraded patches as having leaf canopy areas of >80%

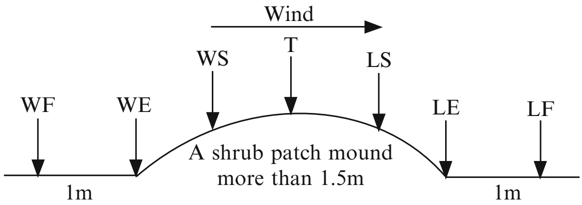

Fig. 13.13 Seven iron rods on and near a shrub patch soil mound on the axis of the prevailing wind inserted at the top of the mound (*T*), windward mound shoulder (*WS*), leeward mound shoulder (*LS*), windward mound edge (*WE*), leeward mound edge (*LE*), windward flat pasture 1 m from the windward mound edge (*WF*), and leeward flat pasture 1 m from the leeward mound edge (*LF*)

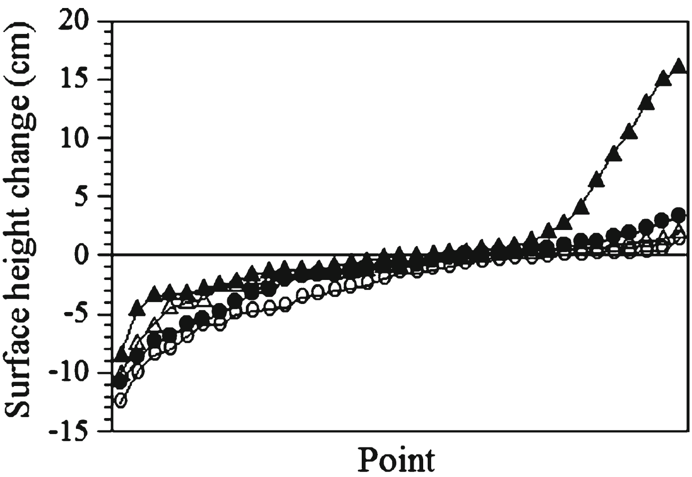

Fig. 13.14 Increase and decrease in soil surface around normal and degraded *Caragana* patches between October 2009 and August 2011. *Triangles*, *C. microphylla* in Mandalgobi; *circles*, *C. stenophylla* in Huld. *Black figures*, normal patches; *white figures*, degraded patches

and <20% of the patch area, respectively. We used five patches for each group at both sites. We measured the vertical distance up or down from the soil surface to the iron rod tip in mid-July 2010 and mid-August 2011. We judged soil accumulation and erosion by the position from the top of each iron rod.

Figure 13.14 shows the changes in soil surface along the prevailing wind axis in normal and degraded shrub patches from early October 2009 to mid-August 2011. The soil erosion was greater at the *C. stenophylla* site in Huld than the *C. microphylla* site in Mandalgobi, and the mound soil erosion of the normal shrub patch was lower than that of the degraded patch at both locations. The average changes were +1.2 and −1.3 cm on and around the normal and degraded patches, respectively, at the *C. microphylla* site in Mandalgobi and −1.7 and −2.8 cm on and around the normal and degraded patches, respectively, at the *C. stenophylla* site in Huld. In Huld, in mid-July 2010, the soil erosion was low as a whole and the soil was on average accumulated on and around the normal shrub patches, but, in mid-August 2011, soil erosion had occurred even on and around the normal shrub patch. In Huld, shrub degradation has already progressed because the present coverage of shrub patch was only 5%. The mound soil of a normal shrub patch that has been isolated can be eroded. Therefore, the degradation of shrub patches promotes wind erosion in pastureland and increases sand fall to the surroundings. Vertical fluctuations of the soil surface differed at different mound positions. Generally, the soil is blown from the windward mound and the top, and the soil is accumulated in the leeward side.

13.11 Goat Grazing Versus Sheep Grazing

To compare grazing effects on vegetation between sheep and goats, we performed raising experiments in the exclosure at two different vegetation sites in Bayan-Unjuul. One is a shrub site. In the pasture (47°01′55″ N, 105°48″08″ E) where *C. microphylla* grew dominantly with rare *C. leucophloea*, we constructed 24 fenced areas, 10 m square, in early October 2009. In the herb layer, perennials such as *Stipa krylovii* Roshev. and *Artemisia frigida* Willd. occurred exclusively. After measuring the area of *Caragana* leaf canopy in each fenced area and the weight of each sheep and goat, from 5 August 2010, we raised sheep and goats in each fenced area in four combinations; that is, one sheep, two sheep, one goat, and two goats, with water supplied using a plastic container. Averaged weights of sheep and goats before the experiment were 43.5 and 35.2 kg, respectively. All combinations had five repetitions. We measured the leaf weight of *C. microphylla* with a 20-cm^2 quadrat and the aboveground biomass of herbs within 1 m^2 using five repetitions in the remaining fenced areas. After 4 days, on 9 August 2010, we measured the weight of each sheep and goat and the remaining coverage of shrub leaf canopy and herbs in each area to determine the weight reduction of each sheep and goat and the mass grazed by sheep and goats in each fenced area for 4 days. We calculated the mass of *Caragana* leaves and herbs grazed from their coverage reduction and dry weight per area. We raised sheep and goats inside fences for two more days, up to 11 August 2010, to examine the effects of heavy grazing pressure by sheep and goats on *Caragana* and herb growth in the next year. We released sheep and goats from the fences on 11 August 2010, but we retained the fences to prevent livestock grazing until the next year. On 16 August 2011, we measured the area of *Caragana* leaf canopy and the coverage of herbs in each fenced area.

The second site is a herb site without shrubs. In the pasture (47°02′27″ N, 105°55′58″ E) where no shrubs were distributed, we constructed 20 fences of 200 m^2 (10 × 20) in early October 2010. In August 2011, annuals and perennials occurred wholly within fences. The most dominant species are *Chenopodium* annuals such as *C. accuminatum* Willd., *C. aristatum* L., and *C. urbicum* L., and dominant perennials

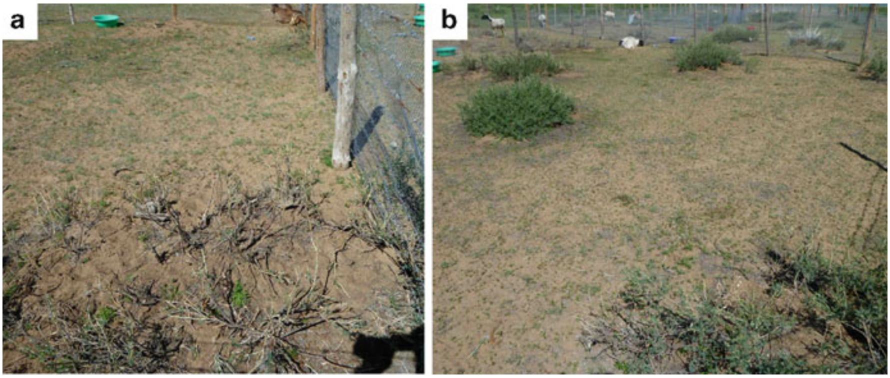

Fig. 13.15 Photographs inside fence after 4 days of experiment: strongly grazed *Caragana* in a fenced enclosure for goats (**a**), and remaining *Caragana* in a fenced enclosure for sheep (**b**)

were *S. krylovii*, *A. frigida*, and *Cleistogenes songorica* (Roshev.) Ohwi. After measuring the coverage percentages of *S. krylovii*, *A. frigida*, and total *Chenopodium* species in each fence and the weight of each livestock, from 13 August 2011, we raised sheep and goats for 3 days in each fenced area in three combinations, that is, two sheep, two goats, and one sheep and one goat, with water supply using a plastic container. Averaged weights of sheep and goats before the experiment were 42.1 and 35.3 kg, respectively. All combinations had five repetitions. On 16 August 2011, we measured the weight of each sheep and goat inside each fence to know the weight reduction of each sheep and goat for 3 days.

Diet preference was clearly different between sheep and goats in the shrub site. Sheep preferred herbs over *Caragana* leaves, whereas goats preferred *Caragana* leaves over herbs (Fig. 13.15). Averaged biomass per area for *C. microphylla* leaves and herbs before the experiment was 265.3 and 17.0 g/m^2, respectively, thus the biomass was more than ten times larger in *Caragana* leaves than herbs (Fig. 13.16a). Grazed coverage of *Caragana* leaves was significantly greater by goats than by sheep, and the mass of grazed herbs was significantly less for goats than sheep (Fig. 13.16b). Weight reduction did not correlated with coverage of *Caragana* leaves within a fence in sheep, but negative correlation between weight and coverage was found to be significant ($P<0.01$) in goats (Fig. 13.16c). This negative correlation was derived from a difference in the mass of *Caragana* leaves and herbs actually grazed (Fig. 13.16d). The difference in diet preference between sheep and goats was recognized in an early stage of livestock hunger, because sheep and goats had eaten up both *Caragana* leaves and herbs under starving hunger conditions after 6 days of the experiment. Growth recovery of *Caragana* and herbs in the next year was not different between sheep and goats (Fig. 13.17). The growth recovery was very good in *Caragana* even after complete defoliation and partial browsing of twigs after strong grazing by goats or sheep (Fig. 13.17a), but recovery was not as good in herbs (Fig. 13.17b), perhaps because of partial grazing of the underground parts of

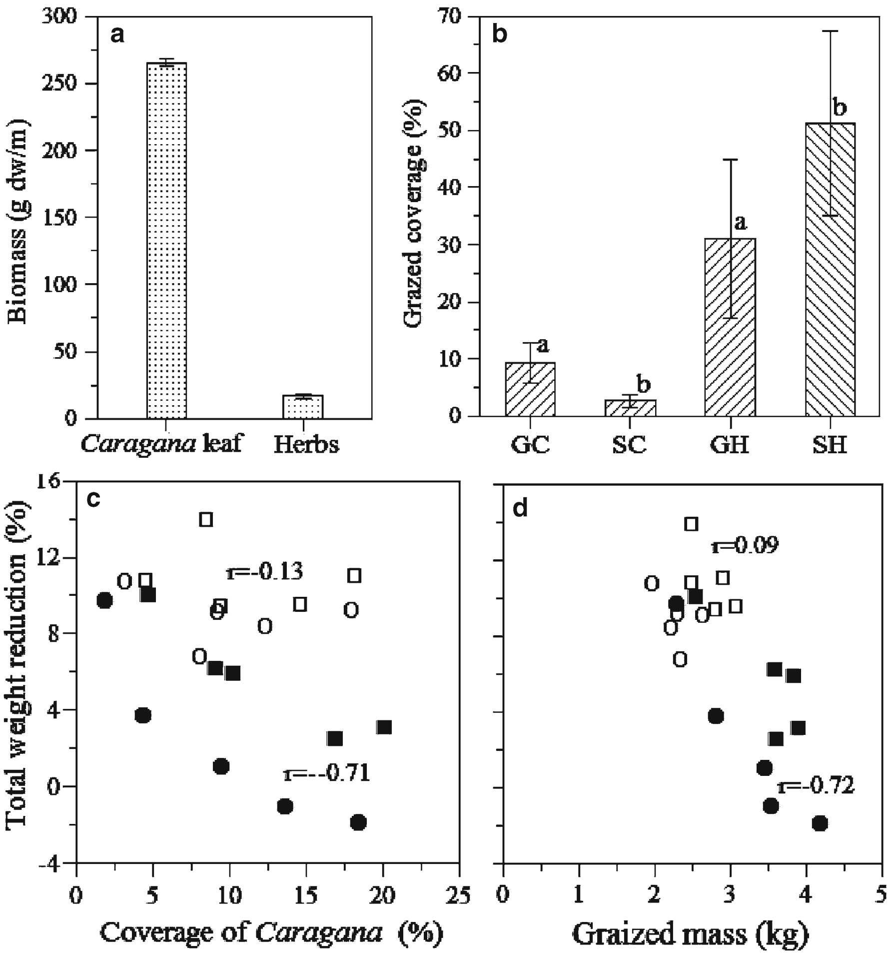

Fig. 13.16 Averages with standard deviations for biomass of *Caragana* leaves and herbs per 1 m^2 before the experiment (**a**), averages with standard deviations for grazed coverage percentages of *Caragana* leaves and herbs per one sheep or goat after 4 days (**b**), relationships between *Caragana* leaf coverage before experiment and total weight reduction of sheep or goats during 4 days inside each fence (**c**), and relationship between total grazed mass of both *Caragana* leaves and herbs by sheep or goats and total weight reduction percentage of sheep or goats during 4 days inside each fence (**d**). *GC* average with standard deviation for grazed coverage of *Caragana* leaves by goats inside fence, *SC* average with standard deviation for grazed coverage of *Caragana* leaves by sheep inside the fence, *GH* average with standard deviation for grazed coverage of herbs by goats inside the fence, *SH* average with standard deviation for grazed coverage of herbs by sheep inside the fence. *a*, *b* statistical significance at $P<0.01$. *White circles* one sheep, *white squares* two sheep, *black circles* one goat, *black square* two goats. *r* correlation coefficient for sheep or goats

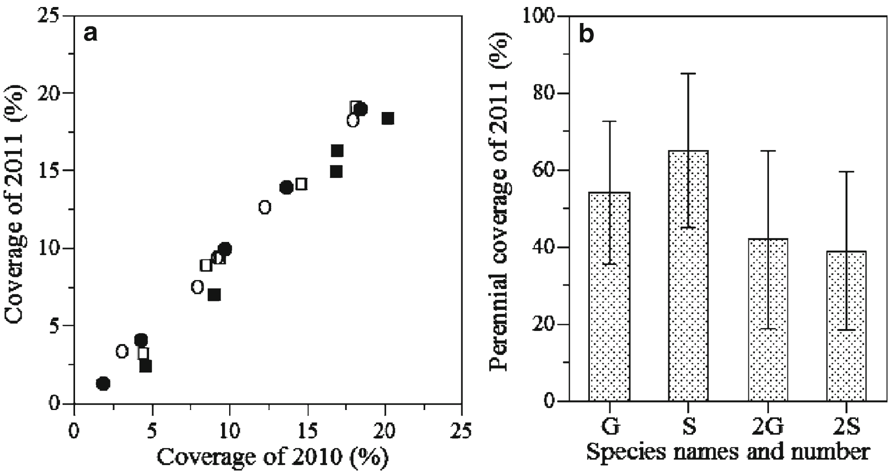

Fig. 13.17 Relationship of *Caragana* leaf coverage inside each fenced area between 2010 and 2011 (**a**) and averaged perennial coverage with standard deviation inside fence areas after the experiment for one and two sheep or goats (**b**). Symbols as in Fig. 13.16. *a*, *b* statistical significance at $P < 0.01$

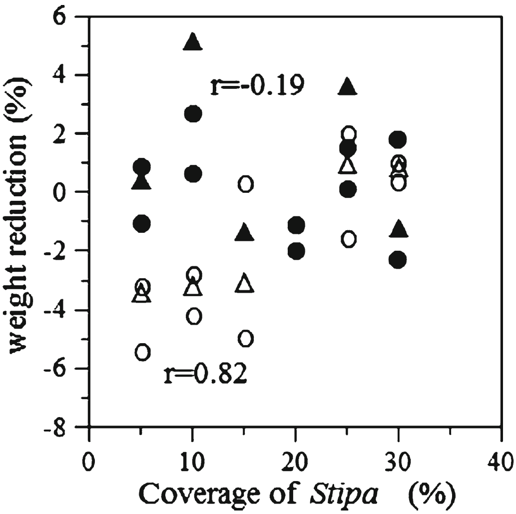

Fig. 13.18 Relationship between coverage of *Stipa krylovii* before experiment in each fenced area and weight reduction of each sheep and goat during 3 days. *White circle* one sheep within a two-sheep fence, *white triangle* one sheep in a sheep–goat-mixed fenced area, *black circle* one goat in a two-goats fence, *black triangle* one goat in a sheep–goat-mixed fenced area. *r* correlation coefficient for sheep or goats

the herbs. Diet preference for herbs alone differed between sheep and goats at the herb site. Weight reduction of goats was not seen during the 3 experimental days, although the weight of sheep decreased in negative correlation with coverage of *S. krylovii* after three experimental days (Fig. 13.18). At this time, diets were not deficient in each fenced area, because the aboveground biomass of herbs remained at more than one-third from that recorded at the start of experiment. Goats grazed various herbs without weight reduction for 3 days inside the fence, but sheep preferred fewer herbs other than *S. krylovii* in spite of weight reduction. The diet preference of sheep for *S. krylovii* only did not change when they coexisted with goats.

There are many reports about differences in diet preference between sheep and goats. Goats consumed more shrubs (Magadlela et al. 1995; Rogosic et al. 2006) and aculeate herbs (Holst et al. 2004) than sheep, although goats ignored some shrubs (Wilson et al. 1975). Sheep and goats preferred better grasses and forbs, respectively (Animut et al. 2005). Sheep grazed deeply but goats feed shallowly in the sward horizon (Gong et al. 1996). Our results do not contradict these reports in general. As for the comparison between grasses and forbs for diet, sheep preferred *S. krylovii* alone for grasses and did not eat *Cleistogenes songolica*, and goats preferred both grasses and forbs. Reaction to hunger from insufficient diet differed between goats and sheep. Goats maintained their weight by grazing every available plant until their weight was reduced by shortage in their diet, while sheep loose their weight easily after grazing all favorite diets available. Although both goats and sheep finally exhaust all plants in response to extreme hunger, goats might avoid weight reduction by grazing less preferred diets whereas sheep might choose weight reduction rather than grazing a lesser diet before hunger become strong.

Based on difference in diet preference, grazing effects on pasture differ between goats and sheep. In early stages of overgrazing, goats might bring about shrub degradation, whereas sheep might cause herb degradation. Pasture species of shrubs and herbs have some degree of grazing tolerance. *Caragana* species could recover well from complete but temporary leaf grazing (Fig. 13.17a). A serious problem is caused in pasture degradation when overgrazing continues for a long time or year after year.

13.12 Conclusions

Pasture production is controlled by precipitation, although temperature is a necessary condition. Sufficient annual herb production in pastureland requires a certain dose of precipitation during a limited timeframe for continued production in the dry regions. For example, at least 10 mm over 15 days is required for useful pasture plant production. Unpredictable, spatial, seasonal, and yearly fluctuation of precipitation causes great spatial and temporal fluctuation of pasture production, although drought damage to a pasture is recoverable by normal precipitation. The free moving of livestock and frequent and seasonal migration of livestock camps in traditional nomadism is a good adaptation to this fluctuation. Migration also helps to avoid pasture degradation and soil alkalization caused by continuous overgrazing, which occurs even in the forest-steppe zone, and irreversibly changes the vegetation through negative feedback.

Moderate livestock grazing pressure facilitates pasture plant production through a positive feedback effect, but overgrazing has a negative feedback effect. Herders, who control livestock density and migration, affect pasture production indirectly, while pasture production affects herders indirectly by influencing livestock production. For example, herders lead cattle to flat valley bottoms and sheep and goats to the upper slopes.

Shrub patches in steppe and desert-steppe pastures are very important for Mongolian nomadism. *Caragana* ssp., including *C. microphylla* in the steppe and *C. stenophylla* in the desert steppe, fix nitrogen from the air and can grow leaves not only after adequate precipitation but also throughout the growing season by absorbing water from deep in the soil. They provide good fodder for livestock, especially during the dry and winter seasons. *K. foliatum* and *R. soongorica* have high drought tolerance and become food sources for livestock in the desert-steppe zone. For this reason, the shrubs have become strongly degraded in the steppe and desert-steppe zones. If no efforts are made to save these shrubs, future extinction is inevitable. Moreover, the degradation of *Caragana* is leading to a crisis for sustainable nomadism. Shrub conservation and recovery is an urgent concern in Mongolia.

Goats prefer *Caragana* leaves, while sheep prefer herbs, especially *Stipa*. In the first stage of hunger, goats graze various plants without weight reduction, but sheep keep to their diet preferences in spite of weight reduction. Under conditions of great hunger, both goats and sheep degrade pasture severely by browsing shrubs and grazing the underground parts of herbs.

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