

Desertification and Blown Sand Disaster in China

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Abstract: Approximately 331 million ha, one-third of China's total land, is prone to desertification processes, leading to natural disasters and economic losses. In this study, the situation, tendency, their influences and their risk governance of desertification and blown sand disaster in China were examined using satellite images, field photographs, field data and a literature review. The desiccated areas in Lop Nor and the lower Heihe River fluvial plain covered about 50,000 km² and 40,000 km², respectively. In Ejina, about 100 species of vegetation became extinct. The rate of wind erosion in China was between 1,000 tons/km²/year and 2,000 tons/km²/year. There were 12 sand deserts and sandy lands, occupying a total of 710,000 km². Salinized soils occurred across 99.1 million ha. The two main sand and dust storm-prone areas in China were the Tarim Basin and its surroundings, and the Alxa Plateau and its surroundings. From 1981 to 2007, the annual average frequency of sand and dust storms varied from 1 d to 37 d with a general increase from southeast to northwest. Since 1978, China has implemented a number of ecological construction projects that have reduced desertification from 1999 to 2004 and from 2005 to 2009, and the number of dust and sand storm days from 9.3 d between 1954 and 1959 to 4.4 d between 2000 and 2007. The results could improve understanding of desertification and blown sand disasters in China and provide valuable experiences for global desertification control.

Key words: Desertification, blown sand disaster, desertification and blown sand control, arid and semiarid China, ecological construction project.

1. Introduction

China has the largest population and the most serious land degradation in the world [1-3]. Land desertification in arid and semiarid China is the outcome of long-term interactions between natural and social-economic factors [4]. Approximately 331 million ha, one-third of China, is prone to desertification, and the direct economic loss caused by desertification is more than 5.4 billion RMB annually [5]. On the Loess Plateau of China, 4.3 million ha is affected by soil erosion, covering 70% of the total area of the Loess Plateau, and soil loss in this region

contributes more than 90% of the total sediments entering the Yellow River [6]. Annually, 1.6 billion tons of sediments are transported from the Loess Plateau to the Yellow River [7]. There is 400 million ha grazing land in China, and 137 million ha is moderately to severely degraded [8]. The total area of degraded grassland increased by about 95% between 1989 and 1998 [9]. The topsoil thickness progressively declined from the 1930s to 1950s, but began to increase again in the 1980s [10]. China's desert lands released 2,168 million tons net of organic carbon from 1960 to 2000; organic carbon release is an important factor affecting changes in concentrations of greenhouse gases [11]. The rapidly expanding population, increasing human land use and

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agricultural development have led to environmental degradation [12]. Over-cultivation on the steppe, overgrazing and forest loss for wood were responsible for 25%, 28% and 32% of the total area of desertification from the 1950s to 1980s, respectively [13].

A combination of climate change, frequent natural disturbances and growing human activities in arid and semiarid regions has resulted in a decline in soil productivity and vegetation coverage. To address this, the Chinese government has implemented several important ecological construction projects to deal with severe environmental problems, such as desertification, soil erosion and blown sand disasters. These include the Three North Shelterbelt Development Program (3NSDP), the Sand Source Control Program (SSCP) in the vicinity of Beijing and Tianjin, the Grain for Green Project (GGP), the Natural Forest Protection Program (NFPP) and the Grazing Ban for Grassland Restoration Program (GBGRP). Great efforts have been made by Chinese government to combat desertification, and the trend of desertification expansion has been mainly contained, although desertification continues to grow in some regions [5]. Here satellite images, field photographs, data from China Meteorological Administration and State Forestry Administration of China and a literature review were used to discuss the factors influencing desertification and blown sand disasters and their risk governance in China. The results could improve understanding of desertification and blown sand disasters in China and provide valuable experiences for global desertification control.

2. Situation and Tendency of Desertification in China

2.1 Land Desiccation

Desertification is mainly found in the arid and semiarid regions of China. Based on thermal conditions and humidity, the arid and semiarid regions, which can be classified into temperate arid and

semiarid, and cold high arid and semiarid zones with areas of 3.6 million km² and 1.9 million km², respectively, cover 57% of China's total land area. The aridity of Northwest China is chiefly due to its inland position [14]. With the uplift of the Qinghai-Tibetan Plateau, Northwest China has experienced a long history of intensified desiccation [15]. In the past five decades, further land desiccation has been induced by both regional warming and human activities [16]. In the arid regions, farmland expansion and excessive use of limited water resources in the middle and upper reaches of inland rivers led to broad scale land desiccation in Gansu province, Xinjiang and Inner Mongolia. The Lop Nor, a former "wandering" terminal lake of the Tarim River, where ancient oasis civilizations, such as Loulan, once flourished, dried out completely in 1972 [17, 18]. In the lower Heihe River in Western Inner Mongolia, the terminal lake Gashun Nor exposed its bottom in 1962, and the Sorgho Nor, Guaizi Lake and Gornai Lake suffered the same fate over time [19]. The desiccated areas in Lop Nor and the lower Heihe River fluvial plain cover about 50,000 km² and 40,000 km², respectively, and are considered important dust source regions in China (Fig. 1).

2.2 Vegetation Degeneration and Wind Erosion

Land desiccation leads to vegetation degeneration and severe wind erosion. Over the past 20 years, the underground water table has fallen by about 5 m in the lower Heihe Plain. Desert vegetation has died in large areas. In Ejina, about 100 species of vegetation became extinct, and the area of *Populus Euphratica* declined from 500 km² in 1949 to 230 km² in 2002 (Fig. 2a).

Wind erosion is the predominant landform process, and wind erosion features are extensive in arid and semiarid China. The rates of wind erosion in the arid region vary significantly due to the differences in lithology, moisture, land cover and wind regimes [20]. It has been estimated through different methods that

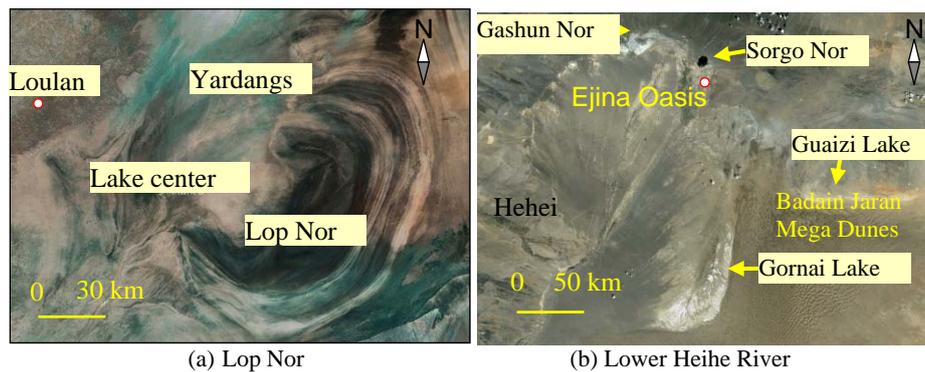


Fig. 1 Land desiccation in Northwestern China.

Source: Google earth.



(a) Ghost Forest (41°48'29.77" N; 101°1'5.07" E)

(b) Swan Lake (42°0'42.29" N; 101°34'15.52" E)

Fig. 2 Vegetation degeneration and wind erosion land form in Northwestern China.

0.5 mm to 5 mm topsoil could be removed by wind every year [21-23]. Studies using the methods of aeolian sand transport, soil texture analysis, Cs-137 tracing and archaeology confirm that the rate of wind erosion is between 1,000 tons/km²/year to 2,000 tons/km²/year [20]. The 1-2 m high wind eroded clay mesas were shaped by wind action over about 1,000 years, chiefly due to land desiccation influenced by human activities (Fig. 2b).

2.3 Sandification

Sandification is a major form of desertification in China. Sandy deserts and sandy lands cover a total of 710,000 km² [1]. In the arid area to the west of the Helan Mountains, sandification was characterized by vast shifting sandy deserts (Fig. 3). In the semiarid and sub-humid areas to the east of the Helan Mountains, sandy lands were normally fixed or semi-fixed sand dunes. The area of sandification fluctuated due to climatic change and human activities.

Remote sensing analysis showed that the area of sandification in China increased by 33,838.3 km² from 1975 to 1990, and 3,441.5 km² from 1990 to 2000 [24]. Since 2000, there has been a trend of recovery with implementation of the policy of returning farmland to forest, and returning grazed to ungrazed grassland. The area of land sandification decreased by 8,176.4 km² from 2000 to 2005 and by 5,571.8 km² from 2005 to 2010 [24]. The changes inland sandification occurred mainly in the agro-pasture ecotone in the semiarid and sub-humid regions, where several ecological construction projects have been carried out over the last decade.

2.4 Gobi Pebblization

Gobi pebbilization represents a desert pavement, which is land surface with pebbles left by wind deflation or wetting and drying cycles. The coarse pebbles on the Gobi surface protect the land from further erosion. However, coarse pebbles can be easily

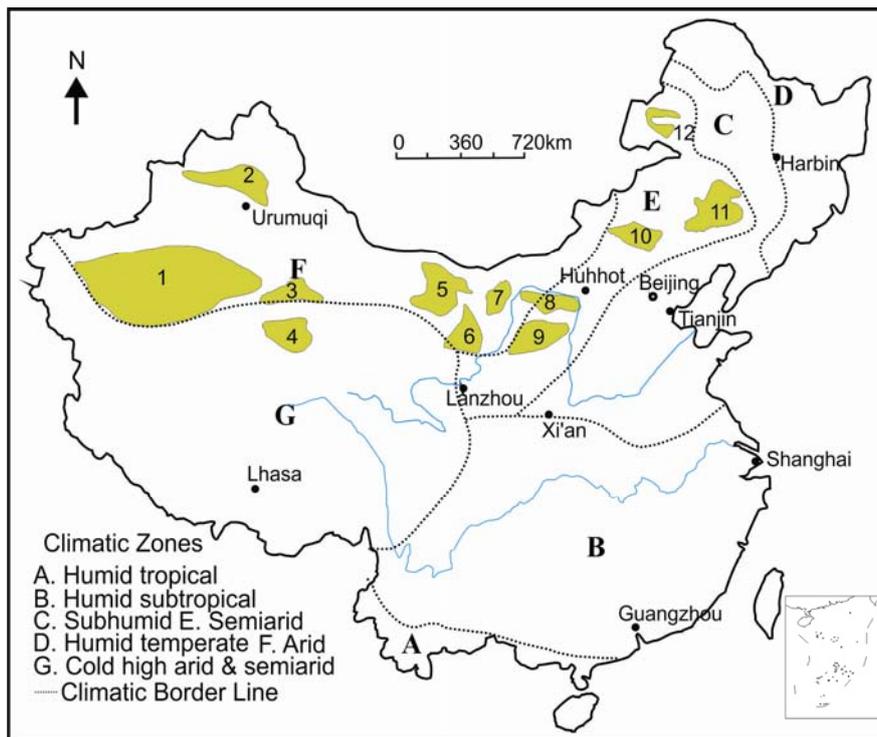


Fig. 3 Climatic zones, sand deserts and sandy lands zones in China.

1: Taklamakan; 2: Gurban Tunggut; 3: Kumtak; 4: Qaidam; 5: Badain Jaran; 6: Tengger; 7: Ulan Buh; 8: Qubqi; 9: Mu Us; 10: Kunshandag; 11: Horqin; 12: Hulun Beir [20].

disturbed and the subsoil can be exposed to further erosion by wind. The area of the Gobi Desert in Northern China is around 569,500 km² [1]. Along the eastern edge of the Gobi Desert in the Central Inner Mongolian region, interannual variation of the Gobi boundary position has been influenced by climatic change and land-use intensity.

2.5 Salinization

Salinization of soils, surface water and ground water is severe in the arid and semiarid areas. Salinized soils in China were mainly found in Inner Mongolia, Gansu, Xinjiang, Qianghai and Tibet. There were 99.1 million ha of salinized soils in China, including recent (36.9 million ha), residual (44.9 million ha) and potential salinized soils (17.3 million ha) [25] (Fig. 4). The water salinity in Qinhai Lake, Bosten Lake and Dalai Nor Lake was 12.9, 1.8, and 5.6 g/L, respectively [20, 26, 27]. The desiccation of bare saline soils could be a major source of salt dust emissions.

3. Blown Sand Disaster in China

Blown sand disasters are caused by various facets of wind-blown sand movement. They can lead to casualties of people and livestock, declining productivity of farmland and grassland, damage to buildings, roads, communications and other facilities, and deterioration of the atmospheric environment. Sand and dust storms have been a notable natural phenomenon in Northern China since ancient times [28]. Increasing human activities have strengthened the combined effect of land desertification and climatic change, enhancing the risk of blown sand disasters in Northern China.

China experiences sand and dust storms every year. From 1981 to 2007, the annual average frequency of sand and dust storms varied from 1 d to 37 d with a general increase from southeast to northwest (Fig. 5). The spatial distribution of sand and dust storms in the north of China showed the following characteristics:

(1) Large areas from Xinjiang in the west to the

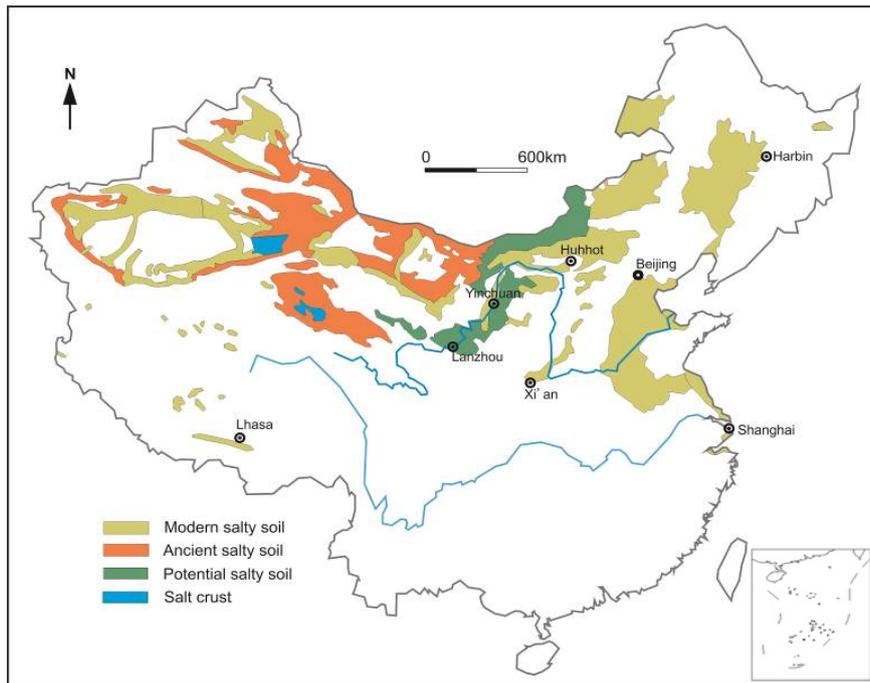


Fig. 4 Salty soils in Northern China [25].

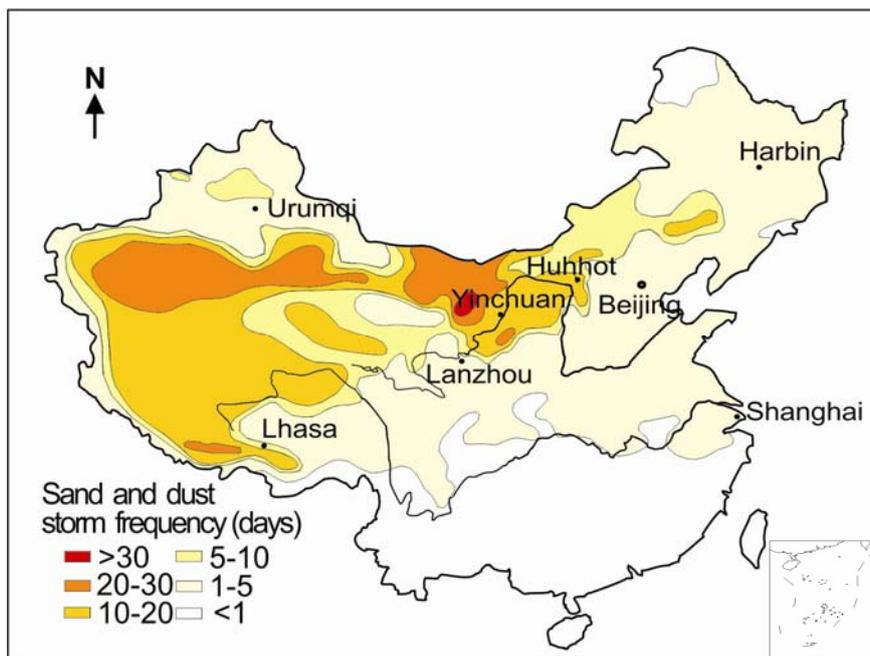


Fig. 5 Annual mean sand and dust storm frequency from 1981 to 2007 in China.

Source: China Meteorological Administration.

coastal regions in the east were affected by sand and dust storms. Thirteen provinces in the north of China were influenced by sand and dust storms to varying degrees;

(2) The sand and dust storm-prone areas were

centralized. There were two main areas—the Tarim Basin and its surrounding areas and the Alxa Plateau and its surrounding areas;

(3) There was a close relationship with regional sandification and human activities. The widespread

desert, sand and farmland surfaces provided extremely rich sand and dust source materials for the formation and development of sand and dust storms.

In total, about 100.7 million people live in China's arid and semiarid dryland areas. Desertification and blown sand disasters lead to damages to traffic and communications, severe atmospheric environmental pollution and widespread dustfall, adverse impacts on land and water resources, and agriculture and animal husbandry (Fig. 6). Extremely strong sand and dust storms, such occurred on May 5, 1993, caused the death of 85 people and the injury of 264 people. Annually, dustfall in continental China due to sand and dust storms was about 400 million tons accounting for 50% of total dust emissions in China [29].

4. Countermeasures of Desertification and Blown Sand Disaster in China

The Chinese government has attached great importance to the prevention of desertification and the governance of blown sand disasters. In the past six decades, China had some successes in blown sand prevention and control measures and technologies, and has developed engineering and biological measures for the prevention and control of blown sand hazards. Since 1978, China has implemented several important ecological construction projects, such as the 3NSDP, GGP, NFPP, SSCP and GBGRP (Table 1).

The 3NSDP, GGP, NFPP and SSCP have restored 26.47, 9.26, 14.0 and 6.0 million ha of forest, respectively. GBGRP has protected 518.66 million ha of grassland with fences and reseeded 12.40 million ha of severe degraded grassland. Ecological restoration programs enhance soil conservation by reducing the amount and velocity of overland water flow as well as the sediment loads on the Loess Plateau [30]. These large-scale programs have not only improved the ecological environment, but also substantially increase forest and soil carbon stocks and sequestration rates at local levels [10, 31, 32]. Liaoning province, where the NFPP has been implemented since 2000, was found to be a carbon sink, with carbon stocks increasing from 63.0 million tons C in 1980 to 120.9 million tons C in 2010, and the average C density of forest biomass increased from 26.2 ton/ha in 1980 to 31.0 ton/ha in 2010 [33]. Plant biomass after afforestation acted as an important sink for N and led to an overall increase in N retention within the system [34]. Data of annual plantation area and biomass N accumulation rates under the GGP indicated that Guizhou province was a net N sink with 2.35×10^8 kg N in 2010 [35]. Moreover, ecological construction projects help local farmers and communities increase agricultural production and escape poverty.

The National Satellite Meteorological Centre of China



Fig. 6 Sand dunes encroaching from Badain Jaran Desert into Linze Oasis.

Source: Google earth.

Table 1 Government investment in five key forestry and desertification control projects in China.

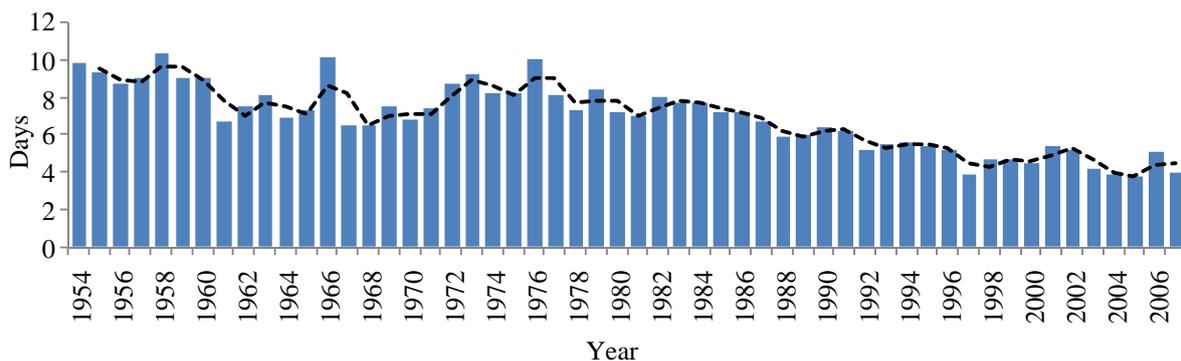
| Key projects | Government investment ($\times 10^8$ Yuan) | Chief benefits of different projects |
|----------------------|---|---|
| 3NSDP (1978-2010) | 128 | 26.47 million ha of afforestation land |
| GGP (2002-2010) | 2,332 | 9.26 million ha of cropland was converted into forest land |
| NFPP (2000-2010) | 784 | Forest area increased by 14.00 million ha, timber production reduced by 220 million m^3 |
| SSCP (2001-2010) | 412 | 6 million ha of cropland was returned to forest |
| GBGRP (2003-2010) | 203 | 518.66 million ha of grassland was protected with fences and 12.40 million ha of severe degraded grassland was reseeded |

Source: State Forestry Administration of China.

Table 2 Areas of sandy desertified land in Northern China since 1994.

| Years | Total area of desertified lands (million km^2) | Total area of sandy desertified lands (million km^2) | Trend |
|-------|---|---|-------|
| 2009 | 2.624 | 1.7311 | ↓ |
| 2004 | 2.636 | 1.7397 | ↓ |
| 1999 | 2.674 | 1.7431 | ↑ |
| 1994 | 2.622 | 1.7259 | ↑ |

Source: State Forestry Administration of China.

**Fig. 7 Changes in sand and dust storm days in Northern China (1954-2007).**

Source: China Meteorological Administration. The dashed line is trend line.

Meteorological Administration began to develop a method of satellite-based remote sensing monitoring for sand and dust storms from the 1990s, which mainly uses multi-channel data of polar orbiting meteorological satellites (National Oceanic and Atmospheric Administration/Advanced Very High Resolution Radiometer, NOAA/AVHRR) to identify sand and dust storms. Also, the State Forestry Administration has conducted periodic monitoring on the area of desertified land in China. The monitoring results showed that nationally desertified land area tended to decrease from 1999 to 2004, and from 2005 to 2009 (Table 2). At the same time, there was a decline in the number of sand and dust storm days in

Northern China (Fig. 7). The highest number of sand and dust storm days was 10.3 d in 1958. The lowest sand and dust storm day was 3.7 d in 2005. Annual sand and dust storm days averaged 9.3 d between 1954 and 1959, 7.6 d between 1960 and 1969, 8.2 d between 1970 and 1979, 7.0 d between 1980 and 1989, 5.2 d between 1990 and 1999 and 4.4 d between 2000 and 2007. The variations were related to the meteorological conditions and human activities. In the desertification regions, wind speed decreased significantly from 1960 to 2013 [36]. Decreasing trends in wind speed and ecological constructions led to a decrease in the number of sand and dust storm days.

5. Conclusions

China has the most serious land degradation in the world. The occurrence and development of desertification involve physical, chemical, ecological and human processes, and appear as land desiccation, vegetation degeneration, wind erosion, sandification, Gobi pebbilization, salinization and various kinds of blown sand disasters. To combat desertification and blown sand disasters, the Chinese government implemented a series of ecological construction projects. In the past 10 years, positive effects have been seen from these projects, such as vegetation restoration. Lessons learned in practice and ongoing improvements to desertification control in China have provided valuable experience for global desertification control. Continuous monitoring of the spatial and temporal variation of forests and its direct and indirect impacts on ecology and environment is necessary to evaluate the effectiveness and improve the implementations of ecological construction projects.

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