

## Rangeland degradation in Ordos Plateau, its nature and assessment

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### ABSTRACT

The Ordos Plateau has a markedly higher percentage (more than 70%) of degraded rangelands than the regions in the same latitude, primarily because of the frequent fluctuation of climate and the heavier grazing pressure, combined with the exploring for fuelwood and pharmaceutical plants and the conversion to farmland. Desert steppe in the area was examined for effects of hundreds years of live-stock grazing and other disturbances. Three permanent sites, including a series of opened plots, light grazing plots and ungrazed plots (excluded or 'closed' from livestock), were designed in 1988 to compare and examine the degradation of rangeland under different grazing pressure. Experimental analysis showed that there was a change of vegetation biomass, botanical composition, species diversity, soil moisture and other factors after different grazing treatment. Biomass of most species increased in the light grazing and the ungrazed plots after two years. Total aboveground biomass ranged from 117.6 g/m<sup>2</sup> in the light grazing plots to 134.1 g/m<sup>2</sup> in the closed plots, compared with 42.3 g/m<sup>2</sup> in the opened plots. But in the seventh year aboveground biomass at the ungrazed plots became 13.2 g/m<sup>2</sup> less than that in the light grazing plots. Species diversity (Shannon-Wiener Index) was highest in the ungrazed plots (2.207), followed by the light grazing plots (1.892) and the opened plots (0.826) in the seventh year. Botanical composition also changed after seven years of treatment. The semi-shrub *Artemisia songorica*, dominant in opened plots, was virtually eliminated in light grazing plots where the perennial grass *Cleistogenes squarrosa* became dominant. Later it was still in abundance at the ungrazed plots, but the dominance had been replaced by another perennial grass *Stipa breviflora*. The soils in the opened plots had lower moisture and higher bulk density than the other plots. Time series analysis showed that yearly mean overgrazing rate is lower than 20%, even negative in some cases. However, when rainfall became less than average, stocking rates were far beyond the carrying capacity and vegetation was severely damaged. It is suggested that the constancy of stocking rate has been the main reason for regional rangeland degradation. Consequently, adjustment of stocking rate according to climate (rainfall) driven fluctuation in carrying capacity is very important for the rangeland restoration in the area.

**Key words:** cumulative grazing impact, degradation, desert steppe, Ordos Plateau, rangeland, stocking rate.

### INTRODUCTION

Rangeland degradation may be defined as the loss of utility or potential utility or the reduction, loss or change of features of rangeland ecosystem which cannot be replaced (Chrisholm and Dumsday 1987). In general, rangeland degradation implies a reduction in rank or status, which includes a loss of top-soil, a change to a simple floral/fauna composition or a transition from one organic form to a lower organic form, and continuous reduction of productivity/biomass of the ecosystem. Generally speaking, a lower biological diversity is supposed to occur in a degraded rangeland, but there is still much research work to be done for the issue. In the view of ecology, degradation can be treated as retrogression of an ecosystem, and recovery of degraded rangeland as secondary succession (Numata 1969). The difference between degradation and fluctuation can be found in their temporal scales and resilience (e.g. Archer and Stokes 2000).

Once rangeland has been degraded, it is often possible to rehabilitate it and thus restore it to a level of utility, possibly not as good as its original state, but better than it was in its damaged state (Ludwig and Tongway 2000; Thurow 2000). Given satisfactory perception of the threat, funding, technology, and organization, degradation,

whatever the cause, would be reduced. Rangeland restoration implies the increasing grazing rate to a standard matching that which it originally had.

Rangeland degradation is the most extensive among the major types of current landuse. Few countries have less than 50 percent of their pastoral lands degraded (World Bank 1992). Overgrazing by livestock is the principal land problem in the arid and semi-arid regions, coupled with landuse change to cultivated farmland in the many countries short of farmland (Barrow 1991). The high percentage of the world's rangeland that suffers from over use stems from the extensive, low intensity character of pastoral land use, the slow response to land management changes in arid climates, and the social and economic problems associated with reducing livestock numbers on heavily used rangelands (Narjisse 2000). Reducing populations of cattle, sheep, and goats among people living on the margin of survival cannot be done without providing other sources of livelihood and that is rarely available. China has a markedly higher percentage of degraded rangelands than the countries in the same latitude, primarily because of the heavier grazing pressure and the conversion to farmland (Jia 1995). Investigations have shown that more than 70% of the Ordos grassland is degraded and undergoing retrogressive succession. The community composition is being simplified, good herbage species are being reduced, production is declining, and environmental conditions are worsening.

## THE STATE AND FUNCTION OF THE ORDOS RANGELAND

### *Landforms and landscapes*

Located at the northern part of China, the Ordos Plateau is bordered by the Yellow River in the west and north, and the Loess Plateau in the south. The plateau can clearly be divided into four parts according to landform and landscape; the Jungle Loess Hills in the east, the Kubuqi and Maowushu Sandy Land stretching north to south, the Wsheng Basin in the center, and a dry plateau in the west (Shi 1991). These four landforms and landscape units are covered by true steppe of *Stipa bungeana*, shrubs of *Artemisia* spp., salt meadows and marshes, and desert steppe of *Stipa breviflora*, respectively (Jia 1995). The great variation of landform and landscape make the plateau featured by a higher ecosystem diversity than most of the other regions (Li 1995) (Figure 1).

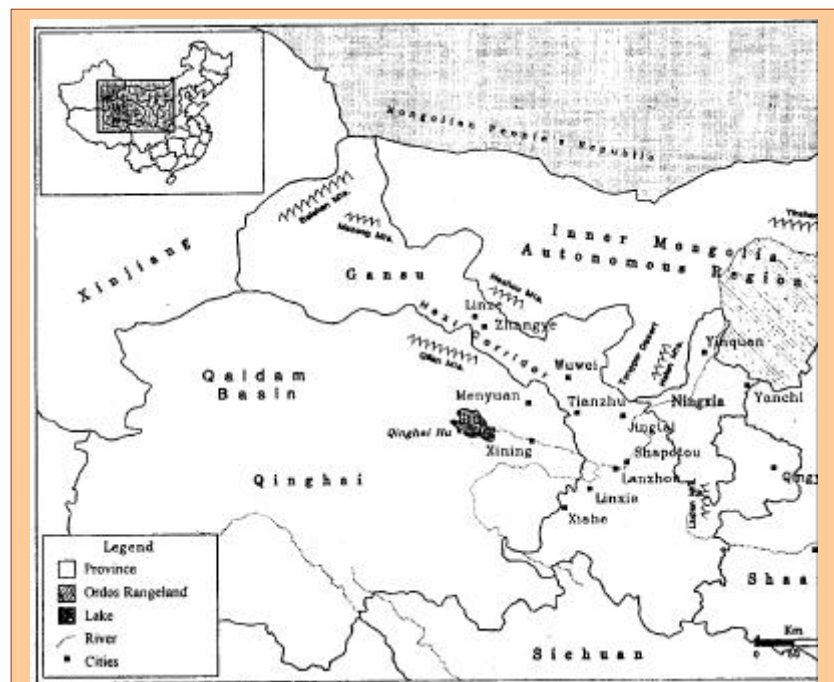


Figure 1. Location of Ordos Plateau.

### *Climate*

The climate in the Ordos region is characterized by cold -dry and hot-wet seasons. The average annual rainfall of 200–450 mm is distributed from June to September. The fluctuation of annual rainfall is another main feature in the region. In 28.7% of the years annual rainfall drops to 100–150 mm or lower (Table 1) (Yang et al. 1990). The high temperature in the hot season is responsible for the high rates of potential evap o-transpiration in relation to rainfall. The ar idity ratio in Ordos rangeland ranges from 1.5–3.4 (Yang et al. 1990).

**Table 1.** Fluctuation of aridity ratio in Ordos. W, M, D represent wet year, median year and drought year separately.

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Otok	M	W	M	D	D	W	M	M	D	M	D
Jungle	D	W	D	D	D	W	M	W	M	W	D

### *Soil erosion*

Chinese grassland scientists have developed advanced approaches for soil inventory in Inner Mongolia grasslands. Remote sensing and field research have shown that features of soil erosion in Ordos include: (1) larger areas with soils transformed by “sa nidization” (shahua); (2) deterioration of the physical properties of soil components, such as declining soil structure and soil water status; (3) decline of soil fertility and organic matter; (4) overall increase in the area of salinization and swamping; and (5) intensification of soil erosion (Li 1990, Jia 1995). According to Li, degradation of grass cover is the most important cause of soil erosion in the natural grasslands. O ver-grazing and trampling by livestock are the main reasons for the loss of grass cover, but the construction of roads, and other activities also play a role.

### *Population and landuse*

Man has influenced the structure of Ordos rangeland vegetation through agr icultural and industrial activities and the introduction of planted woodland. Growing human population was often accompanied by increased grazing pressure on the regional vegetation. The rise of urbanization and industrialization during the last four decade s further intensified these activities. Open coal mining and the harvesting of plants for the Chinese medical industry have also caused serious problems. The present landuse pattern in Ordos rangeland is a reflection of these human pressures (T able 2).

It has been argued that all the Ordos rangeland today has been subjected to agr icultural practices, such that its structure and plant species composition have been a ltered and probably greatly simplified (Gressey 1933, Shi 1991). The impact of sem ipermanent cultivation on Ordos rangeland has been greater since the turn of this ce ntury. From 1922–1937, from 1958–1962 and from 1967–1972 about 15–20% of Ordos rangeland were converted to cropland, most of which was abandoned in the next 5–10 years due to soil erosion and the adjusting of local policies. Frequent fluctuation of climate together with with fragile loess and sandy soils made the surface susceptible to erosion. Because of water and wind erosion, these abandoned croplands recover

very slowly and add to degraded rangeland. There is a village named Kuizhinao where 300 ha of the rangeland were converted and cultivated with potato and bean in 1956. After a continuous drought in the following two years the converted cropland was converted again into sandy land (Tang 1994, personal communication).

**Table 2.** Change of landuse pattern in Ordos from 1960 to 1985.

Landuse	Otok		Wushen		Jungle	
	1960	1985	1960	1985	1960	1985
Farmland	0.49	0.45	2.52	0.88	13.69	15.09
Woodland	0.37	1.21	3.79	12.98	5.67	16.62
Rangeland	86.85	83.44	62.45	52.04	62.32	35.32
Industry	1.16	0.64	0.21	0.22	0.66	0.70
Wetland	0.65	0.57	1.04	0.87	2.81	2.74
Bare land	8.90	13.70	27.23	33.01	13.39	29.54
Total	100	100	100	100	100	100

Besides being used as grazing land for cattle, sheep, and goats, Ordos rangeland is also a source of many useful wood and non-wood products. During the rainy season the rangeland produces up to 50 species of edible herbs (such as *Scorzonera divaricata*, *Allium mongolicum*) and mushrooms although herb and mushroom collection has little effect on vegetation. The collection of fuelwood (mainly *Artemisia ordosica*, *Caragana intermedia*) and medical plants largely contributes to rangeland degradation.

Although the living standard of local people has been greatly improved, and coal and electricity has been widely available for household energy for the last three decades, a certain portion of the rural population in the Ordos region is still partly dependent on firewood for cooking and heating due to traditional customs and lack of money. The plants used as firewood are mainly shrubs and semi-shrubs. Shrubs are usually cut with axes at about 10 cm above ground by either clear or selective felling, but in many other cases roots are also excavated. It was estimated that an average of 2–3 ha of rangeland shrubs were cleared per household each year in western Ordos in the 1970s. In 1979 4,500 t of *Artemisia ordosica* were burned in the region (Local statistic data 1992) with considerable effects on rangeland structure.

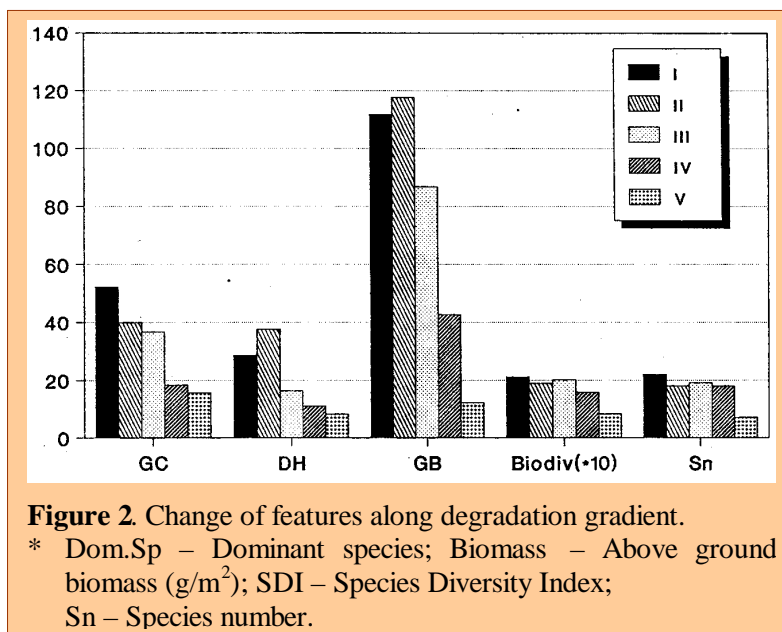
Ordos rangeland produces many medical plants which are valued in both traditional Chinese medicine and modern medical science. *Ephedra sinica*, *Glycyrrhiza uralensis*, *Bupleurum chinensis*, and more than 40 other species of medical plants occur widely in the rangeland communities of the region. Because the roots of medical plants are usually the most valuable part, medicine gathering often means damage to both the plants and the topsoil. According to this author's investigation, gathering one single *Glycyrrhiza uralensis* will cause the damage of 4 m<sup>2</sup> of soil.

#### DESIGNING OF THE SPATIAL ECOLOGICAL SERIES PLOTS

The study area of this long-term ecological research project is the Ordos Plateau in Inner Mongolia. The ultimate objective of the studies discussed here was to estimate change of plant species composition and above-ground biomass of rangeland in the

absence of stress and to examine the effect of disturbance by human impact and grazing by domesticated livestock. The data upon which this paper is based include a series of permanent plots of desert steppes along the gradient of intensities of grazing and human impact.

Originally we designed a series of experiments that included different intensities of grazing, human activities, and soil erosion. We had various numbers of plots, lines, soil cores or other sampling units within the series. Changes can be seen in Figure 2. Plot number represents progressive stages of stress. For example, DS-1 is the plot with no disturbance while DS-5 is the one with heavy disturbance.



### CHANGING OF BIOTIC AND ABIOTIC FACTORS ALONG THE DEGRADATION SERIES

The study begins with the analysis of the changing of structure and function of rangeland ecosystem along a series of desert steppe plots (Figure 2). Based on the analysis of change of rangeland features on different scales, three groups of variations are selected: rangeland status, natural impact, and human impact. Results of multi-factor impact analysis suggested that there are obvious changes in plant biomass, floristic composition, species diversity, soil moisture and other factors along the degradation gradients.

#### *Plant biomass*

Generally, total above-ground biomass is gradually reduced along the disturbance series, i.e., the heavier the disturbance, the less above-ground biomass. In the gradients, estimates of above-ground biomass in the absence of grazing ranged from 42.3 to 134.1  $\text{g}/\text{m}^2$  from sites to sites, but the peaks of biomass occur at a certain stage where vegetation is under light grazing. It is suggested that light disturbance can help to reduce the cover of dead shoot and help the regrowth of plants, mainly forbs, in the spring in desert steppe condition. This could perhaps also be related to the release of nutrients that would otherwise accumulate in litter on topsoil (Coupland 1979). In the middle and heavy grazed condition, above-ground biomass was reduced in almost all sites. The data also suggested that the proportion of perennial biomass reaches peak values at ungrazed plots, and then declines along the degradation series.

It is argued that grazing time and intensity strongly influence animal performance, vegetation regeneration, protection, and future production from these grassland. The later tillering stages of grasses and branching in early flowering stages of legumes are

the best time for grazing to begin. After a period of grazing, the grasses should be allowed to regrow at least 15 cm before further grazing. Liu (1990) recommends that grazing be forbidden during the first 12–18 days after the grass turns green in spring and for 30 days after the cessation of growth at the end of the season.

### Plant species composition

The botanical composition of rangeland changed greatly along the spatial gradient; in the ungrazed condition the steppes were dominated by palatable perennial grasses, such as *Stipa breviflora*, *S. bungeana* and *Cleistogenes squarrosa* (Figure 3). But in the middle-heavy disturbance condition, invading species were common, especially annual plants, such as *Setaria viridis*, *Peganum harmala* and *Artemisia scoparia*.

These species are probably successful invaders under grazing because of abundance of their seed in the soil, and favourable fertility conditions.

Grazing and other disturbances greatly affected the floristic composition, especially the dominant species of the sites. In the desert steppe sites, under light-middle disturbance the dominant species of *Stipa breviflora* was replaced by *Artemisia songorica*, which was later replaced by *Peganum harmala* and *Eragrostis poaeoides* under heavy disturbance. The effect of grazing on floristic composition appears to be greater in desert steppe and sandy vegetation than in salt meadows and true steppe. In true steppe sites, the obvious change of dominant species occurred only under heavier disturbance. This differential effect of grazing may be associated with the degree to which the composition of plant water tolerance type is modified by grazing. We have already noted a marked trend towards meso-species in grazed areas in drier sites that is not present to the same extent eastward (where xero-species are less important constituents of the vegetation). It is probable that there is an interaction between water supply and grazing (Parsons et al. 1983).

### Species diversity

Species diversity (Shannon-Wiener Index) was also impacted by grazing and other disturbance. Species diversity index was reduced by 30% as a result of heavy grazing. At some steppe sites, the species diversity index increased slightly under light-middle grazing pressure and reached its peaks at stage II or even III (Figure 4). It is suggested that certain disturbance can reduce the dominance of current dominant species and create more opportunities for the individuals of different species to live together in a

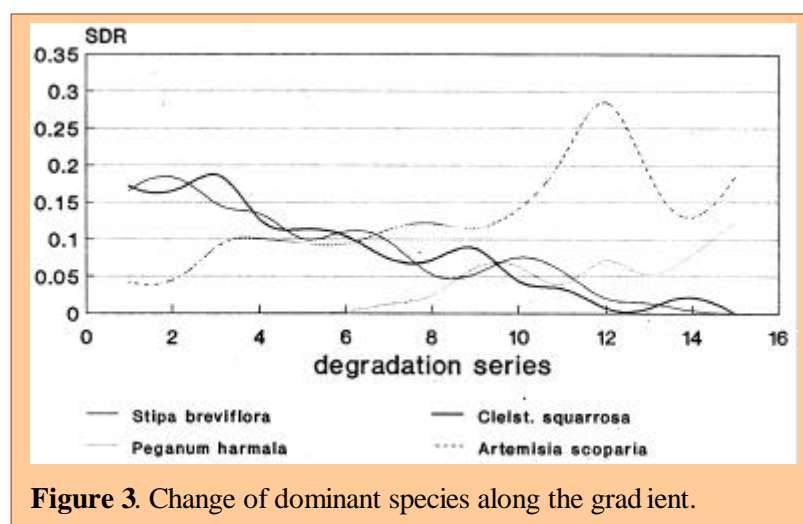


Figure 3. Change of dominant species along the gradient.

more humid condition, but in drier condition forb species are usually reduced with perennial species (Hustor 1979).

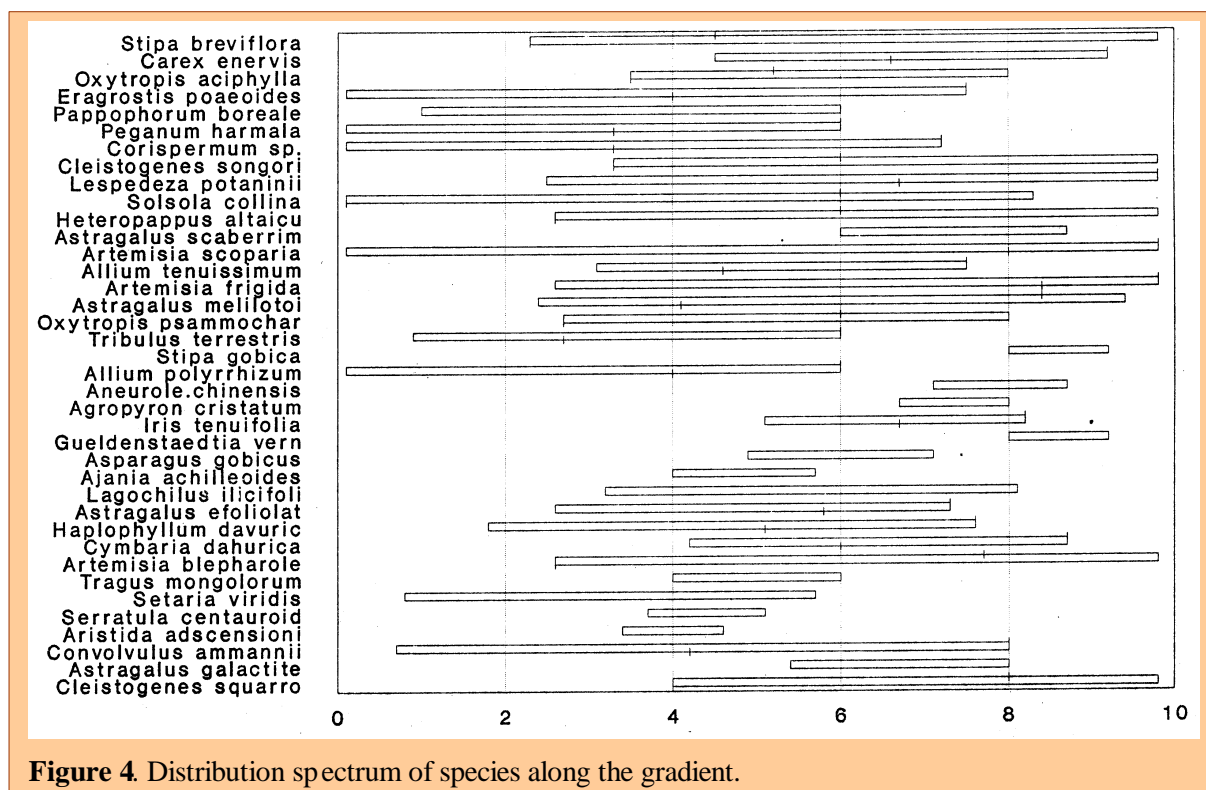


Figure 4. Distribution spectrum of species along the gradient.

### Soil moisture

There were no significant differences in soil moisture along the degradation gradients. Seasonal change in soil moisture was the most pronounced feature of the soil moisture regime in the Ordos rangeland. Mean soil moisture ranged from 3.8–7.5% in the desert steppe site to 15.2–32.9% in the salt meadow site during the rainy season (June–October). Although grazing has no significant impact on top soil moisture regime, there was evidence that this affected the bottom soil moisture regime. In the sites, the bottom soil moisture was lower at the heavy grazed plots than at the light grazed plots during the rainy season. This suggests that perennial grasses such as *Stipa breviflora* and *Cleistogenes songorica* use more water in the upper bottom soil while the invaders such as *Artemisia songorica* use more water in the lower bottom soil. The pattern of moisture recharge reflected this differential utilization of soil moisture between grazed and ungrazed plots. Generally, the soils at the opened plots had lower moisture and higher bulk density than those at other plots.

### CONCLUSIONS AND DISCUSSION

Results of multi-factors impact analysis suggest that heavy grazing can alter the species composition of rangeland sites to annuals and sometimes small shrubs. Most of the damage to range resources occurs because of combined effects of overgrazing and drought. Heavy grazing alters community structure by eliminating species that are less resistant to grazing and promoting resistant species, thereby reducing diversity. Drought never removes a dominant species entirely. Recovery following drought is

more rapid for lightly or moderately grazed range than for heavily grazed range. One of the main conclusions from the analysis is that, in general, we have a very non-linear system. The responses of rangeland to these disturbances, nature-induced or human-induced, are very non-linear and somewhat shown as cumulative environmental change. Linear projections can not be made unless for some special controlled components.

In the study area, yearly mean overgrazing rate is lower than 20%, even negative in some cases, but when rainfall becomes less than average, the stocking rates are far beyond the carrying capacity and the vegetation is badly overgrazed. Many perennials are destroyed and progressively replaced by unpalatable species. It is suggested that constant stocking rate, accompanied by fluctuations in carrying capacity of the land may be the main reason for regional rangeland degradation. The decreasing of stock diversity is another reason (Bell 1971, Jia 1996).

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