Grassland Degradation and Our Strategies: A Case from Shanxi Province, China

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Introduction

Grasslands cover 41% of the earth's land surface and provide livelihoods for nearly 800 million people. Additionally, grasslands provide forage for livestock, wildlife habitat, carbon and water storage, renewable energy, recreation, and tourism. Grasslands also remain the primary source of genetic material for improving our food crops and for an increasing number of pharmaceuticals.[1,2] The health of the world's grasslands is declining largely due to human-induced modifications, such as agriculture, overgrazing, excessive use of fire, fragmentation of areas, and urbanization.[3] A recent study by the World Resources Institute to gauge the impact of human activity on grasslands found that a major reduction in the extent of grasslands has occurred in many areas.[4] For example, only 9.4% of North America is now covered by grasslands, and only 20% of Latin America.[4] Because of their contribution to human welfare, management of grasslands has become a more important part of environmental management worldwide.[5,6] Most research has focused on productivity, biodiversity, and the effects of grazing. Our understanding of grassland degradation includes its causes, mechanisms, restoration, and management but is not sufficient, particularly for grasslands in China.[7–10]

In China, grasslands cover more than 40% of the total land area, with 84% of that being located in western China.[11–13] Grassland is the largest terrestrial ecosystem of China, much of it semiarid and high plateau pastoral land. Grassland is the base of national animal husbandry, and is closely related to the food production of China. However, China's grasslands are being subjected to many negative forces and rapid change. According to Miller, estimates suggest that about 34% of all rangelands in China are moderately to severely degraded and about 90% are degraded to some degree.[14] Therefore, the management of grassland in China is extremely significant. This paper analyzes the present state of grassland degradation and its management strategies for the future, using Shanxi Province as an example.

Definition of Grassland Degradation

Grassland degradation can be defined as a kind of desertification. The desertification can be defined as land degradation in arid, semiarid, or dry areas because of climate change and human activities. The results of desertification are the reduction of biological and economic productivity or the decrease of biodiversity for cropland, grassland, and woodland, including the loss of soil substance, change of soil structure, and disappearance of natural vegetation.[15] In fact, grassland degradation is a retrogressive succession of grassland vegetation.[2,13]

Problems of Grassland Management

Grassland degradation has gradually increased in severity since the 1970s in China. The area of natural grassland is gradually shrinking and the quality is degrading. The capacity of grassland to feed animals is decreasing and most of the grasslands are being overgrazed. The productivity and biodiversity of grasslands are gradually decreasing, as is environment quality, which seriously threatens the sustainable development of China. Currently, 90% of the grassland is being degraded to varying extents,[2,13,16] among which the area of the grassland with serious degradation accounts for more than half of the total. The area of seriously degraded grassland has reached 185 million ha, and is increasing at an annual rate of 2 million ha.[7,17]

Table 1. Ecological types of grasslands and their characteristics in Shanxi Plateau

No.	Grass-land types	Areas (10⁴ ha)	% of the total grass-lands	Distribution and characteris-tics	Eleva-tion (m)	Produc-tivity (t/ha)	Keeping live-stock (sheep/ha)	Main species
1	Temperate steppe grassland	44.0	11.69	low mountain and hills in north and northeast Shanxi; chestnut and loess soil	< 1,500	3.10	270	*Stipa bungeana, Thymus serpyllum, Cleistogenes chinensis, Cleistogenes squarrosa, Astragalus scaberrimus, Polxgala tenuifolia, Artemisia vesti-ta, Lespedeza davurica, Agropyron cristatum, Gueldenstaedtia multifiora*
2	Temperate scrub–grassland	140.1	37.22	low hills in south Taihang, Luliang Mountains, Qinxian, Qinyuan, Zuoquan Mountains; cin-namon soil with bare rocks	800–1,700	4.21	150	*Bothriochloa ischaemum, Themeda triandra var. japonica, Vitex negundo var. heterophylla, Hippophae rhamnoides, Poa annua, Zizyphus juju-ba var. spinosa, Heteropappus altaicus, Roegneria kamojiohwi*
3	Temperate grassland	60.51	16.08	wide area south of Hengshan Mountains; cin-namon and mountain cinna-mon soils	1,300–2,000	5.0	190	*Bothriochloa ischaemum, Arundinekka hirta, Artemisia spp., Pao spp., Carex lanceolata, Themeda triandra var. japonica, Heteropappus altaicus, Elymus dahuri-cus, Festuca sp.*
4	Temperate bush land	80.00	21.26	Luya Mountains, Guandi Mountains, Guanqin Mountains; mountain cinna-mon and mead-ow soils	1,400–2,000	4.70	180	*Hippophae rhamnoides, Rosa xanthina, Lepedeza bicolor, Ostryopsis davidi-ana, Rosa xanthina, Spiraea pubescens, Artemisia spp., Carex spp., Potentilla chineen-sis, Medicago falcata*
5	Mountain meadow	37.00	9.83	cold area above forest line in Taiyue, Taihang, Luliang, Wutai, Hengshan and Zhongtiao moun-tains; meadow soil	> 2,000	6.90	75	*Carex spp., Cobresya bel-lardii, Avena fatua, Oxytropis coerul, Festuca ovina, Sanguisorba offici-nalis, Polygonum viviparum, Cleistogenes spuarrosa*
6	Temperate "Savannah" grassland	11.44	3.03	forest edge and tree windows area in all moun-tains; mountain cinnamon soil	1,700–2,400	4.37	120	*Deyeuxia arundinacea, Spodiopogon sibiricus, Vicia unijuga, Bromus inermis, Setaria viridis, Medicago falcate, Vicia amoena*
7	Wet meadow	3.34	0.89	wet land along rivers, around water reserve and lakes; wet meadow soil	240–800	3.90	105	*Calamagrostis pseudophragmites, Phragmites communis, Tamarix chinensis, Pennisetum alopecuroides, Salsola collina, Carex spp. Ranunculus tanguticus*

Photo 1. Moderately degraded mountain meadow grassland in Luya Mountains, Shanxi.

Grassland degradation is the main challenge facing grassland managers in the new century for China. To establish sustainable grassland farming in China, we have to study the cause, classification, restoration, and control strategies of grassland degradation. Here we use Shanxi Province as a case to study these problems.

Shanxi Province, a part of loess plateau, is located at N34°35′–N40°43′, E110°15′–E114°33′, and is a mountainous province in China rich in natural grassland resources. There are 3.76 million ha of natural grasslands. However, large areas of grasslands were degraded in the past few decades because of overutilization and worsening natural conditions. Over 80% of the total land area is mountainous, and most lands are over 1,000 m. The highest mountain in Shanxi is Beitai, the main peak of the Wutai Mountains with an elevation of 3,058 m, and the lowest land, with an elevation of 245 m, lies in Yuanqui County in the south of Shanxi. The area has a continental climate, being warm and rainy in summer, cold and dry in winter. The annual mean temperature varies from 8°C in the north to 12°C in the south; the mean precipitation varies from 350 mm to 570 mm. Based on the system of national vegetation regionalization, 2 vegetation regions are recognized in this province:[17] a temperate steppe region distributed in the north, and a warm temperate deciduous broad-leaved forest region in the south. The boundary of these 2 vegetation regions is the Hengshan Mountain range. Correspondingly, 2 soil regions, the chestnut soil region and cinnamon soil region, can be identified.[18]

The Causes of Grassland Degradation

There are various factors causing grassland degradation, such as long-term drought, wind and water erosion, dust storms, plagues of rats and insects, and other natural factors as well as excessive grazing, heavy mowing, transferring grassland to farmland, digging medicinal plants, mining, and other human economic activities.[8,19–20] The interactions of these factors can speed up grassland degeneration; for instance,

wind erosion of soil can lead to loss of soil water and to desertification, which could cause plagues of rats and insects.[2,8] In the literature, different authors emphasize different factors.[21,22] The grasslands have been used for a long time by human beings in northern China, but their serious degradation started only 40 years ago when population increased quickly, which implies that human activities are the main factors affecting grassland degradation.[8,23]

Almost all grasslands in Shanxi plateau are in a degrading condition.[2] Human activities are the principal factors affecting this procedure. Many grasslands in mountainous areas below 1,200 m have been reclaimed into cropland. It is difficult to find a continuous grassland in this region due to such reclaiming. The water and soil loss becomes serious and soil quality becomes low after reclaiming. The local farmers do not invest in the land by using grassland–cropland rotation farming systems; rather, they continuously grow crops, which destroys the land.[2]

Digging medicinal plants, collecting fire-grass, and felling firewood in a grassland can cause its degradation. There are many medicinal plants in Shanxi, including licorice, Huangqi, mahuang, and huangqin. Shanxi was famous for its production of licorice in 1950s–1970s, but now it is not worth it to collect this medicinal plant in this province because of extensive digging and degradation of grasslands. The diggers of licorice have moved to other provinces to continue their digging.[24,25]

In upland grasslands above 1,200 m, overgrazing is common and its influence on grassland degradation is obvious. Grassland farming in Shanxi mainly uses natural grasslands. The farmers wantonly increase the number of livestock regardless of the carrying capacity of grasslands. Excessive grazing may result in 3–5-fold decreases in grassland productivity. Soil structure is destroyed because of heavy trampling by animals, which will cause plagues of rats and insects.[22] Some grasslands cannot be used for grazing any more. In addition, the development of industry and urbanization are also factors affecting grassland distribution area and degradation.[8]

The excessive cutting of plants is another cause leading to grassland degradation. Because of limitation of transportation and difficulty in obtaining fossil fuels in some mountainous areas, the local residents mainly use biological energy.

Photo 2. Seriously degraded temperate grassland in Western Shanxi.

Mowing natural grasslands to provide winter feed for livestock is very common in mountainous areas because of the relatively long period of snow cover and the very limited area of artificial grasslands in Shanxi. These actions are detrimental to grasslands and may cause further grassland degradation.

Aside from human activities, some natural factors cannot be ignored in their role in grassland degradation in Shanxi. Frequent droughts, global warming, strong winds, uneven precipitation, and other factors all affect grassland degradation.[26] According to the climate records of the past 40 years, the change of annual precipitation in Shanxi is great, with a ratio of 46%–95% change between years. The precipitation in a rich year is 2.6–3.5 times of that in a poor year. In the years of drought, wind and dust storms, hailstones, plagues of rats and insects become frequent, which may quicken grassland degradation.[27]

Grassland Degradation in Shanxi

Grasslands are principally distributed in mountains and hills in Shanxi Province. The classification of grasslands in Shanxi has been carried out many times by using different standards.[15,23] The vegetation classification standards are the most common regulations used in grassland classification,[17] ie, the constructive species, dominant species, and compositions of plant communities are the major principles for grassland classification in Shanxi. Based on remote-sensing image data of 2000 and a field survey in 2001, 7 types of grassland can be identified according to the criteria above (Table 1).

Shanxi is one of the provinces most seriously affected by grassland degradation in north China.[21] Over 95% of grasslands in this province have been degraded to some extent.[2] By using the degradation classification system summarized in Table 2, the area and percentage of degraded grasslands for each type of grassland in Shanxi are listed in Table 3. Some examples of degraded grasslands in Shanxi province are shown in Photos 1–3.

Strategies of Controlling Grassland Degradation

From the analysis above, we can see that Shanxi's grasslands are under unsustainable utilization. Degradation of grassland is continuing and worsening. Additionally, the demand for livestock industry development is imminent because of the increasing population and desired improvement of quality of life. Local government has to pay more attention to grassland-based economics, with a focus on protecting natural grassland and recovering degraded grassland, to meet the requirement of sustainable development. We put forward the following suggestions:

1) Establish a capital value system for grassland. Because the possession of grasslands belongs to the government and the access rights to grassland are not clearly established, grassland has no perceived value in China. This is one cause of grassland degradation. We should treat grassland as an important asset, and get reimbursement and invest-

Photo 3. Extremely degraded temperate scrub–grassland in Northwest Shanxi.

ment from its utilization and for its use, restoration, and protection. It is urgent to establish a capital value system for grasslands, and to implement a series of policies to determine the accessibility of grasslands.

2) Harness and restore degraded grasslands and reconstruct pastoral grasslands. The number of livestock has exceeded the carrying capacity of grasslands in Shanxi because of large-scale degradation. If the husbandry industry needs further development, grassland area and yield will first have to increase. There are 2 ways to solve this problem. One is to harness and recover the degraded grasslands and improve their ecological situation by increasing yields. The other is to develop pastoral grasslands. There are many successful examples in practice; in one case, great ecological and economic benefits have been obtained from restoring natural grasslands and developing planted grasslands as part of the management of small watersheds of the Wangjiagou Valley in western Shanxi.[27]

3) Manage grasslands legally. The management of grasslands has to comply with *The Law of Grasslands, The Law of Environmental Protection,* and *The Law of Natural Conservation* to protect grasslands from such unsustainable utilizations as reclaiming, denudation, overharvesting, and excessive grazing, and enforce punishment for illegal activities. In mountainous regions with large contiguous grasslands, national parks or natural reserves should be developed to meet the needs of biodiversity conservation, ecological traveling, and scientific research.

4) Control population in mountain regions. Overpopulation is one key reason for grassland degradation; populations are too large, with high rates of increase in mountainous and poor regions in Shanxi. The pressures of population on grasslands and other natural environments are so great that ecological damage is serious. Controlling population is urgent if the natural environment is to be conserved in these regions.

5) Strengthen grasslands research and training programs. There are many theoretical and practical problems that

Table 2. The classes of grassland degradation and their characteristics based on the usability for livestock and availability of the grassland environment

Degradation class	Species composition	Biomass and cover above ground	Surface coverage and situation	Soil status	Ecosystem structure	Resilience
I. Weak degradation	no change of original species composition, individual number of dominant species and palatable species decreased	< 10% decreased	good surface coverage	no change	no change	self-recovered in natural conditions
II. Light degradation	no great change of original species composition, individual number of dominant species decreased, palatable species decreased or disappeared	20%–35% decreased	surface coverage decreased	no obvious change, soil rigidity increased	no obvious change	quickly recovered in natural conditions after closed
III. Moderate degradation	constructive and dominant species change greatly, most original species still remain	35%–60% decreased	surface coverage disappeared	1-fold increase of soil rigidity; soil erosion obvious; salinity increased in wet areas	carnivores decreased; herbivores including rodents increased	May recover in natural conditions after closed
IV. Serious degradation	most original species disappeared, composition simplified, short and trampling-tolerant species dominated	60%–85% decreased	soil surface bared	2-fold increase of soil rigidity; soil organic matter decreased obviously; soil sand increased; salty patches obvious	food chain shortened; ecosystem structure simplified	Hard recovery in natural conditions, need improving measures
V. Extreme degradation	vegetation disappeared, only some weed species	> 85% decreased	bared land or salty patch	no value to its use	ecosystem disorganized	Need reconstruction

need to be solved to control grassland degradation. Research programs studying mechanisms of degradation, identifying main factors affecting degradation, and controlling degradation should be established.[7] Scientific management of grasslands based on these research programs may result. It is necessary to have many technicians, managers, and teachers working to control grassland degradation and management. We should start training programs to train technical persons and educate farmers, who will be important in future efforts to recover, harness, conserve, and manage grasslands.

Table 3. Statistics of degradation for each type of grassland in Shanxi Plateau														
		Degradation classes and areas (10^4ha)												
Types	Areas (10^4ha)	No degraded		I		II		III		IV		V		
		Area	%	Area	%	Area	%	Area	%	Area	%	Area	%
1	44.0	0	0	0	0	5.1	11.6	8.6	19.6	17.2	39.1	13.1	29.8
2	140.1	2.8	2.0	4.4	4.0	41.5	29.7	56.7	40.5	29.3	21.0	5.4	3.9
3	60.51	0	0	3.6	6.0	8.1	13.4	28.7	47.5	18.9	31.3	1.21	2.0
4	80.0	2.1	2.7	6.3	7.9	26.5	33.2	27.4	34.3	16.5	20.7	1.2	1.5
5	37.0	6.0	16.3	8.6	23.3	15.8	42.7	6.1	16.5	0.5	1.4	0	0
6	11.44	1.7	14.9	3.9	34.1	4.1	35.9	1.1	9.7	0.64	5.6	0	0
7	3.34	0.6	18.0	0.8	24.6	0.9	27.0	0.54	16.2	0.3	9.0	0.2	6.0

Note: Grassland types same as in Table 1.

6) Constitute favorable policies for grassland industries and intensive management. The current government investment in the grassland and husbandry industries is small, and farmers themselves have little capital. Therefore, the mismanagement and overutilization of grasslands are only continuing. Shanxi should constitute favorable policies to attract capital investment to grassland farming and industry, which would be conducive to sustainable development of Shanxi's economy and environment.

Summary

The present utilization and management practices of grassland farming in China, as the above case of Shanxi Province illustrates, are unsustainable. They do not accommodate the requirements of future development.[8,13] The sustainable development of grassland farming refers to the enlarging of resource potential and the increased carrying capacity of grassland, which demands the improvement of grassland quality and primary production.[3,23] The restoration of degraded grassland is critical for realization of sustainable grassland farming in China. Like the management of any natural ecosystem, grassland management is also important to keep natural environments stable. Therefore, sustainable grassland farming is a part of a larger process of environmental sustainable development.[2,19,28]

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