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Rangeland degradation and restoration management in China

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Abstract. Rangelands of China have for centuries provided forage for livestock but now their role in water, soil, and biodiversity conservation is being recognised by Governments and people. However, much of the rangelands has recently degraded and desertification is now a widespread problem. The cause of the degradation is over-grazing and over-cultivation. Climate change is exacerbating the problem. The Chinese Governments have begun to address these severe problems through policy adjustments and projects. In parallel, some research and development is taking place. There are major impediments to addressing the problem; the importance of rangelands to China and its people are generally underestimated, legislative protection is incomplete and often ineffective, little attention is paid to scientific knowledge for development of management of natural resources, there is insufficient technological support, and Governments are not able to invest sufficiently to effectively restore and develop rangeland natural resources. However, with this background we propose how the problems might be more effectively addressed in the future.

Additional keywords: desertification, development, environment, grasslands.

Introduction

China is second in the world, just behind Australia, in area of rangelands. There are 400 million hectares of rangelands, of which 313 million hectares can be grazed. China rangelands are 41.7% of the land area (Ren *et al*. 2008, this issue) and on a world scale are 11.8% of the world's rangelands (Zhao *et al*. 2005). The climate within China ranges from tropical to cold temperate to permanent ice and together with the large variation in soil types, is home to rich plant and animal diversity and ranks China as the second most species diverse rangeland area in the world (Animal Husbandry and Veterinary Medicine Division of Ministry of Agriculture of China 1996). As such the rangelands of China are a very significant repository of genetic resources and of natural grasslands and other diverse plant communities. However, the area of degraded rangeland is now very large. This has come about by over-population, over-grazing, improper reclamation and adverse effects of droughts exacerbated by climate change (Li *et al*. 2008, this issue). Rangeland degradation in China and the increased frequency of sand and dust storms, particularly in Beijing have attracted world attention. Since 2000, the Central Government has invested in projects to restore degraded and dysfunctional rangelands and to generally better protect rangeland resources.

In this paper, we review rangeland degradation and restoration management in China. Our aims are to evaluate the condition of China rangeland, analyse the causes of degradation, and review the restoration efforts undertaken by the Governments.

Rangeland degradation

Degradation and desertification

We define degradation as a decrease in plant species diversity, plant height, vegetation cover and plant productivity. Recently, degradation has also come to mean deterioration in ecosystem services and functions, such as decreased water and soil conservation, recreation values, carbon balance and so on (Ren 1985). Rangeland degradation is thought to have begun in China by the late-1960s, and since then the area degraded has increased by 15% each decade (Wang and Han 2005). However, in the last 10 years the area degraded has risen from 55% to over 90% (Lu *et al*. 2006). A recent survey revealed that 91% of temperate typical steppe and 91% of desert steppe were degraded but the temperate meadow rangeland was not so severely affected (Table 1).

The pastoral zone rangeland comprises 49%, the semi-pastoral zone rangeland 15%, and the agricultural zone rangeland 36% of China's rangelands (Animal Husbandry and Veterinary Medicine Division of Ministry of Agriculture of China 1996). It is the agricultural and semi-pastoral rangelands that are the most degraded and together account for 90% of the degraded rangeland (Han *et al*. 2004; Lu *et al*. 2006; Huang *et al*. 2007).

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Table 1. Percentage of rangeland types in different degradation states (Lu *et al.* 2006)

Rangeland type	Number of samples	None	Light	Moderate	Heavy	Extremely heavy
Lowland meadow	483	21.6	8.7	54.2	15.5	0
Cold alpine meadow	792	14.8	9.5	43.9	31.8	0
Cold alpine steppe	681	30.8	5.3	22.5	41.4	0
Temperate meadow grassland	1059	83.0	8.8	3.1	5.1	0
Temperate typical steppe	615	9.8	10.7	26.8	37.6	15.1
Temperate desert steppe	1095	9.6	15.1	43.0	25.7	6.6
Temperate desert	1623	13.3	28.7	35.1	20.5	2.4

Diversity and productivity

The major evidence for rangeland degradation in China is lowered plant productivity and biodiversity, increased frequency of rodent and grasshopper infestations, and of large scale dust storms (Chen and Wang 2000; Lu *et al.* 2005). Lowered plant diversity is commonly used in China as an indicator of rangeland degradation. For example the climax rhizome grass meadow steppe community in Inner Mongolia province (see Wang and Ba 2008, this issue) is dominated by *Leymus chinensis* (Trin.) Tzvel. and *Stipa grandis* Roshev. but when degraded these dominant species are replaced by low palatability grasses and shrubs (Li and Wang 1999; Wang and Li 1999; Chen *et al.* 2003). The degree of degradation is directly proportional to stocking rate (Wang *et al.* 1998), and is associated with loss of high quality forage plants and increases in poisonous and other plants harmful to livestock health. The aboveground net primary productivity (ANPP) of rangelands overall is now 30–50% lower than 50 years ago (Alima and Cai 2002; Chen *et al.* 2002; Cui and Cui 2005). The economic consequence of this widespread degradation of rangelands is enormous and has been calculated to be 15–20 Yuan/ha.year (Wang and Han 2000). Landsat images have revealed that saline affected rangeland is increasing at a rate of 2000 km^2 per year (Wang *et al.* 2006).

Ecosystem services and function

Rangelands of China provide essential ecological services to the nation in several major ways; they are the largest area of natural vegetation and ecosystem for sequestering carbon and fixing nitrogen, they are the source of three major rivers in China and are a genetic bank for plants and animals. The dust storms that have increased in frequency in recent years and polluted major population centers in north-east China (Shi *et al.* 2004) largely arise from arid rangeland in central Inner Mongolia (Lu *et al.* 2005). Here overgrazing has reduced plant cover and exposed the soil surface. In addition to the loss of topsoil, over-grazing has also reduced root biomass thereby lowering the C and N storage capacity of the soil. By volatilisation of N and dislocation of C by erosion, huge amounts of C and N previously stored in this grassland ecosystem are lost (Schlesinger *et al.* 1990; Li and Chen 2004). For example, soil organic C decreased by 25% over 15 years of heavy grazing in a desert steppe ecosystem in northern China (Fu *et al.* 2004). Removal of large herbivore grazing from this desert steppe, significantly increased soil organic C levels (Zhang *et al.* 2006). Other functions of rangeland ecosystems are weakened by over-grazing and livestock production may no longer be tenable (Xie *et al.* 2001).

Causes of rangeland degradation

General

Rangeland degradation, a worldwide problem, is serious in China, especially in northern China. In mesic north-east China, conversion of rangeland to cropland is the leading cause. In the arid north-west, wood harvesting and over-grazing by livestock are the main causes (Committee on Scholarly Communication with the Peoples' Republic of China and National Research Council 1992). In recent years, climate change has exacerbated the problem (Bai *et al.* 2004). Cai (2000) calculated that the proportions of desertification attributable to each known cause in northern China were; deforestation 32%, over-grazing 29%, cultivation 23%, excessive improper water use 9%, sand dune expansion by wind 6%, and communication construction 1%.

Climate change

Rise in temperature and fall in rainfall has been measured at the Inner Mongolia Rangeland Ecosystem Research Station in the last 20 years (Fig. 1). With temperature increase has come more dry and windy periods and hence increased erosion events (Chen *et al.* 2003). As such the arid rangelands are non-equilibrium systems and management based on this paradigm should be opportunistic (Westoby *et al.* 1989; Ellis and Swift 1988; Oba *et al.* 2000; Briske *et al.* 2005). Traditional management has assumed an equilibrium system but this is no longer appropriate, especially since there is ongoing climate change (Li 2007).

Over-grazing

Over-grazing of rangelands is a problem worldwide and China is no exception. For example, in Inner Mongolia the livestock numbers increased significantly from 1994 to 2006 with sheep numbers almost doubling (Fig. 2). In China the number of livestock grazing rangelands increased from 11.9 million in the 1950s to 61.3 million in 2001. The current large herbivore numbers on China rangelands are equivalent to 89.4 million sheep and this is double the number considered to be the safe carrying capacity of 44.2 million sheep (Chen *et al.* 2003). In some arid rangelands over-grazing is as high as 50–120% and even 300% (Lu and Ci 1997). One third of the Xilinguole rangeland of Inner Mongolia Province is degraded as a result of livestock increasing from 2 million in 1977 to 18 million in 2000 (Wang and Han 2005).

Soil cover, water infiltration, and soil structure are well known to adversely change with over-grazing especially in arid rangelands (Horn and Fleige 2003; Fu *et al.* 2004). In six

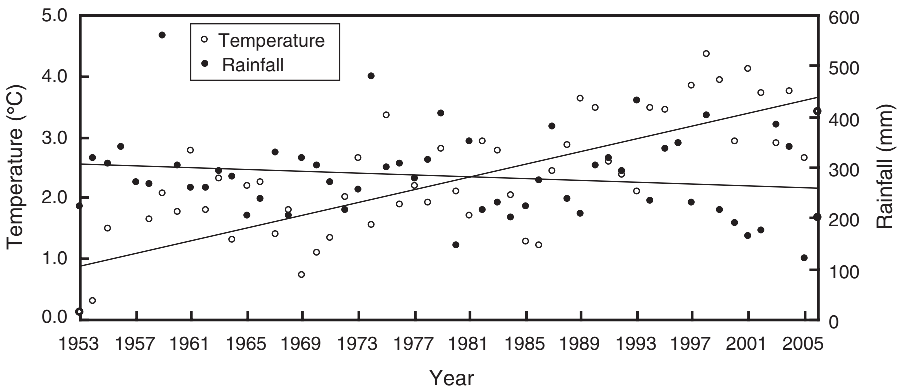

Fig. 1. Average annual temperature and rainfall at the Inner Mongolia Grassland Ecosystem Research Station during 1953–2006. Lines were derived by linear regression.

rangeland Provinces the proportion of degraded rangelands rose between 1990 and 1999 due to over-grazing (Table 2).

Cultivation

Over many decades large areas of rangeland has been converted to cropland. It is estimated that the area of rangeland converted to cropland in the fifty years between 1949 and 1999 was 19.3 million hectares, and that 18.2% of China's current cropland was derived from rangeland (Han *et al*. 2004). It is assumed all cropland in the agro-pastoral region was historically rangeland (Ren *et al*. 2008, this issue). Currently, more than half the rangeland (50.8%) is distributed in the agro-pastoral and agricultural regions in China (see Hou *et al*. 2008, this issue). Often the conversion to cropland fails, especially in arid rangelands where 30% to 80% of the cropland degrades and is then abandoned (Li 1999).

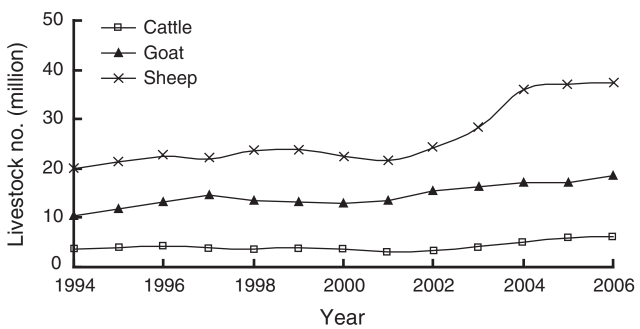

Fig. 2. Livestock numbers from 1994 to 2006 in Inner Mongolia (derived from the Inner Mongolia Rural Economy Statistical Yearbook, from 1994 to 2006).

Table 2. Percentage of rangeland in selected Provinces which was estimated to be over-grazed and/or degraded in 1990 and 1999 (Lu *et al.* 2006)

Province	1990		1999	
	Over-grazed	Degraded	Over-grazed	Degraded
Tibet	none	14	30	15
Inner Mongolia	none	40	32	60
Xinjiang	none	0	60–70	65
Qinghai	none	17	31	39
Sichuan	none	24	13	28
Gansu	none	40	35	50

Restoration of rangeland

Governance

Rangeland restoration is now a goal of Government. The first major attempt to improve the rangelands and their management occurred in 1985 with the enactment of the Rangeland Law. This law prohibited activities understood to damage rangelands and empowered Provincial Governments to prevent unauthorized cropping, to order restoration of damage and to impose fines for serious breaches. Rangeland monitoring and management departments were established within the Animal Husbandry Bureau. Since 1990 the Government and related sectors, have enacted a series of policies and regulations to protect the environment and resources of rangelands (Table 3).

Research

Research to understand the mechanisms of degradation is occurring. It is argued that unless the mechanisms are understood,

Table 3. Policies and programs enacted by the Central Government related to rangeland management in China (Hong 2006)

Year	Policies and programs
1985	The Rangeland Law
1999	The Conversion of Cropland to Forest and Grasslands
1990–2000	Wild Flora Protection Regulation
	Desertification Prevention and Control Law
	Nature Reserves Act
	Agricultural Flora Management Measures
2001	Bill on Liquorice and Ephedrine Collection
2002	Bill on Enhancement of Protection and Construction of Grassland
2003	The Rangeland Law (amended)

restoration will be more costly and likely to fail. Grazing weakens the ability of grasses (Wang *et al*. 2000) and plant communities to withstand stresses, biomass decreases (Li and Wang 1999; Zhao *et al*. 2005), and spaces relinquished by plant death are often taken by unpalatable plant species.

Species richness decreased with grazing intensity. The changes in evenness contributed more to the rate of change in diversity than the change in species richness (Yang *et al*. 2001). Yuan *et al*. (2004) found that summer grazing differed from winter grazing in the plant species number recorded in alpine meadows of Qinghai. Summer grazing increased species as the grazing intensity increased. Winter grazing increased species number up to moderate grazing pressure and then there was a decline at high grazing pressure. Zhu *et al*. (2006) found a similar response.

There has been a concerted effort to breed new grass cultivars and develop guidelines for rangeland resource evaluation, rangeland utilisation, disease and pest management, sown pasture development, forage processing and rangeland livestock management. The benefits to farmers and pastoralists have been considerable (Hong 2006). By the end of 2001, 232 herbage varieties had been evaluated and registered (Su and Zhang 2002). A national database for herbage diseases and pest management was established at Lanzhou University (Chen and Ren 2004).

Continuous heavy grazing accelerates soil erosion by wind (Faraggitaki 1985). The desertification process was found to involve an increase in the amount of bare ground. It is now agreed among scientists that excluding livestock from severely degraded rangeland is required for restoration (Chen *et al*. 2003; Su *et al*. 2005).

Defining safe stocking rates for particular rangelands has been identified as an important objective for research (see Wang and Ba 2008, this issue). Grazing experiments on rhizome grass meadow steppe showed 1.3 sheep/ha was the upper limit for safe stocking rate (Wang *et al*. 1999; Li and Wang 1999; Wang, 2000; Liu *et al*. 2004). Mixed species grazing and seasonal grazing of these rangelands, if used wisely, should raise the safe stocking rate limit (Yu *et al*. 2004).

Fertiliser, irrigation and reseeding of degraded rangelands bring short-term benefits (Yao *et al*. 1997; Guo *et al*. 2006). However, these treatments, because of high costs, are limited to small areas and the lack of capital. It is problematic whether these high inputs are sustainable and profitable.

Management after a restoration treatment to degraded rangeland should be directed at the maintenance of reseeded species etc. Treated areas may need to be protected from grazing for at least one year following good rainfall, while in the second and third year, the areas should only be grazed lightly (Snyman 2003).

In another paper in this collection, Wang and Ba (2008, this issue) reviewed research on meadow steppes and identified several key areas for future research including plant adaptation, grassland function and value, monitoring of range health, and ecological consequences of climate change on biodiversity and ecosystem function. Fundamental research on these key areas for other rangeland types (Ren *et al*. 2008, this issue) is required to protect and restore the more fragile rangelands, especially in arid and semi-arid zones.

Projects

Over recent years there have been several international cooperative projects for the arrest of rangeland desertification and restoration of degraded rangelands, including China-Canada, Sino-Australia, China-Japan, Sino-German, China-Korea projects. These have operated in Xinjiang, Gansu, Inner Mongolia and Jilin Provinces. The World Bank has also contributed to the rangeland and livestock production improvement in rural areas in the northern rangelands. By the end of 2004, there were 11.3 million ha of sown pastures, 13 million ha of improved pastures, 30 million ha of fenced rangelands and 450 000 ha of grass seed fields around the country as a result of the projects (Hong 2006).

Various restoration techniques are used in projects. Grazing exclusion and rotational grazing systems are commonly used to protect rangeland from grazing. Exclusion never exceeds three years. Most investment in range improvement since 2000 has been for fencing (Zhang and Du 2006). The potential of rotational grazing systems for restoring degraded rangeland has yet to be exploited (Han *et al*. 1990). Nomadic herders practiced rotational grazing in the past. This balance between livestock numbers and the forage on offer needs to be restored. In recent years, native species are being promoted for use in restoration elsewhere (Semple *et al*. 2006). In China, seed is mostly sown by hand but large areas have been sown from planes since 1980 (Liu 2001). Range management after seeding is now recognised as an important area for research. Restoration techniques such as irrigation, fertilising, surface tillage are used in the projects if available (Guo 1996). Surface flooding is the main irrigation method, but sprinkle irrigation is starting to be used where deep wells have been dug. Fertiliser is used to boost the growth of sown pastures. Fertilising by night penning on natural rangeland is common and effective, that is, the concentration of animals for two nights and then moving them to another (Zhang *et al*. 1999). Shallow tillage with a surface cultivator is used in rhizome grass meadow steppes (Hu and Zhang 2001). Restoration of rangelands can be enhanced by grazing rangeland livestock on sown pastures during drought periods (Han *et al*. 2004). A mixed rangeland system, where grazing alternates with hay production each year, has found to be productive and stable in Inner Mongolia (Susenbeth *et al*. 2008).

Development of rangeland industries

The main rangeland industries of grass seed production, forage processing and livestock production annually earn ~350 billion Yuan and employ ~50 million people (Hong 2006). More than 10 grass seed production areas have been established, and 190 forage processing enterprises have been developed with an annual production capacity of over 4.6 million tons (Hong 2006).

Strategies

There is a need to shift the focus for rangelands from economic development to the provision of ecosystem services that rangelands provide for people and nature (Li *et al*. 2008, this issue). This shift in focus will require integration of rangeland protection, development and utilisation, with economic development and ecological management. The key strategic objectives should be; establish a multi-investment fund to transform rangeland industries and to secure ecosystem services, enforce rangeland protection regulations, especially the Rangeland Law, strengthen the organisation of development of the rangeland industries, and extend investment in range science and technology. From the farmer's perspective, the relevant basic administrative units in villages should be encouraged to cooperate and support rangeland restoration programs. Incentives should also be granted to increase cooperation among herders.

Major problems to be addressed

Poor appreciation of the relationships between rangeland production and environmental protection has led to misunderstandings among herders and farmers. They require capacity building to understand that although their incomes will be reduced for a short time after switching to practices that restore the natural environment, incomes will improve in the longer term. Currently the rangeland industry comprises small businesses, large markets, and a low level of technology. It is difficult for farmers and herders to grasp a new initiative for rangeland industry development while they are caught up in the existing systems and market places. Finally, there is a lack of leading enterprises and strong brands. Without strategic planning and corresponding macroeconomic policy, the rangeland industries will not develop.

Although much effort has been invested in rangeland restoration and development, incomplete governance, low adoption of scientific management and lack of appropriate technologies, make rangeland development difficult. In particular, low investment and lack of technology transfer and extension hold back development of rangeland industries.

Perspectives

It seems to us that the importance of rangelands to the development of China has been underestimated. Rangelands have never given sufficient support; they have been exploited by overuse, not protected and undercapitalized for a long time. Protecting the rangelands from further degradation, and restoring those rangelands that are degraded are complicated and socially demanding projects. We suggest that the way forward is to focus on the *functional transformation of rangeland* and the *production style transformation of pastoral areas*.

Functional transformation attaches more importance to the ecological functions than to productive functions of rangeland. *Productive style transformation* is directed towards changing the traditional and extensive grazing style into more intensive rotational grazing or modern stall-feeding. Whether exclosure or self-recovering measures widely used at present, or the grazing ban and grazing-rest policies, are successful depends on a sound understanding of ecological processes, such as plant community succession. Such measures, if appropriately applied, can prevent crossing of critical thresholds to less desirable range condition states, strengthen self-organizing and self-regulating ability of the ecosystem, and increase plant diversity.

Establishing productive and high quality pastures is an effective way of alleviating grazing pressure at critical times for the rangeland and to prevent environmental deterioration. Forage plantings and stock-breeding, especially establishing pastures with stable and highly productive varieties, are effective ways of alleviating the pressure on natural rangelands (Hou *et al*. 2008, this issue). Using sown pastures is also an important practice to solve the imbalance between forage and livestock on rangelands. To complete the production chain, modern feedlots, stockbreeding centers, modern processing plants, and marketing procedures are required along with technical institutions and rangeland research facilities.

Conclusion

The achievement of sustainable rangeland ecosystems remains a challenge for China; rangeland degradation has not been arrested and the ecosystem services provided by the rangelands are not valued by the people in general or Governments in particular. The stresses imposed on rangeland by livestock production continue to rise, driven by rapid economic development and growing demand by urban people for more meat in diets. The tension between production and the health of the environment is not China's problem alone; it is shared by people throughout the world in this 21st century. It is time in China to focus research and development on sustainable rangeland industries and to develop regional strategies for connecting grazing/cropping/forage systems that relieve disturbance of rangelands and permit the repair of stressed and dysfunctional rangelands.

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