DOI: 10.1007/s00267-004-0064-3

Potentials for Combating Desertification in Hunshandak Sandland Through Nature Reserve

YU PENG
GAOMING JIANG*
MEIZHEN LIU
SHULI NIU
SHUNLI YU
DILIP KUMAR BISWAS
Laboratory of Quantitative Vegetation Ecology
Institute of Botany
The Chinese Academy of Sciences
Nanxincun 20, 100093, Xiangshan, Beijing, China

QIAN ZHANG
XUAN SHI
School of Environmental Science
Peking University
100871, Beijing, China

QISEN YANG
Center of Zoological Evolution and Systematics
Institute of Zoology
The Chinese Academy of Sciences
No. 130 Zhongguancun Road, 100080, Beijing, China

ABSTRACT / Desertification directly threatens more than 250 million people and one third of the earth's land surface. Although it is well known that desertification could be reversed in most cases if the intensity of land use were reduced, there have been no studies on how to achieve this reversed desertification on a large scale. We conducted a case study in Hunshandak Sandland of North China, exploring how creation of a nature reserve might aid restoration of a degraded ecosystem. Experimental data indicated that desertified regions, if designated as a nature reserve, could be restored with conservation of biodiversity. The buffer zones in moderately desertified lands could serve as a base for forage production and/or ecotourism industry. The construction of ecologically designed towns (ecotowns) in transition zones could accommodate migrants moved from core zones so as to develop stock production, related industry, and ecotourism, enabling both economic and environmental development. Up to now, 5778 local inhabitants in the core zones of Zhenglan Banner (county) in the Hunshandak Sandland have been moved out of the severely degraded areas with the financial assistance of the central government. Those people have been moved into three ecotowns of the Banner with an objective of greatly enhancing the economic and social status while restoring the degraded sandlands.

More than 250 million people and one third of the earth's land surface are directly threatened by desertification (Diallo 2003). Desertification comes from land degradation in arid, semiarid, and subhumid areas resulting from various factors, including climatic variations and human activities (UN 1992, Fernández 2002, Sansom 1999, Zhang and others 2003). China is one of several countries severely affected by desertification. For example, almost 90% of natural grasslands have been affected (SEPAC 2002). Hunshandak Sandland is one of the four major sandy grasslands in China, with an area of 53,000 km^2. The area of moving sand dunes was only 2.3% of the total area in 1950, 8.2% in the mid-1970s, 13% in the 1980s, and 50% in 1996; however, it was 70% in 2002. The number of grazing animals (mainly cattle and sheep) has increased by 3.3-fold since 1949. The rapid increase in population (more than sixfold during the past 50 years) is believed to be the primary reason for the rapid desertification (Li and others 2001). Both the grazing animals and human beings have exceeded the threshold of the carrying capability of the grassland (Jiang 2002) in the severely degraded areas.

A number of case studies (Dobson and others 1997, Bradshaw 2000, Okin and others 2001) have shown that natural processes are effective ways in arresting desertification in most arid or semiarid areas with most of the animal and human populations moved out. Thus, a naturally restored ecosystem can be established as a nature reserve. A nature reserve, including core zones, buffer zones, and transition zones, is reserved for natural processes (Bridgewater 2002, Kingsland 2002). The core zone is strictly protected according to

KEY WORDS: Desertification; Sustainable development; Nature reserve; Restoration ecology; Hunshandak Sandland

Published online April 25, 2005.

*Author to whom correspondence should be addressed; *email:* jgm@ht.rol.cn.net

well-defined conservation objectives and should have little human interference. It is normally surrounded by a buffer zone. Activities that do not conflict with the protection of the core zone, such as ecotourism, education, training, and research, are allowed within the buffer zone. The core and buffer zones are surrounded by a transition zone where land use is usually not strictly delineated. Cities and towns can be located in a transition zone. To ensure both environmental and economic sustainability, those planning to establish a natural reserve have to balance the requirement of the core zone (natural restoration), buffer zone (service some infrastructure), and transition zone (population location, economic development), respectively (IUCN 1987).

In this article, we explored the potential of controlling desertification on a large scale using a multidisciplinary approach to establish a nature reserve. Figure 1 illustrates the thinking behind this article: Zhenglan Banner, located in the center of Hunshandak Sandland, is to be designed as a nature reserve and zoned with core zone, buffer zone, and transition zone. The core zone is designed to combat severe desertification by restoration of the degraded ecosystem with concomitant conservation of biodiversity. The inhabitants and their domestic livestock must be moved into ecotowns. Establishing the necessary buffer and transition zones, this will enable the local inhabitants to raise livestock and to develop industry and ecotourism. The resultant improvement in their standard of living is designed to be an example of sustainable development of the environment, society, and economy. The potential of this approach to combat desertification in the Hunshandak Sandland through establishment of a nature reserve is fully discussed.

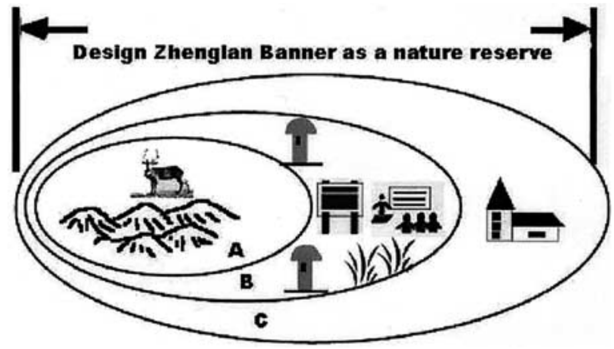

Figure 1. Designing Zhenglan Banner as a nature reserve. **A**: Establishing the core zone in severe desertification grassland for restoration of degraded ecosystem and biodiversity. **B**: Establishing the buffer zone in moderate desertification grassland for environmental education, ecotourism, forage base, and ecological research. **C**: Establishing the transition zone in least desertification grassland, enlarging the size of towns and city in transition zone for accommodating people moved from severe desertification region, and for development of industry, stock raising.

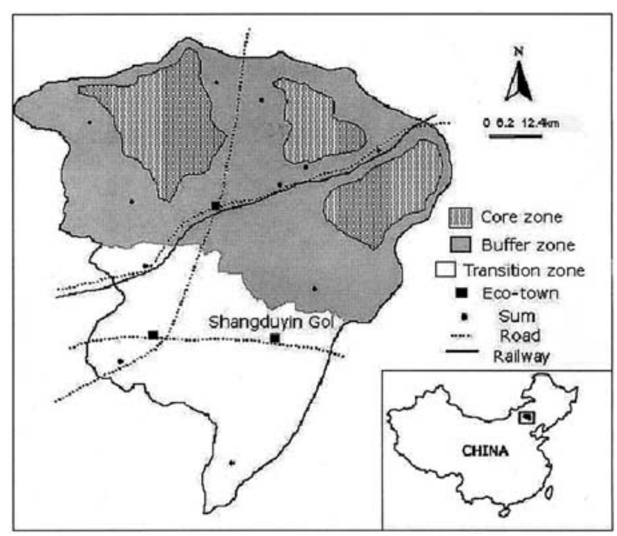

Figure 2. Map of China showing the location of Hunshandak Sandland, with its center located in Zhenglan Banner, and planned zoning in potential nature reserve.

Methods

Study Area

Hunshandak Sandland is situated in Inner Mongolia of North China (Figure 2) with an average altitude of 1201 m above sea level. Zhenglan Banner (N41°46′–43°69′; E114°55′–116°38′), in the hinterland of Hunshandak, has an area of 10,182 km^2 and a population of 78,400. Thirty-two percent of the population lives in three towns: Shangduyin Gol, Sanggandalai, and Habiriga, and the rest (68%) are scattered throughout the rural areas. Of the total Banner area, the towns comprise 1%, and the grassland comprises the remaining 99%. However, most of the land is seriously degraded due to overgrazing. The prevailing climate is temperate semiarid, with an annual mean temperature of 1.7°C, annual precipitation of 250–350 mm (80–90% falls between May and September), and annual transpiration of 2000–2700 mm. About 801 higher plant species, more than 402 vertebrate species, 174 birds, and 526 insects have been recorded, with the total species number exceeding 1500 (Zhenglan Banner Government 2001). Some six rare or threatened species listed by the IUCN are also reported. The financial income of the Banner was 21 million USD in 2002 (1 US$ approximately equal to 8.3 RMB). The average income of one herdsman during 1960–2002 in Zhenglan Banner is shown in Figure 3C.

Data Collection and Analysis

A wide range of policies and statistical documents related to our study were collected at four administrative levels: county, league, province, and national. Historical data in Zhenglan Banner from 1950 forward include population enumeration, livestock number, land area, and other socioeconomic data of a comprehensive nature. The gathered data were analyzed and synthesized to formulate the action programs discussed here. The numbers of expected population in towns and economic trends in the future 10 years were forecasted based on historical trends and incorporated into ''The Long-term Developmental Plan of Zhenglan Banner'' (Zhenglan Banner Government 2000). The assessment of tourism resources and cultural diversity was taken from the local governmental reports (Zhenglan Banner Government 2001) and reviewed by the experienced experts. Person-to-person interviews were conducted to assess the attitude of local people towards establishing a nature reserve and moving into new places; 65 families in severely desertified grassland were interviewed at random. The questionnaire design is seen in Table 1.

Determination of Desertification Degree

Land desertification was estimated by combining remote sensing data (Landsat TM image) with GIS and statistical data from the Grassland Administration of Zhenglan Banner, and confirmed through field surveys. Grassland was classified into four landforms: sparse-elm-forest, low grassland, hills, and wetland. The method of Chen and Wang (2002) was used for the determination of desertification degrees. The desertified grassland was classified into three categories, integrating both ecosystem and herbage quality for animals. The ratios of plant community height to the potential plant height (without grazing) of <20%, 21–50%, and >50% corresponded to ''severe,'' ''intermediate,'' and ''least'' desertification, respectively. The degree of decrease in reproductive branch (categories <50%, 51–90%, >90%) and edible grass production (category <30%, 31–65%, >65%) were both determinants for the three categories of desertification. We based our calculation on a 1:250,000 topographic map. The data—plant community height, the degree of decrease in reproductive branch, and edible grass production—were obtained from the Zhenglan Banner Grassland Bureau (2001), which developed the information by investigating at the local Gacha (village) level. The investigation was conducted by technicians under the guidance of experts from the Institute of Botany, the Chinese Academy of Sciences in 2001. In each Gacha, 50 sample areas (1 m × 1 m each) were investigated at a distance of 300 m apart from each other. The data were segregated into four landforms (sparse-elm-forest, low grassland, hills, and wetland). Then the average values in plant heights, reproductive branches, and edible grass productions were respectively calculated to determine desertification degree in each Gacha. Finally, the desertification

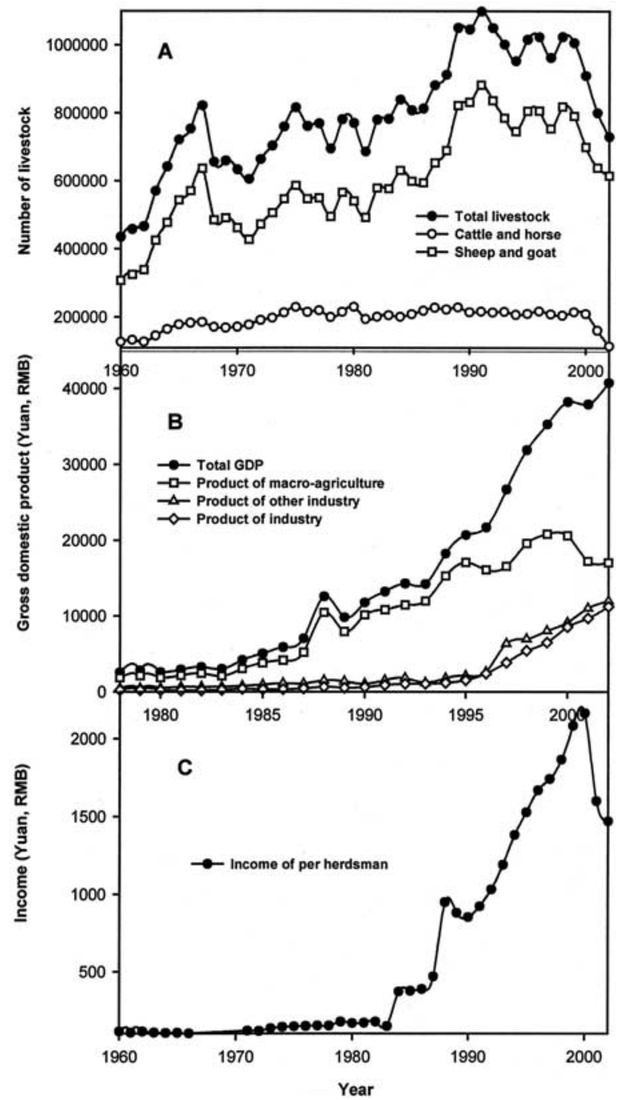

Figure 3. Changes in the number of livestock (**A**) and its formation, GDP (gross domestic product) and its structure (**B**), and average income per herdsman (**C**) in Zhenglan Banner during 1960 (1978)–2002. 1 USD = 8.3 RMB.

Table 1. A questionnaire form showing the attitude of respondents within people living in severe desertified grassland towards the establishment of potential nature reserve in Zhenglan Banner of Hunshandak Sandland, China

Question (n = 218)	Yes (%)[a]	No (%)[a]
Do you think your household could benefit from the establishment of potential nature reserve?	76 (166)	24 (52)
Do you agree to be moved into town after establishing of nature reserve? when		
1) Without economic compensation	2 (3)	98 (214)
2) With sufficient compensation	64 (140)	35 (76)
3) Without compensation but being provided a constant vocation	83 (181)	15 (33)
Do you agree to be transferred into other vocation? As in		
1) Tourism	62 (135)	38 (83)
2) Commerce	69 (150)	27 (59)
3) Construction	23 (50)	74 (161)
4) Industry	86 (187)	14 (31)

[a]Effective sample size is given in parentheses with all numbers being in percentage of surveyed respondents.

degree of the whole Zhenglan Banner was determined.

Experiment on Natural Restoration

In order to assess the effect of natural processes to restore degraded grassland, some 2668 hm^2 severely desertified grassland in Bayin Hushu Gacha of Zhenglan Banner was fenced in 2000. Meanwhile, some plots in lowland that exhibited considerable fertility with an area of 67 hm^2, adjacent to the fenced area, were chosen to serve as a forage base, supplementing forage shortage resulting from grassland fencing. A variety (Yinhong) of corn (*Zea mays* L.) producing much higher biomass was planted in the forage base employing intensive agriculture (i.e., fertilizers, irrigating systems, and farmland management). Plant biomass (fresh weight) and coverage were collected in July 2001 and 2003 from each of the four habitats: fixed sandy dunes, semifixed sandy dunes, shifting sandy dunes, and lowland in six treatments: degraded area, severely degraded area, protected area, interval protected (with rotational grazing), unprotected area, and forage base. In each habitat of the six treatments, the biomass and coverage were calculated on average based on 10 samples (1 m × 1 m) that were selected randomly. Analysis of variance among different treatments was performed on each measurement: biomass and coverage, respectively, with mean value of 10 replicates, and the least significant differences between the means were estimated at 95% confidence level.

RESULTS

Desertified Degree

Of the 10,182 km^2 of land in Zhenglan Banner, almost all the grasslands are affected by desertification in different degrees (Table 2); the ratio of the area between severely, moderately, and least desertified degrees was 22:13:15. The biodiversity exhibited can be well protected by establishment of a core zone. The population in severely degraded grassland accounts for 10,507, amounting to 13% of the total population of Zhenglan Banner.

Restoration Through Natural Process

For the restoration of desertified grassland, the experiment has provided positive results. Comparing biomass and gross vegetative coverage among protected, interval protected, and unprotected areas, protected area biomass yields and coverage increased significantly ($p < 0.05$) in 2 years compared to the unprotected or interval protected areas (Figure 4). Shifting sand dunes did not have any vegetation before this field trial; now the biomass was found to have attained some 1560 g m^{-2} compared to 220 g m^{-2} in protected area and interval protected areas. Plant community coverage also achieved 60% and 32%, respectively. These facts indicate that the unprotected sites will have their coverage and biomass increase if these sites are protected, and the sites have different yields at different protection levels. The nature of vegetation also changed after the area was protected; the vegetation in fixed sandy dunes was previously dominated by *Artemisia frigid*, *Cleistogens squarrosa*, and *Carex duriuscula*. After protection, the species *Agropyron michnoi* and *Kochia prostrate* were found to be dominant. A similar phenomenon was also found in lowland, where the species *Leymus chinensis* and *Elymus dahuricus* were found to be dominant instead of the species *Chenopodium glaucum* and *Chenopodium acuminatum*. The number of plant species in unprotected vegetation of lowland was observed increasing in plant samples

Table 2. Area (km^2) of desertification grassland and human population in four landforms of Zhenglan Banner, Hunshandak Sandland

Landform	Desertification area	Severe desertification area	Population in severe desertification area
Sparse-elm-forest	4582 (45%)	2138 (21%)	4121
Low grassland	3258 (32%)	1629 (16%)	2237
Hills	1222 (12%)	407 (4%)	3526
Wetland	1018 (10%)	305 (3%)	623
Total	10,080 (99%)	4480 (44%)	10,507

[a]Percentage to total area is given in parentheses.

after 2 years' protection compared to protected and interval protected areas on average by 121% and 74%, respectively, in all habitats.

Experiments on Forage Base

Some lowlands in the planned buffer zones with higher fertility and soil moisture could serve as forage bases. The average biomass yield of a corn variety (Yinhong), planted in lowland, was 8 kg m^{-2} in 2001 and 9 kg m^{-2} in 2002, compared with the yield of 0–400 g m^{-2} in desertified grassland and 0–45 g m^{-2} in severely desertified grassland. This means that biomass of 1 m^2 in the forage base was equal to that of 20–1000 m^2 in the desertified grassland or that of 180–1000 m^2 in the severely desertified grassland. When the severely desertified grassland with an area of 4480 km^2 is designed as the core zone of a nature reserve (Table 2), it is necessary also to establish a forage base with an area of 4–25 km^2 outside of the core zone inasmuch as some plots demonstrate more fertility in supporting restoration.

After improving both the quantity and quality of the grass, the survival rate of young lambs and calves increased by 10% and milk production in 2003 doubled that of 2001. The direct economic value of grass in protected areas was 800,000 RMB (according to the market price of grass in 2003), and expenditures in purchasing of forage in winter decreased by 7500 RMB compared with the year 2000 in an average family. Family income in Bayin Hushu Gacha also increased after establishing the protected area and forage base, some 500 RMB higher than that of residents in similar villages. One measure of success of this approach is that more than 76% of the herdsmen interviewed supported the idea of establishing a nature reserve [65 families were interviewed at random (Table 1)].

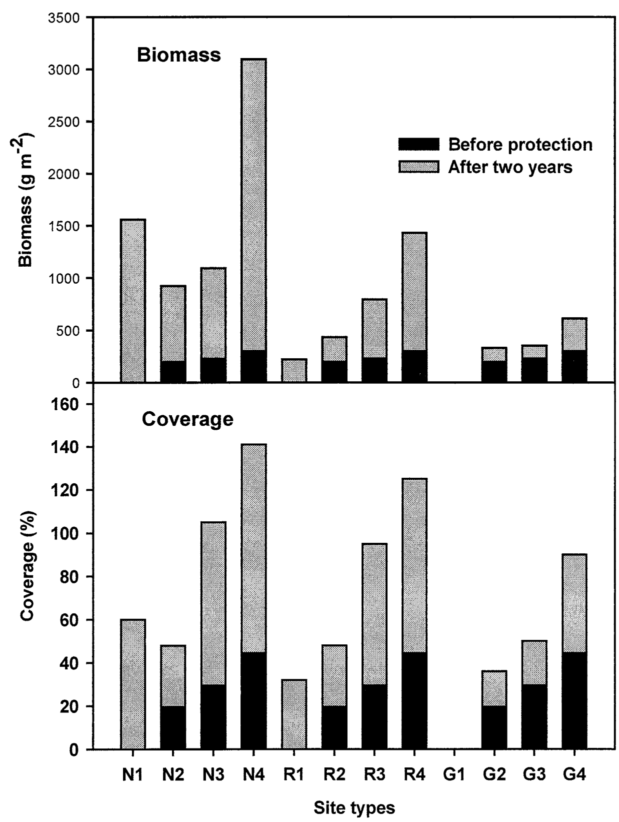

Figure 4. Changes of biomass and coverage of different plant communities before and after being protected in different sites. In protected area, N1 = fixed sand dunes; N2 = semifixed sand dunes; N3 = shifting sand dunes; N4 = lowland. In interval protected area, R1 = fixed sand dunes; R2 = semifixed sand dunes; R3 = shifting sand dunes; R4 = lowland. In unprotected area, G1 = fixed sand dunes; G2 = semifixed sand dunes; G3 = shifting sand dunes; G4 = lowland. Values are means, n = 10.

Feasibility of Urbanization to Alleviate Population Pressure

Once the nature reserve is established, the people living in severely desertified grassland, accounting for 13% of total population, needed to move out. Small ecotowns located in a potential transition zone could accommodate these dislocated persons. There are three small towns (Figure 2) distributed in the moderately and least desertified grassland, i.e. Shangduyin

Gol, Sanggandalai, and Habiriga, to which rural residents have expressed willingness to be moved. These three towns cover an area of 10.2 km^2 (0.1% of the Zhenglan Banner's total area), but now contain 32% of the Banner's total population, and still will have a large potential for holding more people.

The feasibility of moving people living in severely desertified grassland into three ecotowns is based on the following reasons. First, the population in towns has been increasing at the rate of 1–1.9% per year since the 1950s (Figure 5). Most of these people came from the pasture areas. Establishing the nature reserve would increase the population in towns by 40–50% (Figure 5). Second, moving population from the pastures into towns will satisfy the needs for human resources required in the future by economic development of towns and cities. At present, there are more than 10 major projects under construction or being planned in Shangduyin Gol (Table 3), including tourism, livestock processing, real estate, and other industrial development; the total investment is projected to come to 21,000 million RMB, requiring a population of 20,700 in 2002 and 51,200 in 2010. Third, the form of income has changed in the past 50 years (Figure 3B). The ratio of income from stock production to gross domestic product (GDP) has shrunk, whereas income from industry and other activities has increased. This indicates that some parts of traditional stock production would be gradually replaced by modern stock production methods (restricted grazing, breed selection, etc.) and related agribusiness and other industry. Thus, the pressure of livestock on degraded grassland would be alleviated after the traditional stock production being replaced.

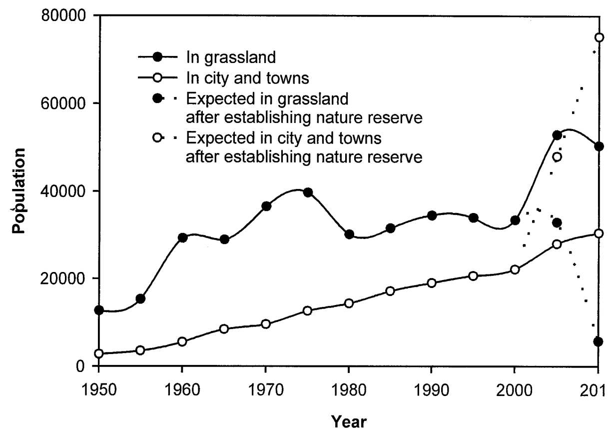

Figure 5. Changes of population in cities (towns) and in grassland during 1950–2000, expected trend during 2005–2010, and expected population after the establishment of nature reserve in Zhenglan Banner, Inner Mongolia, China.

Discussion and Conclusions

Nature reserves have three functions: protecting biodiversity, supporting inhabitant cultural proclivities, and socioeconomic development (NCMAB 2000). Establishing core zones in severely desertified lands could help to restore degraded ecosystems and protect biodiversity. In our experiment, the plant community has been restored in both coverage and biomass after protection, and there has also been restoration of species diversity, with different degrees of restoration at different protection levels. In order to restore degraded grassland and to protect its biodiversity, we originally proposed three core zones in severely desertified grasslands (Figure 2). Establishing buffer zones in less degraded areas could provide forage, serve as a base for education and ecotourism, as well as providing copious research material for ongoing study and evaluation. Forage bases would mainly be located in lowlands where there would be higher productivity, owned privately or collectively, and the participants would be the herdsmen themselves. Enlarging the size of towns and cities in transition zones could accommodate people being relocated from core zones. Their involvement in developing animal production and processing, other ecological industry, and ecotourism will raise the standard of living with far less pressure on the grassland than previous intensive livestock grazing.

From the local, regional, and policy points of view, Jiang and others (2003) have pointed out that nature reserves provide several functions in terms of supporting the relocated residents, e.g., personal training and education; science and technology transfer; information and awareness of local, regional, national, and international issues; entertainment; sanitation and medical care; cultural activities (folk music and ceremonies, gymnastics, etc.); and social welfare and services. All of the above are attractive to people who will need to be moved from the core zone. In the case of Zhenglan Banner, after moving people into three ecotowns, the ratio of urbanization, an indicator of developmental level of a region, would increase, with the quality of life of the relocated persons being markedly improved.

Shrinking of incomes from grazing, eliminated by the establishment of the core zone, could be compensated by ecotourism, commerce, traffic, and transportation, as well as by improving of quality of livestock products. Archibald and Naughton-Treves (2001) among others outlined that it is a feasible way to improve economic level by developing a nature reserve. In the case of Zhenglan Banner, it does appear to have special tourism features that are unique: sparse-elm-

Table 3. Population demand for present and planned industrial items in Zhenglan Banner

Items[a]	2002	2005	2010
Ecotourism	5600	10,600	23,000
Dairy and meat industry	2400	5200	15,600
Power plant	200	420	620
Fur, leather, textile industry	1600	2400	6500
City construction[b]	220	2120	5500
Total	10,020	20,740	51,220

[a]Other forecasted data according to corresponding item plans and the long-term development plan of Zhenglan Banner (Zhenglan Banner Government 2000).
[b]Forecast according to city planning of Shangduyin Gol in Zhenglan Banner.

forest, sandy land accompanied by many lakes, and low grassland, as well as special biodiversity and culture diversity in Mongolian styles, including famous historical sites, the Chahar culture (Chahar is descendant of one tribe of the Mongolian People), and historic people. Shangduyin Gol Town was once the summer capital (1256–1369) of the Yuan Dynasty whose territory traverses Europe and Asia. Thanks to Marco Polo's Travel Notes, Shangduyin Gol has been well known to the world as early as the thirteenth century. These sites have been well preserved. The gross estimate of the Tourism Program of Zhenglan Banner (Zhenglan Banner Tourism Bureau 2001) is that the ratio of income from tourism to GDP would be increased to 8% in 2005 and 15% in 2010; up to 20,000 of the present herdsmen would be engaged in tourism and benefit from tourism in 2008, when the Beijing Olympic Games are held.

In order to settle the people from the severely desertified grassland, a special fund of 45 million RMB, averaging 30,000 RMB per family, had been invested in 2000–2001 by the Central Government of China. The funds are meant to be invested in the entire range of activities discussed here including ecological transmigration, town construction, milk, beef and mutton factories, training people to succeed in a new environment, and ecotourism facilities. The goal is to attain gross revenues of $14.5 million USD within the next 5 years. In fact, some 5778 people and their livestock have been moved into three towns, matching their preferences with the needs and priorities of Zhenglan Banner. With the startup funds, the relocated people began to engage in commerce, tourism, the transportation industry, or modern livestock raising. The income of relocated people has been improved in different degrees. The balance of the rural population is now scheduled to be moved in the next 5 years.

In order to achieve a better result, the cooperation of scientists, governmental officials, entrepreneurs, and herdsmen is needed (Burger 2002). Responsibility of government officials is to integrate the establishment of nature reserves into a regional developmental plan, organizing a management committee. This committee must include not only scientists, but also entrepreneurs, local residents, and all the skills and experts any modern community requires, e.g., grasslands management, farming, forestry, science, finance, water conservation, law, and so forth. Although this paper reports the results of a demonstration project in one small village, it has encouraged Banner officials to begin a concerted effort to establish a nature reserve in the entire Zhenglan Banner. The preliminary plan is that the severe desertification grassland would be left in a natural state, which would stimulate reestablishment of biodiversity, wildlife, and vegetation. Forage bases would be constructed in the buffer zone to compensate for the forage shortage brought about by reduction of grazing area; the people now living in the severely degraded land (population of 10,507) will be relocated to three towns. In turn, this would satisfy the requirements of three towns for development, with the ratio of urbanization being increased to 40–50%. The town of Shangduyin Gol would be enlarged into a center city in Hunshandak Sandland. In Zhenglan Banner, there is an estimated 67,000 km^2 lowland, which has higher production potential. If all the lowlands are reasonably managed, the grass yield potential should reach 300 million RMB (calculated as 2250 kg/ha). Furthermore, ecotourism and culture-tourism are estimated to produce an income of 50 million RMB (Zhenglan Banner Tourism Bureau 2001); stock production and further processing-related agribusiness would produce an income of 950 million RMB, and income from other industry and commerce would be 50 million RMB (Zhenglan Banner Government 2000).

If we are able to combat desertification in a 10,000-km^2 unit, as well as to meet other human needs, such as economic development, by establishing of a nature reserve, this might be an accepted political weapon in combating the world's desertification on a large scale.

Acknowledgments

This study was funded by the Chinese Academy of Sciences as a Key Creative Project (No. KSCX1-08-02). We would like to express our appreciation and thanks to the Editor-in-Chief for facilitating the review and the excellent suggestions from the two anonymous reviewers. We would also like to thank Professor Gordon of Arizona State University for his comments and for checking our English, and Drs. Yonggen Li, Chuangdao Jiang, Guangmei Wang, Li Ding, and Hongxia Cui for their assistance in conducting fieldwork.

References

Archibald, K., and L. Naughton-Treves. 2001. Tourism revenue-sharing around national parks in Western Uganda: early efforts to identify and reward local communities. *Environmental Conservation* 28:135–149.

Bradshaw, A. 2000. The use of natural processes in reclamation—advantages and difficulties. *Landscape and Urban Planning* 51:89–100.

Bridgewater, P. B. 2002. Biosphere reserves: special places for people and nature. *Environmental Science & Policy* 5:9–12.

Burger, J. 2002. Restoration, stewardship, environmental health, and policy: understanding stakeholders' perceptions. *Environmental Management* 30:631–640.

Chen, Z., and S. P. Wang. 2002. Chinese typical grassland ecosystem. Chinese Science Press, Beijing (in Chinese).

Diallo, H. A. 2003. On the occasion of the world day to combat desertification and drought. www.unccd.int.

Dobson, A. P., A. D. Bradshaw, and J. M. Baker. 1997. Hopes for the future: restoration ecology and conservation biology. *Science* 277:515–522.

Fernández, R. J. 2002. Do humans create deserts? *Trends in Ecology & Evolution* 17:6–7.

IUCN. 1987. Buffer zones: development that protects parks. *IUCN Bulletin* 18:10–11.

Jiang, G. M. 2002. Strategy of regeneration of the degraded ecosystem in Hunshandak Sandland. *Chinese Science and Technology Forum15*. 3:13–15 (in Chinese with English abstract).

Jiang, G. M., M. Z. Liu, N. R. Han, and W. J. Li. 2003. Potential for restoration of degraded steppe in the Xilingol Biosphere Reserve through urbanization. *Environmental Conservation* 30:304–310.

Kingsland, S. 2002. Designing nature reserves: adapting ecology to real-world problems. *Endeavour* 26:9–14.

Li, Q. F., C. Y. Hu, and M. J. Wang. 2001. Study on causes of deterioration of Hunshandak region and its treatment strategy. *Resource and Environment in Dryland* 15:9–17 (in Chinese with English abstract).

NCMAB (National Committee of Man and Biosphere Program in China). 2000. Study on sustainable management policy of nature reserves in China. Chinese Science & Technology Literature Press, Beijing, China (in Chinese).

Okin, G. S., B. Murray, and W. H. Schlesinger. 2001. Degradation of sandy arid shrubland environments: observations, process modelling, and management implications. *Journal of Arid Environments* 47:123–144.

Sansom, A. L 1999. Upland vegetation management: the impacts of overstocking. *Water Science and Technology* 39:85–92.

SEPAC (State Environmental Protection Administration of P. R. China). 2002. Gazette on environment 2002. http://www.zhb.gov.cn/649368298894393344/20030605/1038712.shtml.

UN. 1992. Agenda 21: The United Nations Plan of Action from Rio. United Nations, New York.

Zhang, L., L. P. Yue, and B. Xia. 2003. The study of land desertification in transitional zones between the MU US Desert and the Loess Plateau using RS and GIS—a case study of the Yulin region. *Environmental Geology* 44:530–534.

Zhenglan Banner Government. 2000. The long term development plan of Zhenglan Banner. Unpublished document (in Chinese).

Zhenglan Banner Government. 2001. A feasibility study report on the establishment of Zhenglan Banner National Rank Nature Reserve. Unpublished document (in Chinese).

Zhenglan Banner Grassland Bureau. 2001. Report on the distribution, types and utilization of grassland in Zhenglan Banner. Unpublished document (in Chinese).

Zhenglan Banner Tourism Bureau. 2001. Tourism development plan of Zhenglan Banner. Unpublished document (in Chinese).