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COMMENT

Control of sandstorms in Inner Mongolia, China

About one third of the world's land surface is covered with arid and semi-arid areas. It is predicted that global warming will increase desertification by 17% before 2050. At present, desertification is making approximately 12 million hectares every year useless for cultivation and grazing worldwide. Over 250 million people and one third of the earth's land surface are directly threatened by desertification (Diallo 2003). China is one of several countries severely affected by desertification; almost 90% of natural grassland has been affected to differing degrees (Lu & Yang 2001; State Environmental Protection Administration of the People's Republic of China 2002). The land desertification rate in China was 1560 $km^2\ yr^{-1}$ in the 1970s. This rate had increased to 2100 $km^2\ yr^{-1}$ by the 1980s, and was 2460 $km^2\ yr^{-1}$ by 1995 and 3436 $km^2\ yr^{-1}$ in 1999 (Zhu *et al.* 1999). Areas that have shown increased desertification are derived from degraded grassland or cultivated land (Zhang & Cheng 2001). One very serious direct consequence of grassland degradation is thought to be the frequent occurrence of sandstorms. Whereas China was hit by almost 70 sandstorms over the past century (Qing 2002), with an average frequency of one sandstorm every three years in the 1940s, this had increased to one every two years by the 1960s. By the 1990s, the sandstorms in north China took place several times a year and this increased further to 12 in 2000 and 18 in 2001 (Jiang 2002*a*). The frequency of sandstorms in north China appears to be a direct consequence of grassland degradation. Taking Hunshandak Sandland in Inner Mongolia as an example (Fig. 1), the proportion of sand dunes that are shifting rose from 2.3% in the 1950s to 50% in the 1990s, while available grasslands declined by some 40% between the 1950s and the 1990s. The economic cost of these sandstorms has prompted the Chinese government to commit substantial funds to meet this loss, but the degradation is ongoing in the area and the living standards of local people are still low (Liu *et al.* 2003). It is opportune to adjust strategies to reach two objectives simultaneously, namely to restore the degraded grassland, and improve the living conditions of local people. To illustrate this, we focus on Zhenglan Banner (county), which is representative of the whole Hunshandak Sandland in terms of climate (Ma *et al.* 1998), economy and ecology (Fig. 1). Zhenglan Banner has a total area of 100 600 km^2, a human population of 78 730 and stock raising is the dominant industry, the average income per person per year being US$ 225 (Bureau of Stock Raising in Zhenglan Banner 2002).

Climate change may have intensified grassland degradation (Ye & Cheng 1992; Ding & Wang 2001), but annual precipitation has remained similar in Inner Mongolia (Chen *et al.* 2002) or increased slightly (369 mm in 1960–1989, 407 mm during the 1990s) in Zhenglan Banner. Inter-annual fluctuations of temperature and precipitation are still within the 'normal' range of the past 3000 years (Zhu 1972). We therefore believe that degradation of the sandy grasslands was driven by prolonged and unmanaged human exploitation (Jiang 2002*a*). Because increases in the human population have led to overexploitation of the grassland (Ware 1997; Ci & Liu 2000; Li *et al.* 2001), grassland degradation is caused by growing erosion following changes to the soil structure and mineral content induced by overgrazing and human activities. From 1949 to 2000, the population of Zhenglan Banner grew more than threefold, from 22 550 to 78 730 (Fig. 2*a*). With this population increase and demand for higher living standards, the abundance of domestic livestock increased more than sixfold (Fig. 2*b*), increasing the foraging pressure by 527% to a level unsustainable for the grassland ecosystem. The average pasture area available to support a standard sheep's grazing has dropped from 6.32 ha to 1.01 ha. Nomadic life has been replaced largely by fixed settlements in order to improve living conditions. Such fixed settlements are normally composed of several families in a small village, jointly possessing a certain area of grassland. Animal numbers are gradually increasing with economic development, increasing the pressure on grassland (Humphrey & Sneath 1999).

Shortcomings of previous preventative measures

During the 1950s, the Chinese government encouraged people to exploit arid lands for both agriculture and afforestation. Despite huge government investment, any effects of most of those

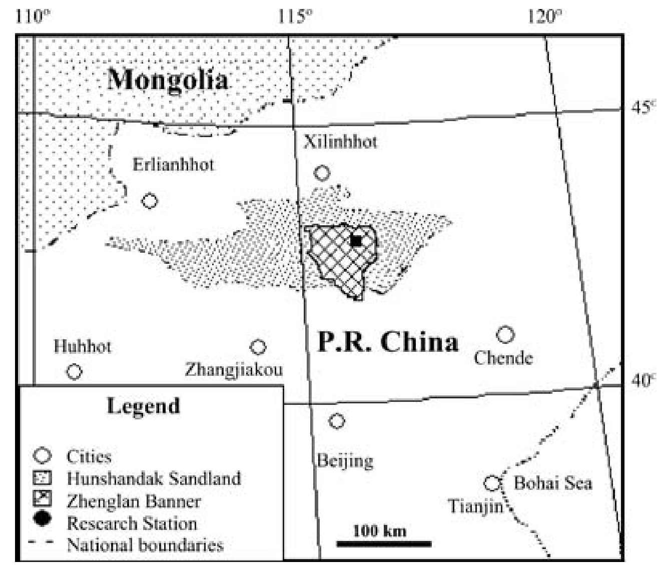

Figure 1 Location of Zhenglan Banner (county) and Hunshandak Sandland, Inner Mongolia Autonomous Region.

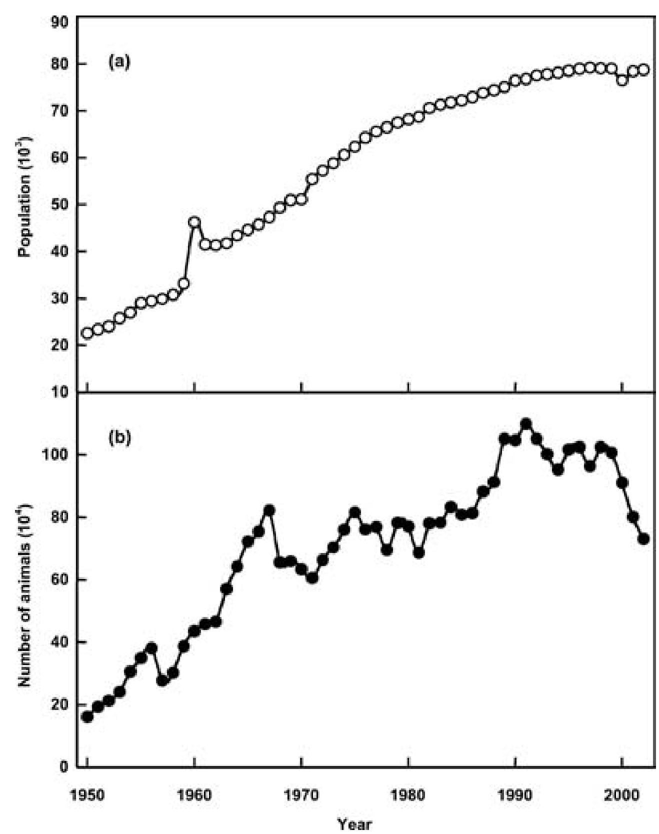

Figure 2 (*a*) Human population and (*b*) number of livestock in Zhenglan Banner of Inner Mongolia Autonomous Region from 1950–2002. Source: Statistic Bureau of Zhenglan Banner.

schemes were short-lived (Jiang 2002*b*); yet the state today still allocates substantial funding for sandy grassland restoration. For example, Zhenglan Banner of Inner Mongolia received US$18.07 million from 2000 to 2003 to address the serious desertification of Hunshandak Sandland. These funds were mainly spent on tree planting, aerial sowing and well sinking as a prerequisite for rearing livestock in fenced enclosures. We argue here that the last measure is an effective use of funds to this end, while tree planting and aerial sowing are ineffective relative to the large investment.

In an area with an annual precipitation of less than 400 mm yr^{-1}, the native vegetation is herbaceous, consisting only of bushes, shrubs or thickets (Wu 1980; Zhao & Cheng 2001). The evapotranspiration of trees is generally much higher than that of shrubs or herbaceous plants (Zhang 2000), and tree planting in arid or semi-arid areas is expected to intensify water consumption. Therefore, afforestation would aggravate the drought (Yang 1996; Huang 1982).

Trees themselves cannot stem the movement of sandstorms. In the early spring, when most sandstorms occur, the sand streams still move through poplar forest. The visibility declines to less than five metres in these artificial poplar forests, while tracts of grassland satisfactorily covered by bushes, shrubs or grassy layers retain a visibility of more than 200 m (M.Z. Liu *et al.* unpublished manuscript 2004). A plantation's capacity to stabilize soil is also much lower than that of grassland or land protected by bushes (French 2004). The costs incurred in afforestation, by contrast, are much higher than those required for the restoration of native grassland.

The topsoil on grassland contains a great number of seeds and other diverse vegetative forms that lack the opportunity for germination and subsequent strong growth because of intense grazing pressure. As pre-existing seed density can reach 459 ± 76 seeds m^{-2} (Liu 2004), aerial sowing is of limited value in rehabilitating the native vegetation. Aerial sowing also favours the use of alien species of forage grass with the purpose of encouraging high yields. A serious consequence of this is to disturb normal regeneration and succession (Shen 1998).

Suggestions for the future

We believe that human infringement is the predominant reason for grassland degradation, while natural factors remain secondary. Reduction of sandstorm occurrence can be achieved by reducing livestock grazing pressure on the depleted ecosystems, together with satisfying both life and productive requirements. This would allow the native vegetation to re-establish naturally and obviates the need for planting exotic trees or aerial sowing. We have five suggestions for restoration of degraded grassland.

(1) Incentives should be offered to the human population of the regions concerned to relocate to areas with better natural conditions or to towns. In the degraded areas, the quality of life is poor. Centralization of the nomadic population into specific areas would encourage the development of a more economically viable community. Improved forage-grass strain development and cultivation, together with better animal husbandry in fenced areas, would allow better monitoring of milk, mutton and beef production.

(2) Natural processes can be used to restore degraded ecosystems. In 1959, the Australian government removed all livestock and people from a small town in New South Wales in order to restore degraded grassland without any artificial assistance (Walker 1976). After 16 years restoration, the coverage and height of grasses and scrubs improved significantly (Noble 1997). There are many successful examples of ecosystem revival by natural processes in other areas (Dyson 1996; Bradshaw 2000; Economic Research Service of United States Development of Agriculture 2002). In China, if no soil erosion were occurring, various vegetative forms (such as seeds, spores, fruits, germinated roots and germinated buds) might develop naturally, free from any external interference. In our demonstration area, degenerated vegetation was restored to the 1960s level after only three years of fencing (Jiang *et al.* 2003). The pioneer species, such as the colonizing grasses that provide soil stability, are first to occupy the degraded areas, and are gradually replaced by the herbs and shrubs that offer plant community structure (Liu *et al.* 2004).

(3) In the course of improving degraded sandy grasslands, a model of 'land self-improvement' has been developed. The approach involves improving land-use efficiency in smaller areas by using modern technologies, thereby increasing the living standards of local inhabitants. By reducing the amount of land being used for cultivation, more land is left to recuperate naturally. The approach is both simple and effective. Demonstration districts could be developed in areas where water and electricity supplies exist, and fertilizers, transportation and agronomic techniques are available. The rest of the degenerated land would then be enclosed to prevent grazing and mowing, thereby allowing the natural revival of the native vegetation. The next step would be to designate such areas as nature reserves under administrative protection.

(4) The practice of planting solitary species such as poplar on natural meadow is detrimental to the revival of grassland. Natural ecological revival should be the most immediate, economic and effective approach involving the least risk. At present, in their struggle against sandstorms,

people attempt to take advantage of natural forces, but human interference in the ecosystem is not addressed comprehensively. Natural revival will not be successful without consideration of the original destructive factors involved in the ecosystem's decay. We suggest there are many projects claiming ecological revival, while in fact they are doing nothing more than manipulating or constructing an ecosystem.

(5) The restoration of degraded grasslands can result in increased hardship through increased production costs. Funding is required to boost urban development in small cities and towns. Funds should be used to solve various practical issues, such as water and electricity supply, telecommunication networks, transport systems, educational infrastructure and generally improving the living standards of local residents. Funding is currently available for returning the original vegetation to reclaimed farmland, but there are few incentives for grass planting. If this policy is continued, grassland depletion will be aggravated further. By transforming the existing pattern of interrelated interests and land use, local residents can take the initiative in ecological restoration and turn themselves from being predators of nature to being its protectors.

Conclusions

The key to sandstorm control remains in financial aids and ecological planning to change local people's land-use practices, by allowing intensive agriculture only in very small confined areas, improving grazing systems and creating alternative livelihoods. In this way, restoration of degraded grasslands on a large scale can be realized through natural processes. However, this does require a truly interdisciplinary approach that integrates science, technology and economic development.

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