Land degradation and blown-sand disaster in China

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Summary. China is a country with severe land degradation and blown sand disasters. The arid and semi-arid regions, in which land desiccation, vegetation degeneration, wind erosion, sandification, Gobi-pebblization and salinization occur, take up one third of China's total land area. Vegetation degradation is most serious in lower flood plains of the inland rivers and the semi-arid Agro-pastoral Ecotone due to excessive use of water resources, grassland reclamation, overgrazing and collection of firewood and herbal medicines. Wind erosion features are common around terminal dry lakes, in inland-river fluvial plains, and the semi-arid dry grasslands. Studies by the methods of aeolian sand transport, soil texture analysis, Cs137 tracing and archaeology confirmed that the rate of wind erosion is normally between 1000 to 2000 ton km-1 a-1. The gravel Gobi on Mongolian Plateau has been formed to a large degree by wind erosion. The severity of sandification has been manifested by the twelve sandy deserts and lands occupying 710, 000 km^2, and the enlargement of sandy land at increasing spreading rates in the past three decades. Salinization has not received enough public attention yet, but soil salinization in Ningxia and Hetao Plains and dry lake basins is unfavorable for crop growth and natural vegetation. Salinization of surface water and ground water in the lower reaches of most inland rivers restricts utilization of insufficient water resources. The exacerbation of sand and dust storms disasters is the ultimate outcome of desertification in China.

Key words. Land degradation, Arid and semi-arid regions, China, Blown sand disasters

1. Introduction

Land degradation is a global environmental issue on account of its genesic ubiquity, damage severity and subsequent adverse impacts. China is a country with the largest population and the most serious land degradation in the world (Ci 1995). Land degradation in the arid and semi-arid China, the so-called land desertification, is the outcome of long-term interaction between natural and social-economic factors (Shi 1991). It is complex and disastrous due to its multiple genesis, and various damage manifestations (Dong et al. 1987; Yang et al. 1991; Kar and Takeuchi 2004). Relevant research in China has been chiefly in sandification, or sandy desertification, which is characterized by wind-induced sand actions under dry windy climate, sandy ground conditions and various hu-

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man disturbances (Wu 1987; Zhu and Chen 2000). Investigations by the Bureau of Forestry indicated that desertification in China has been worsened as a whole, and meliorated at some local parts (Ci 1995). The exacerbation of sand and dust storm disasters in China is generally thought as the aftermath of land degradation in the arid and semi-arid regions (Shi et al. 2000).

Multidisciplinary approaches confirmed that land degradation in China involves with physical, chemical, ecological and human processes and appears as land desiccation, vegetation degeneration, wind erosion, sandification, Gobi pebblization, and salinization. Up to now, the various types of land degradation other than sandy desertification in China have been rarely documented. For a better understanding of the overall status of land degradation in China, we present firstly the distribution of the arid and semiarid areas; then discuss the characteristics of land degradation and blown sand disaster; and finally try to reveal the relationship between land degradation and blown sand disaster.

2. Distribution of the Arid and Semiarid Areas

Under influence of the East-Asian Monsoon and continentality, large-scale horizontal climatic zonation takes place from the southeast humid to the northwest arid regions in China (Fig.1). Vegetation, soils, landforms and social-economic features differentiate correspondingly in a similar spatial pattern. By thermal conditions, the arid and semiarid regions in China could be classified into: (1) The temperate arid and semiarid, and (2) the cold high arid and semiarid zones. The arid and semiarid region with humidity index <0.5 covers 3.15 million km^2, and makes up 32.78% of the total territorial area of China (Ci 1995). Due to insufficient rainfall, sparse vegetation, and frequent strong wind, land degradation occurs mainly in the arid and semiarid regions.

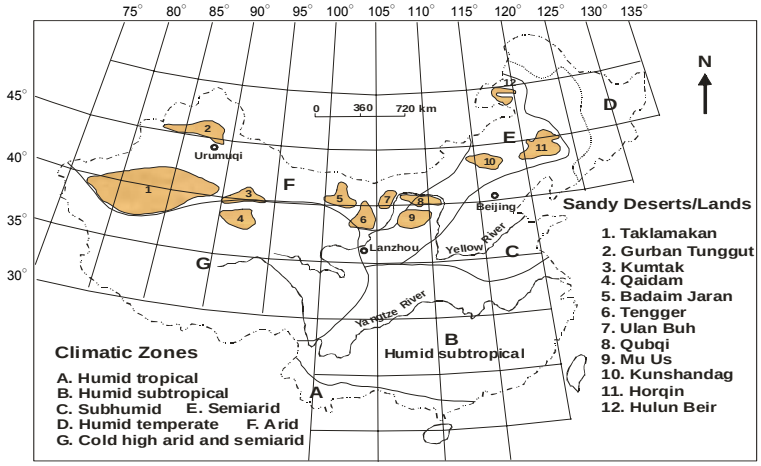

Fig. 1. Distribution of the climatic zones and major sandy deserts and sandy lands in China.

3. Distributions and Tendency of Land Degradation

3.1 Land desiccation

The aridity of northwestern China is chiefly due to its inland locality and far from the world oceans (Cooke et al. 1993). With the uplift of the Qinghai-Tibetan Plateau, northwest China has experienced a long history of intensified desiccation (Zhang 1992). In the past several decades, further land desiccation was induced due to both climatic fluctuation and human activities. In the semiarid area, annual rainfall change significantly with monsoon fluctuation, periodical land desiccation takes place due to frequent droughts. In the arid regions, irrational reclamation and excessive use of limited water resources in the middle and upper reaches of inland rivers, such as in Gansu, Xinjiang, led to large-area land desiccation, vegetation degeneration, and severe wind erosion in the lower reaches. The migrating lake Lop Nor in the terminal of Tarim River became completely desiccated in 1972 (Yan et al. 1998). In the Heihe River in Western Inner Mongolia, the terminal lake Gashun Nor, exposed its bottom in 1962, while the Sorgo Nor, shared the same fate in 1992 (Zhang et al. 1998).

3.2 Vegetation degeneration

Vegetation degeneration is the most important indicator of land degradation (Fig. 2). In the inland river basin, natural forest in the lower reaches degrades as a result of water shortage. Over the past twenty years the underground water table has descended at least 5 m. The root systems of natural desert vegetation can hardly absorb any moisture and died

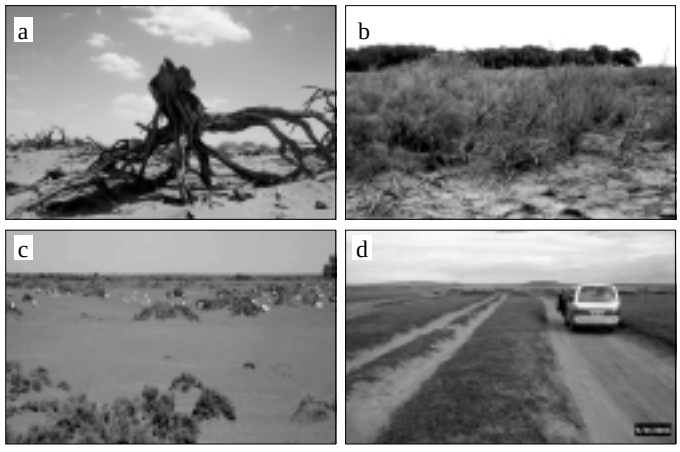

Fig. 2. Degeneration of vegetation due to (a) land desiccation, (b) salinization, (c) over-grazing, and (d) random traffic.

due to land desiccation. The area of *Populus Euphratica* in Ejina reduced from 50,000 ha in 1949 to 23,000 ha in 2002, and about 100 species of vegetation became extinct. In the rangeland, vegetation deteriorates due to reclamation, grazing and traffic. Since the 1950s about 87 M ha grassland in China has been degraded (Li 1993).

3.3 Wind erosion

Wind erosion takes place in succession to land desiccation and vegetation degeneration. Wind erosion features are extensive in China (Fig. 3). Numerous streamlined Yadangs occupy vast area of the Qaidam Basin. In the vicinity of Lop Nor, the White Dragon Mounds more than 20m-high, which were described in the Han Dynasty 2000 years ago, might have a history of 20,000 years (Huntinton 1907). Even the 1-2m-high clay mesas took its shape in about one thousand years. The rates of wind erosion on bare land in the arid region vary significantly due to the difference in lithology, moisture, land cover, and wind regimes. It has been estimated through different methods that 0.5 to 5mm thick top-soil could be removed by wind every year (Hedin 1905; Liu 1999; Dong et al. 2000). Wind erosion in the semiarid regions could be more intense due the accelerating effects of various human activities, such as reclamation, over-grazing and traffic disturbance (Liu et al. 2003; Li et al. 2004).

3.4 Sandification

Sandification is the major form of the land degradation in China (Fig. 1). Sand deserts and sandy lands total 710,000 km^2 in area (Zhu et al. 1980). There are 11 provinces and

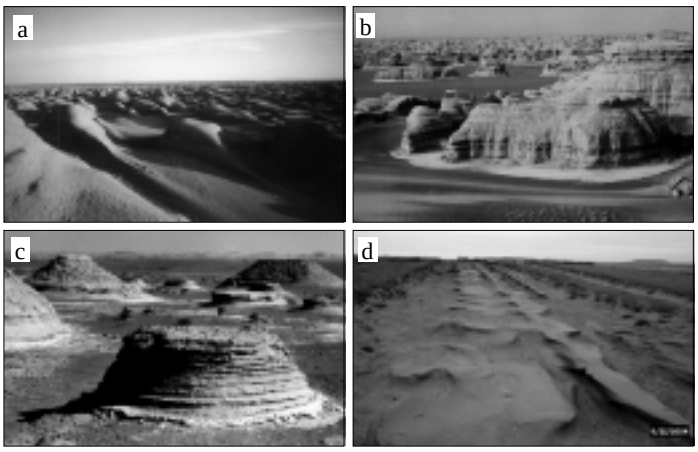

Fig. 3. Wind eroded features in China: (a) mega Yadangs in Qaidam Basin, (b) the White Dragon Mounds, east Lop Nor, (c) clay mesas in western Inner Mongolia, and (d) sand abraded grooves along traffic tracks, Xilin Gol Grassland, Inner Mongolia.

212 counties impacted by sandification. In the arid area to the west of Helan Mount, sandification is characterized by shifting sand seas. The Taklamakan Desert has an area of 337,600 km^2. Sand deserts distribute in huge tectonic basins where alluvial, fluvial and lacustrine sediments are transported from the surrounding mountains. In the semiarid area, sandification is distributed as fixed or semi-fixed sandy lands (Fig. 4). The area of sandification increased due to climatic change and human disturbances. Sandified land expanded at a rate of 1570 km^2 a^{-1} from the end-1950s to mid-1970s, 2100 km^2 a^{-1} from mid-1970s to mid-1980s, 2460 km^2 a^{-1} from mid-1980s to mid-1990s, and 3450 km^2 a^{-1} from mid-1990s to the end-1990s (Wang 2000).

3.5 Gobi-pebblization

Gobi pebblization represents a desert pavement, a surface concentrated with pebbles lagged by wind deflation or wetting and drying cycles. The coarse pebbles, which prevent the land from further erosion, can be easily disturbed. In northern China, the area of Gobi desert totals 569,500 km^2 (Zhu et al. 1980). It is mainly distributed in Xinjiang, Inner Mongolia and Gansu Province (Fig.5).

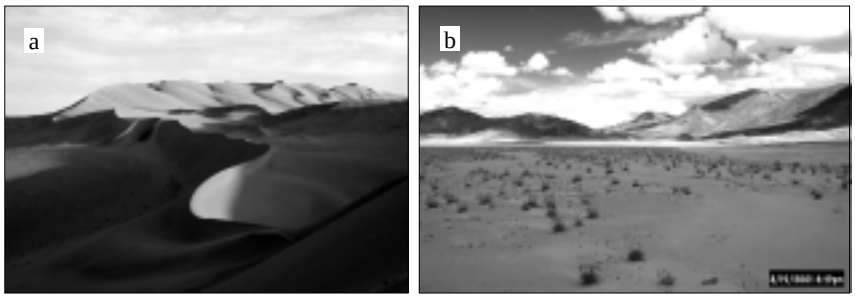

Fig. 4. Sandification (a) the Sand Mount near Dunhuang, (b) sandified grassland in Tibet.

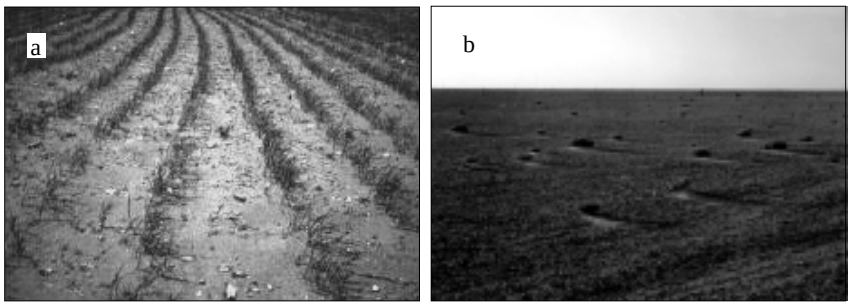

Fig. 5. Gobi pebblization: (a) farm land texture coarsening, (b) the black Gobi in Inner Mongolia.

3.6 Salinization

Salinization of soils, surface water and ground water is common in the arid and semiarid area. There are 99.13 M ha salinized soils in China (Wang et al. 1993). Salinized soil could be classified into recent (36.93 M ha), residual (44.87 M ha) and potential salinized soils (17.33 M ha). Due to intense evaporation and climatic fluctuation, soil salification is characterized by alternate intense surface salt accumulation and desalinization. Salinized soils in the arid and semiarid areas in China are distributed mainly in Inner Mongolia, Gansu, Xinjiang, Qianghai and Tibet. The water salinity in Qinhai Lake, Bosten Lake, and Dalai Nor is 13.13, 1.58, and 5.55 g l^{-1}, respectively.

4. Distribution of Sand and Dust Storms in Relation to Land Degradation

Accompanied by intense Siberian/Mongolian cold fronts, sand and dust storms in eastern Asia move out of the Gobi and sand desert regions of China along varied southeastward trajectories (Qiu et al. 2001). The annual average frequency of sand and dust storms in the arid and semiarid regions vary from 1 to 37 days with a general increase from southeast to northwest. Strong sand and dust storms occurs mainly in southern Xinjiang, in the middle and western Inner Mongolia. About 70 percent of the sand and dust storms occur in Spring.

Sand and dust storms occur under strong wind conditions, and sand entrainment, dust emission vary significantly from one land surface type to another. The ratio of sand and dust storm days to strong wind days at different land surfaces indicates the susceptibility of blown sand disasters on different degraded lands. The data in Fig. 6 and Table 1 imply that sand and dust storms can take place most easily in the sand desert and farmland areas, moderately in the grassland and gobi area, but most rarely in the salinized land.

Suspended particles carried in sand and dust storms from the arid and semiarid regions of China have caused extensive consequential effects on the atmospheric environment of Northern China, Eastern Asia and even the northern hemisphere (Duce et al. 1980; Liu et al. 1985). Air quality monitoring indicated that PM_{10} was the chief pollutant of the major cities in northern China (Shi 2000). The seasonality of sand and dust storms coincide with the severest air pollution in the major cities in China (Fig. 7).

5. Conclusions

Land degradation occurs widely in the arid and semiarid regions due to insufficient rainfall, sparse vegetation, and frequent strong wind. Land degradation in China involves with physical, ecological, chemical and anthropological processes. Land desiccation is the ultimate reason for vegetation degeneration, salinization, wind erosion, sandification, and Gobi pebblization. Suspended particles carried in sand and dust storms from the arid and semiarid regions have caused extensive effects on the atmospheric environment. Sand and dust storms occur most readily from the sand desert and farmland regions.

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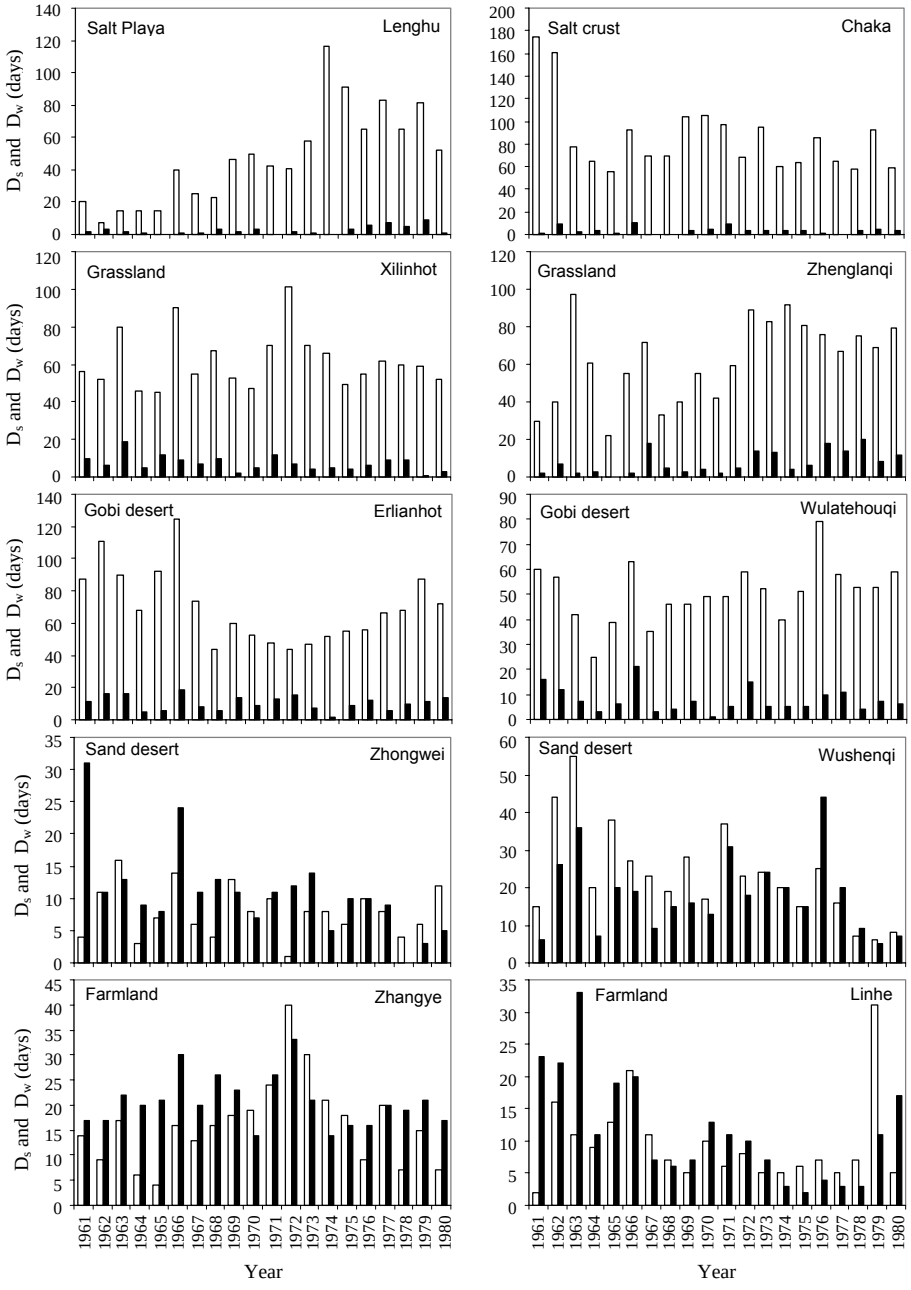

Fig. 6. Relationship between: ■ the days of sand and dust storm (D_s), and □ the days of strong wind (D_w) at stations under different land cover and use conditions.

Table 1. The days of sand and dust storm (Ds) and strong wind (Dw) under different land surfaces.

Land surfaces	Stations	D_s / D_w	Period
Salinized land	Lenghu	1/15.0	1961-1980
	Chaka Salt Lake	1/23.0	1961-1980
Grassland	Xilinhot	1/8.5	1961-1980
	Zhenglanqi	1/8.1	1961-1980
Gobi Desert	Erlianhot	1/6.7	1961-1980
	Wulatehouqi	1/6.6	1961-1980
Sand Desert	Zhongwei	1/0.7	1961-1980
	Wushenqi	1/1.3	1961-1980
Farmland	Zhangye	1/0.8	1961-1980
	Linhe	1/0.8	1961-1980

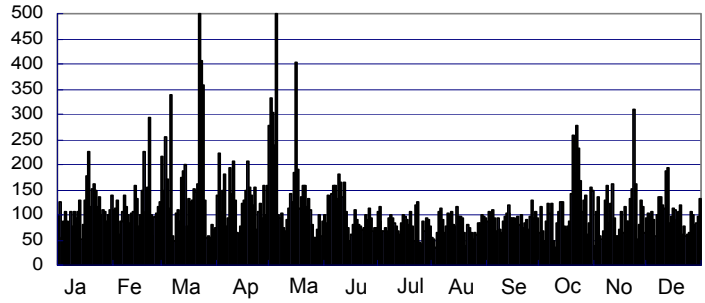

Fig. 7. Air pollution index affected by dust storms in Beijing, 2002.

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