Effect of Grazing on Steppe Vegetation in Semi-arid Zone of China

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1. Distribution of steppes in China

Steppe vegetation is distributed in the semi-arid zone of China, where the precipitation is usually from 250 to 350 mm (Fig. 1). Five types of steppes are observed, viz. meadow steppe, typical steppe, desert steppe, shrub steppe and alpine steppe. Dominant and typical species are *Aneurolepidium chinense*, *Stipa* and *Artemisia* species. Many species of genus *Stipa* are observed in the semi-arid zone as shown in Table 1.

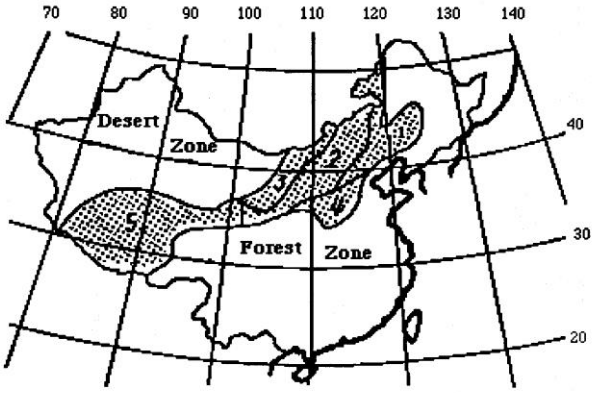

Fig. 1. Distribution of steppe vegetation in China (Zhu, et al., 1985)
1: Meadow steppe 2: Typical steppe
3: Desert steppe 4: Shrub steppe
5: Alpine steppe

2. Steppe vegetation and grazing pressure

It is said that *Artemisia* species, especially *A. frigida*, are the best indicator of grazing pressure. Both *Aneurolepidium* and *Stipa* steppes degrade into Artemisia steppe under sustained grazing pressure (Li 1989). Conversely, the conservation of deteriorated steppe for six years caused vegetational change from *Artemisia* steppe to *Stipa* steppe (Ma 1985).

Table 1. Stipa species in various types of steppes (Zhou & Li, 1982)

Type of Steppe	Dominant species
Meadow steppe	*Stipa baicalensis*
Typical steppe	*S. breviflora, S. krylovii, S. breviflora*
Desert steppe	*S. glareosa, S. klemenzii, S.gobica*
Shrub steppe	*S. bungeana*
Alpine steppe	*S. purpurea*

3. Problems of steppe management

At present, the three major problems of steppe management are cited as degradation of steppe vegetation, desertification and rat infestation.

To examine the suitable management of land resources from a global point of view, a rehabilitation program was commenced in the Loess Plateau in 1988 cooperatively by Japanese and Chinese scientists (Tamura 1989). The problems of steppe management will be examined in the following sections.

3-1. Steppe vegetation in the Loess Plateau

The Loess Plateau, with an altitudinal range from 1500 to 2000m, is situated in a semi-arid region of north-west China (Fig. 2). In general, the vegetation varies from desert in the north to shrub-steppe in the south which follows the increase annual precipitations. Semi-arid areas of northwest China have been subjected to degradation of vegetation due to overgrazing (Sun 1988). In the Loess Plateau, in addition, the growing human population has led to the extension of cultivated fields to hillsides and recently even to a steep slopes. The characteristics of mechanically unstable loess are responsible for widespread sheet and gully erosion. These human-induced perturbations result in surface runoff of water carrying the soil away on slopes and wind-erosion on flat land. Eroded areas are said to occupy more than 70 % of the Plateau (Zhang et al. 1989). To conserve soil and water, intelligent ecosystem management strategies should be implemented

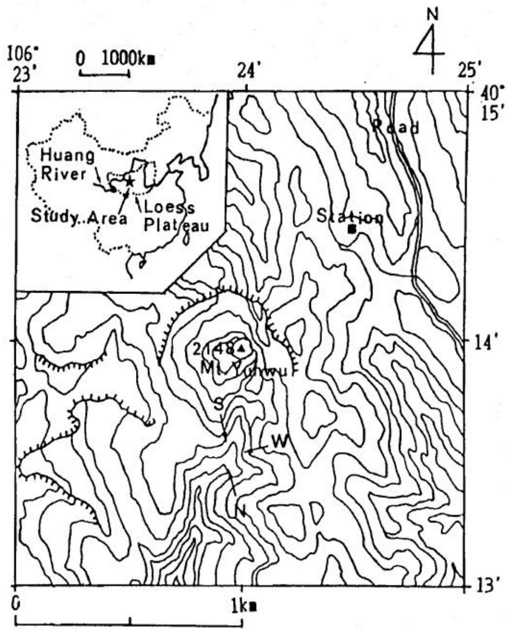

Fig. 2. The study area on Yunwu Mountain
S, N and W show sampling sites on the southern, northern and western slopes, respectively. Contour lines are placed at 40 m intervals.

immediately (Beedlow et al. 1988). Recovery of dense plant cover is an important factor to prevent erosion.

3-2. Steppe vegetation and micro-topography

It is well known that steppe vegetation varies with micro-topography. Completely different vegetations are observed on the southern and northern slopes of the same hill because of different hydrological cycles (Iwata 1942; McNaughton & Jarvis 1983). It is necessary to examine the shrub-steppe vegetation and environmental variables at different slope intervals in order to achieve success in the practical rehabilitation.

3-3. Climatic condition at the experimental station

The field survey was carried out at the Yunwu Mountain Pastoral Preserve Station. It is said that the mean annual air temperature is 5-6°C, which is similar to 6.1 °C in Obihiro, Japan. The frost-free period is from 120-150 days and the mean annual precipitation is 400-480 mm (Zou et al. 1986). About 60% of the total annual precipitation fell during July to August. The mean maximum temperature for the decade was 17.8°C and the second week of July was hottest.

Solar radiation on the northern slope decreased remarkably in comparison with the southern slope in winter, causing a drop in the soil temperature. (Takahashi et al. 1991). Estimated evapotranspiration is 1.1 to 1.6 times higher on the southern slope than on the northern slope.

3-4. Soil temperature at different slopes in winter

Soil temperature at 5 cm depth during winter is shown Fig. 3. Soil temperature on the northern slope deceased gradually with a little fluctuation. After the onset of freezing temperatures in middle December, below-freezing temperatures continued over two months. It is evident that a dense layer of ice accumulated in the top-soil and its melting pattern may play an important role in soil water balance. On the contrary, great fluctuations in soil temperature was observed on the southern slope. In this region, there is little precipitation from autumn to spring. The characteristic fluctuation in soil temperature above 0°C is also probably a major reason for the continued loss of water during the winter on the southern slope. Little attention has been attracted to water balance during cold winters in the shrub-steppe ecosystem (Gee et al. 1988).

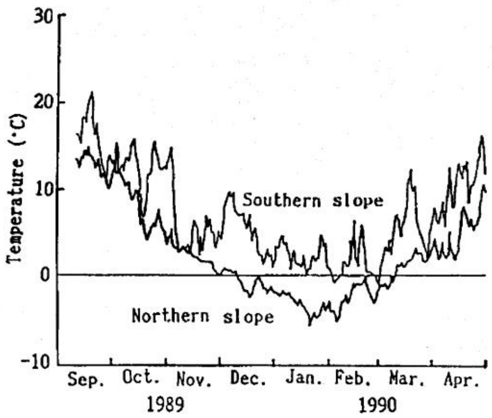

Fig. 3. Soil temperatures at a depth of 5 cm on the southern and northern slopes i Yunwu Mountain during the winter season.

3-5. Shrub-steppe vegetation

Vegetation in the Yunwu Mountain region is classified as shrub-steppe, since the annual precipitation is higher than in other regions of steppe or typical steppe. In this study, however, no shrub species were observed. This is due to grazing and human disturbance for long time periods before the commencement of protection measures in 1983. Most shrubs are said to be cut by villagers for fuel.

Four species are cited as dominant herbs in this region: grass species of *Stipa bungeana* and *Poa sphondylodes*, *Thymus mongolicus* belonging to the family *Labiatae*, and *Artemisia sacrorum* (Zou et al., 1986). In the northern area, there was a dense vegetation, usually dominated by grass species such as *S. bungeana*, *S. grandis*, P. *sphondylodes* and *Agropyron cristatum*. *S. bungeana* was the most predominant with a plant height of above 50 cm. A carpet of *T. mongolicus* patchily occurred between grass stubbles. Its stoloniferous growth with a dense and low form may be an adaptation due to past overgrazing. Therefore, the carpet of *T. mongolicus* will be replaced by *S. bungeana* under lax grazing pressure. Many small herbs with rosette life form grew between grass stubbles. The occurrence of fourteen species was limited to the northern slope.

Species of the genus *Artemisia*, especially *A. sacrorum* with their great tolerance for drought, were the predominant species on the southern slope. The next most important species were *P. sphondylodes*. *Artemisia* grasslands, called desert steppe, are widely distributed over arid regions in China (Ren 1982).

3-6. Vertical distribution of soil properties

The Loess Plateau is overlaid by 100-200 m layers of loess, which were derived by winds from the desert in the northwestern zone (Ren 1982).

The result of the chemical analysis of the soil is shown in Fig. 4. Soil moisture decreased to depths of about 20 cm and then maintained at the same level at greater depths on all slopes. Higher moisture at the surface was influenced by precipitation immediately before the soil sampling. According to the meteorological observation at Shunghuang-sun, about 20 km due south to the studied site, it rained at a rate of 3 mm on one day earlier and 5.5 mm 10 to 11 days earlier. Soil moisture below 50 cm depth appeared to be the stable source for plant growth, corresponding to mean values of 15.3, 10.8 and 9.3% on the northern, western and southern slopes, respectively. These differences may interpret the variation of the floristic composition and grassland production.

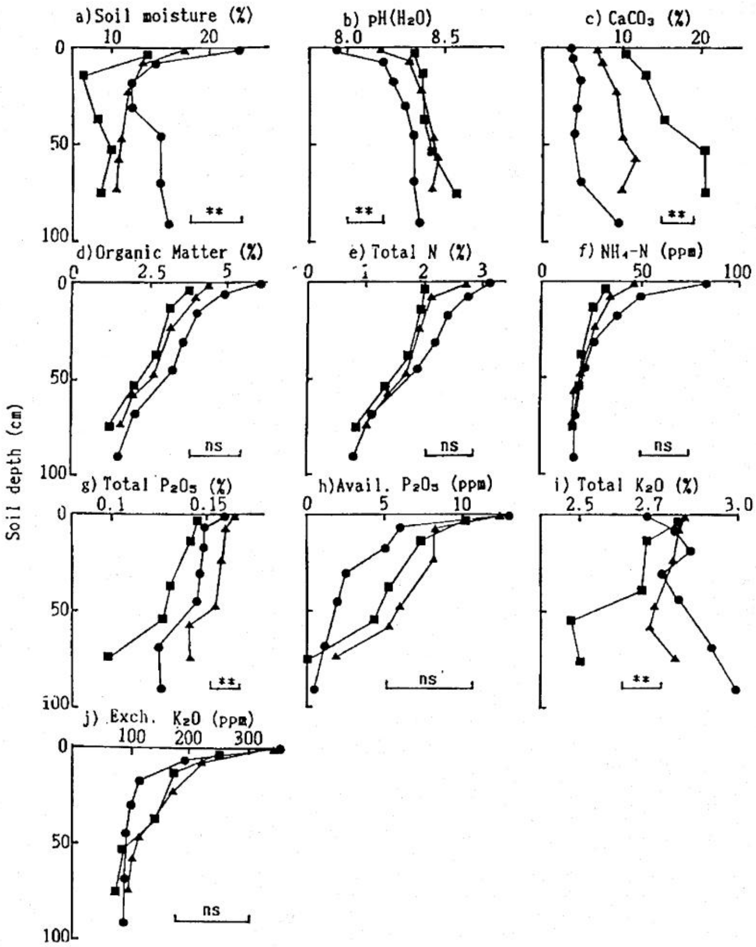

Fig. 4. Vertical distribution of soil properties on the northern (•), western (▲) and southern (■) slopes. Horizontal bars and symbols indicate the standard error of the difference, and significance (**, $p \leq 0.01$) between means of three slopes.

On the surface, pH (H_20) was lowest on the northern slope (7.94), followed by the western (8.17) and southern (8.32) slopes. At increasing depths, pH increased with the same pattern on all slopes.

The vertical pattern of calcium carbonate contents was characteristic on each slope. On the northern slope, its contents were almost the same from the surface down to 70 cm depth. Slightly higher contents were obtained on the western slope compared with those on the northern slope. Although the increasing pattern on the southern slope was similar to that on the western slope, its increasing rate was apparently high. These vertical patterns clearly reflect the water movement in each soil profile (Jeffrey 1987). They suggest that water moves downward in the soil on the northern slope, but upward movement of water is caused by severe evaporation at the soil surface, resulting in the accumulation of calcium carbonate at the upper layers on the southern slope.

Organic matter, total nitrogen and ammonium nitrogen at the surface layer were higher on the northern slope than on the southern slope. These contents markedly decreased at increasing depths with the same pattern.

The decreasing pattern of available potassium and available phosphorus contents was similar to that of organic matter, but it is not known why these contents below a depth of 10 cm are lower on the northern slope than other slopes. There was no tendency in the contents of total potassium and phosphorus.

With respect to soil physical properties, the solid phase in the surface layer was apparently lower on the northern slope (33.2%) than other slopes (39.6 - 39.8%). The reverse trend was observed in liquid and gaseous phases. Higher values of the liquid and gaseous phases are related to higher contents of soil moisture and organic matter.

3-7. Method of restoration of destroyed steppe

In the semi-arid region of China, land resources are mostly destroyed by overgrazing (Zhu et al., 1985). Although grassland plants are able to prevent or control soil erosion (Spedding 1975), these important functions are usually depressed in overgrazed land. As Beedlow et al. (1988) pointed out, the restoration of a destroyed ecosystem can be characterized by regaining control of water and nutrients, and regaining its energy capture efficiency. Other reports show that overgrazed Artemisia grassland is improved into typical steppe dominated by *Stipa* species after the conservation for six to seven years (Ma 1985: Iwata1947). In order to improve steppe vegetation, various methods should be applied according to micro-topography. From our field work, the recovery of steppe vegetation may be fast on the northern slope because of the high level of soil moisture and organic matter. On the southern slope, however, the rehabilitation of overgrazed vegetation seems to require an enormous effort and long time period. It is possible to accelerate the recovery by artificial application of organic matter into the soil and utilization of introduced species (Zhu et al. 1985). In addition, the formation of contour ditches on a slope may be effective in reducing runoff and soil erosion (Chisci & Boschi 1988). This method is practically used for the reclamation of overgrazed slopes.

Although many species were present in this region, three grasses viz. *S. bungeana*, *A. cristatum* and *P. sphondylodes*, will be useful in order to recover steppe vegetation in the future. These native grasses have an advantage over other plants in term of adaptability, small seed size, quick germination, capacity to prevent soil erosion, and agricultural usage as a feed (Huang & Li 1985).

3-8. Mole-rats and steppe vegetation

Mole-rats of genus *Myospalax* are distributed in a wide zone from eastern China to the Altai mountain range in the west. The sub-family *Myospalacinae* is composed of one genus *Myospalax* including eight species . The habitat of mole-rats is steppe or open forest. They usually feed on plant roots, root stock or bulbs in a subterranean tunnel and sometimes on plant seeds, leaves or stems above ground. These feeds are stocked in underground store halls and used during winter.

In the Loess Plateau, mounds constructed by Cansu mole-rats have led to the extension of eroded areas. In order to construct underground tunnels, soil materials are thrown out and accumulated on the ground surface, resulting in a characteristic formation of mole-rats' mounds. Immediately after construction, these mounds have no vegetation. One mole-rat usually builds 15 to 20 mounds annually. In some shrub-steppes with a high population density of mole-rats, mounds may occupy 40 percent or more of the total area. Thus, mounds apparently depress shrub-steppe production and accelerate hillside soil erosion.

3-9. Vegetation of mole-rats' mounds

Stipa bungeana was the most predominant, followed by the *Artemisia* species and *Thymus mongolicus* belonging to the family *Labiatae*. The characteristic pattern of occurrence was observed in *Leontopodium leontopodioides*, *Allium lodidum* and *Cleistogenes squarrosa*. These were observed exclusively on flat fields and old mounds. On the contrary, *Thymus mongolicus*, *Trigonella ruthenica* and *Potentilla tanacetifolia* showed a high coverage on new mounds. Their stoloniferous growth may be adaptable especially for soil disturbance.

Species of the genus *Artemisia* are said to have a great tolerance for drought. *Artemisia*-dominant grasslands, called desert steppe in China, are widely distributed over the arid zone. In this study, *Artemisia* species seem to be intolerant of soil disturbance because of its low coverage on new mounds.

3-10. Steppe vegetation destroyed by mole-rats

On the northern slope in this area, there were an average of eight mounds per 100 m, and the mean mound size of 5 sites selected at random was 1.84 m. According to these parameters, the damaged area corresponded to about 15 percent of the total area. Another report shows 200 mounds per hectare and a damaged area of 20 percent. It is also estimated that a mole-rat usually builds 15 - 20 mounds annually.

For the revegetation of mole-rats' mounds, it is necessary to control most of the mole-rats. Agricultural chemicals are used for this purpose. However, enormous efforts must be invested in applying chemicals. A farmer finds a tunnel, bore a hole into it and set in chemically treated food. The high price of chemicals and a lack of information on their importance to control, also contribute to the fact that chemicals are rarely used.

In an undisturbed ecosystem, rodents are kept at a reasonable level by natural enemies. Carnivores for mole-rats are mustelids, especially mountain weasels (*Mustela altaica*) and steppe polecats (*M. eversmanni*). Systematic destruction of these valuable predators may prove costly to farmers. In the future, the restoration of steppe vegetation will be achieved in parallel with the recovery of these natural enemies.

4. Herbage legume for restoration

Astragalus adsurgens Pall., a perennial and leguminous forage crop, is native to China. Two types of *A. adsurgens* have been recognized: the cultivated type with erect growth form and the creeping wild type. These are taxonomically treated as the same species, but generally considered as different ecotypes.

The cultivated type of *A. adsurgens* is termed "Shadawang" in Chinese, and the wild type as "Xiepie-Huangqi" (Wang & Ren 1989). The cultivated type is widely distributed from northeast China to Siberia including northern Japan (Ohwi 1978). The area of distribution of the indigenous populations are observed to be as far north as Heirongjiang Province, as far south as Yunnan Province, as far east as Shantung Province, and as far west as the Tibet Autonomous Region in China, as shown in Fig. 1 (Li 1987: Liu 1990).

The cultivated type of *A. adsurgens* is widely utilized as a forage legume in order to improve grasslands badly damaged by overgrazing. It is characterized by its erect form, tall plant height, thick stem and late flowering. Its outstanding feature is a high tolerance to drought and low temperatures. These advantages result in high productivity in semi-arid areas. On the other hand, the creeping wild type grows naturally on the northern slopes of Yunwu Mountain and Liupan Mountain at an altitude about 2000 m. The wild type, with smaller leaves and fine stems is a perennial, low in plant height and early-flowering.

The creeping type of *A. adsurgens* is a very important germ plasm source for early maturity, fine stem, improved palatability etc. At present, the erect cultivated type of *A. adsurgens* is late flowering and rarely reaches maturity to allow for natural reseeding in the Loess Plateau. Perhaps, an early maturing variety of the cultivated form, which has been developed by radiation breeding, could be used (Ma 1986). However, there still remain undesirable agronomic characteristics in this variety such as thick stem, poor palatability and so on. Therefore, the creeping wild type of *A. adsurgens* may be invaluable as an important gene source for the development of new varieties in the future. In this case, attention must be paid to the drought resistance of the wild type of *A. adsurgens* (Hongo et al. 1992).