Human Causes of Aeolian Desertification in Northern China

Tao Wang1,*, Xian Xue1, Yiqi Luo2,3, Xuhui Zhou2, Bao Yang1, Wanqun Ta1, Wei Wu4, Lihua Zhou1, Qingwei Sun1, Xunming Wang1, Halin Zhao1, Xueyong Zhao1

1. Key Laboratory of Desert and Desertification, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou Gansu 730000, China
2. Department of Botany and Microbiology, University of Oklahoma, Norman, Oklahoma 73019-0245, USA
3. School of Life Sciences, Fudan University, Shanghai 200433, China
4. Institute of Tibetan Plateau Research, Chinese Academy of Sciences, Beijing 100085, China

*Corresponding author: Tao Wang, Key Laboratory of Desert and Desertification, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou Gansu 730000, China.
E-mail: wangkan@lzb.ac.cn

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ABSTRACT

Aeolian desertification has rapidly developed in the past 50 years in Northern China, covered an area of 0.386 million km² by 2000, affected nearly 170 million population, and caused the direct and indirect economic loss of about $6.75 (U.S. dollar) billion per year. Here we present several lines of evidence to demonstrate that human activities guided by policy shifts have been a major force to drive aeolian desertification via changes in land-use patterns and intensity. It is suggested that the desertification can be curbed or even reversed by adopting prevention and control measures with ecologically sound land-use practices in China.

KEY WORDS: aeolian desertification; climate change; drought; human activities; Northern China

1. Introduction

Desertification in arid, semiarid and dry sub-humid areas destroys land resources, reduces ecosystem productivity and services, exacerbates the poverty, and incurs instability of political systems in many developing countries (UNCCD, 1994). China, for example, has seriously suffered from the desertification in past decades, particularly from the aeolian desertification. The aeolian desertification is the land degradation characterized by wind erosion. Aeolian desertification of China reached 0.386 million km² in 2000 (Wang et al, 2004) and contributed significantly to dust loading in the atmosphere, which was carried by wind to the eastern China, such as Beijing and Nanjing, and even to foreign Korea, Japan, and west coast of the United States. The direct and indirect economic loss by the aeolian desertification was estimated to be more than 54 billion Chinese Yuan ($6.75 billions U.S. dollar) per year and threatens nearly 170 million populations in Northern China (http://www.cpcir.org.cn/rkkx/2003_3.htm, 2003). Despite grave consequence of desertification, it is very controversial on its causes. Without sound understanding of the causes, we could not develop effective measures to combat desertification.

Desertification generally results from climatic variations, human activities, and their interplay (UNCCD, 1994; Reynolds et al, 2002). The relative importance of climate and human factors in desertification has been debated for different regions at different periods of time. Climate variation has been consi-
dered to be a major cause, leading to desertification in the Sahel (Xue et al., 1993), the ‘Dust bowl’ in south Great Plains of USA (Siegfried et al., 2004), and land degradation in India (Sinha, 1983) and China (Lin et al., 2002). However, other researchers argued that over-grazing, over-farming, and over-exploitation of natural resources are the most important causes of desertification. Thus, anthropogenic pressure is considered as the key factor of desertification in Sahel (Rapp, 1974), Cameroon (Etienne, 1998), Central Asia (Babaev, 1999), Kuwait (Jasem et al, 2003), Mediterranean region (Balabanis et al, 1999), Mexico (Mario et al, 2000), and China (Zhu, 1998). Many of the case studies emphasized on the interplay of climate and human activities and found it difficult to attribute desertification to any individual factors (Vetter, 2005). Indeed, desertification most likely results from complex interaction among meteorological (e.g., temperature, rainfall, and wind) (Okin et al, 2006), biophysical (e.g., vegetation, soil, animals, and biodiversity) (Hoffman et al, 2000; Li et al, 2005), hydrological (e.g., runoff and groundwater) (Martinez-Fernandez et al, 2005), and socioeconomic factors (e.g., farming, grazing, policy shifts, land management, and land-use patterns) (Fernandez, 2002; Hiernaux et al, 2002; Walker et al, 2002). We have conducted comprehensive studies on desertification processes in China in the past two decades. Here we report results of our studies and argue that aeolian desertification developed in the past few decades in Northern China was largely attributable to human activities.

2. Methods

2.1. Monitoring of aeolian desertification areas by remote sensing

Aeolian desertification areas were monitored in 177 counties (or cities) of 10 provinces or autonomous regions of Northern China, covering an area of 2.56 million km² from the Hulun Buir steppe in the Northeast China to the inland oases locating in desert margins of Northwest China. The monitored regions mainly contain the semi-arid, sub-humid agro-pastoral ecotones, semi-arid grassland regions, arid inland oases, and alpine meadows.

The monitoring of aeolian desertification areas was done with aero-photography in 1950s, Landsat Multi-Spectral Scanner (MSS) images in 1980s, and Thematic Mapper (TM) images in 2000. The areas and distribution of aeolian desertification lands in Northern China were obtained with the tools of geographic information system such as ARCVIEW and ARC/INFO through the man-machine dialogue interpretation of remote sensing data. To better reflect the vegetation situation, autumn imagery has usually been analyzed. The monitored aeolian desertified areas were separated into the four categories of aeolian desertification levels as in Table 1.

2.2. Analysis of climate change in Northern China

To understand the cause of aeolian desertification, we analyzed drought frequency in past 500 years and drought index in past 120 years in the eastern arid region of the Northwest China (from the eastern margin of Taklimakan Desert to Helan Mountain), the western semiarid region of the Northern China (the west part of Inner Mongolia and the north part of Shanxi and Shaanxi provinces and Ningxia province), and the eastern semiarid region of the Northern China (the middle and east part of Inner Mongolia and the north part of Hebei province) (Figure 1).

We first constructed a 500-year time series of drought frequency in Northern China. The decadal regional proxy records of precipitation fluctuations (a. ice cores at Dunde in Gansu province and Guliya in north Tibet Plateau; b. tree rings and their correlation with summer rainfall at Wulan in Qinghai province; c. sedimentation in the Qinghai Lake of Qinghai province; d. water discharge rates in the upstream of Yellow Rivers; and e. historical documentation) were used to quantify drought frequency in the Northern China for the last 500 years. Second, a yearly dryness/wetness intensity value between 1 and 5 which represents heavy flood, flood, normal, drought, and heavy drought conditions was assigned...
TABLE 1 The aeolian desertification classification system in Northern China

<table>
<thead>
<tr>
<th>Grades of desertification</th>
<th>Desertification characters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sand dunes and sheets activation</td>
</tr>
<tr>
<td>Primitive landscape</td>
<td>Fixed dunes or steppe, farmland</td>
</tr>
<tr>
<td>Lightly desertification</td>
<td>Wind erosion pits emerge on the windward slope of dunes; shifting sand emerge on the spot; and $P=5%-25%$, $C=90%C_p$</td>
</tr>
<tr>
<td>Moderately desertification</td>
<td>Erosion and deposit slopes apparently emerge on dunes; $P=25%-50%$, $C=50%-90%C_p$</td>
</tr>
<tr>
<td>Severely desertification</td>
<td>Sand land become semi shifting and $P&gt;50%$, $C&lt;50%C_p$</td>
</tr>
<tr>
<td>Very severely desertification</td>
<td>Shifting sand lands emerge and $C&lt;10%C_p$</td>
</tr>
</tbody>
</table>

Note: $C=$ coverage of vegetation; $C_p=$ coverage of primitive vegetation; $P=$ the proportion between sifting sand area and total area.

to each meteorological station in the study region. The grading standard is the same as that used in book “China Flood/drought Category Map for the Last Five Centuries” (1981) and that by Zhang and Crowley (1989). In cases when meteorological observations were available, measured amounts of rainfall for the May-September month were used to calculate the intensity values for the late twentieth century (Wang, 2000). Then, yearly regional means of dryness/wetness intensity values were calculated, and mean values greater than 3.0 were denoted as drought events. Finally, a decadal-scale regional drought frequency series was derived by counting the occurrences of drought in each decade. Following the procedure, we extended all the drought frequency series to the 1990s (Figure 2).
We also constructed a 120-year time series of precipitation anomalies, temperature anomalies, and drought index (Figure 3), based on (a) the mean annual temperature of 10 regions in Northern China; (b) the precipitation of 35 stations over China from 1880 to 2000 (Wang et al, 2000). The climatic data during the latest 50 years were mainly from instrumental records.

The drought index (DI) was formulated to represent the difference between standardized anomalies of surface air temperature and atmospheric precipitation in the study areas. In this study, the DI is defined according to Pedj (1975) as:

\[
DI = \frac{\Delta T}{\delta T} - \frac{\Delta P}{\delta P}
\]

Where, \(DI\) is the drought index, \(\Delta T\) and \(\Delta P\) is the departures of surface air temperature and annual total precipitation, whereas \(\delta T\) and \(\delta P\) is the standard deviations of temperature and precipitation.

To calculate the drought index, we used the long-term data of the mean annual temperature of 10 regions in Northern China and four seasonal precipitations of 35 stations over China from 1880 to 2000 (Wang et al, 1998; Wang et al, 2000; Ye et al, 1998). Weather stations with long-term observations have been available in Beijing since 1873. In addition, several data sources, including ice cores in western China, 5-grade data of temperature and precipitation based on the documented records in China, have also been used in the construction of drought index for the period without instrumental records. In particular, \(\delta^{18}O\) data from the Dunde ice core were used to extend temperature data for Northwest China before instrumental observation (Wang et al, 1998; Wang et al, 2000).

2.3. Data on human activities

Data on human activities such as population, livestock number, farmland areas and so on were collected in last 50 years in these study areas. Some
state’s policies, such as “Great Leap Forward”, “Regarding Grain as Key Link”, “Household Contract Responsibility System” and “Grain for Green Project” also were analyzed.

![Drought frequency in three regions of North China for last 500 years. The horizontal dotted lines indicate long-term averages of each series. The step-type lines indicate decadal averages of drought frequency. The smoothed red curves were derived by Fast Fourier Transform (FFT) filtering of drought frequency to illustrate long-term fluctuation. The dotted curve for the eastern arid region of the western China was the proxy record of Wulan tree-ring width.](image)

**FIGURE 2**

2.4. Analysis of field wind

Windy days with instantaneous wind speed exceeding 17.2 m/s within a day and wind speeds in spring were obtained from 175 meteorological stations located throughout northern China (meteorological stations and data sources from [http://www.cma.gov.cn](http://www.cma.gov.cn)) from 1961 to 2002.

2.5. Wind tunnel study

Two to four samples of chestnut soil, brown soil, Sierozem, Chernozem, and aeolian sandy soil were collected in the dry steppe of Gonghe Basin of Qinghai province, Etuoke of Inner Mongolia, Gulang of Gansu province, and Zhenglanqi of Inner Mongolia, respectively. Each sample size was 95×30×20 cm³ with weight of 60~80 kg. Additional five samples of aeolian sand soil were collected in Shapotou of Ningxia. To avoid damages of soil structure and the vegetation covers, the soil monoliths were contained in woody boxes with the topside open during the transportation from soil sampling sites to the wind tunnel experimental laboratory in Lanzhou, China. Before the wind tunnel experiment, all the soil samples together with plant vegetation have been air-dried for about one year.

The soil monoliths of each soil type were carefully cut into soil blocks with dimension of 10cm wide×10cm long ×5cm thick. Four soil blocks were used as the control with their top surface undisturbed and six as treatment with their top surface disturbed with a knife to 1 cm deep. The disturbed areas were in shape of rectangles and randomly distributed on the soil surface.
The aeolian sandy soil samples were cut into eight blocks with a dimension of 10cm wide×10cm long×5cm thick. The soil surface of the eight soil blocks was undisturbed. The dried vegetation covers of the soil blocks were carefully altered to 60.4%, 49%, 40.3%, 33.7%, 27.2%, 19.7%, 10.9%, and 5.47% of the soil surface, respectively, for studying effects of vegetation covers on wind erosion.

The experiment was conducted in the wind tunnel in the Key Laboratory of Desert and Desertification, Chinese Academy of Sciences, Lanzhou, China. The wind tunnel is 38 m long overall with a test section of 16.23 m long and its cross section is 1.0m wide × 0.6m high. Wind speed can be continuously adjusted from 0.5 m/s to 40 m/s. Each soil sample block was horizontally laid on the automatic weighing balance at the end of the test section of the wind tunnel. The soil surface of the sample block was on the same level with the bottom board of the wind tunnel during the experiment. When the wind tunnel experiment began, the sample was first covered by a board until the target wind speed was reached. Each tunnel test lasted for 10 minutes and the soil sample was weighed to record the amount of soil lost by wind erosion, from which a wind erosion rate was calculated. The wind tunnel test was repeated 5 times for each soil block.

3. The development of aeolian desertification in Northern China

From the remote sensing monitoring, aeolian desertification has developed mainly in the agro-pastoral zones and pastoral zones, and in the marginal lands located in outskirts of deserts and low reaches of inland river basins in Northern China in the past 50 years (Figure 4). The total aeolian desertified area in China was 0.137 million km$^2$ in 1955, increasing to 0.176 million km$^2$ in 1975 and 0.334 million km$^2$ in 1987, and reaching to 0.386 million km$^2$ in 2000 (Wang et al, 2004b) (Figure 5c). On average, aeolian
desertified land was developed at a rate of 1,560 km²/yr from 1955 to 1975, 2,100 km²/yr from 1976 to 1987, and 3,600 km²/yr from 1988 to 2000 (Wang et al., 2004a). We examined climatic, socioeconomic, and policy factors in influencing the rapid development of desertification.

**FIGURE 4** Spatial distributions of aeolian desertified land in Northern China in 1950s, 1987, and 2000. Due to restoration policy, the desertification was reversed in some areas in the Northern China by the end of 1990s. Human activities have also pushed the agro-pastoral boundary northwards by approximately 200 km from 1950s to 2000.

### 4. The impact of drought on aeolian desertification

The constructed time series showed that dry periods occurred once per century on average in the Hexi region of Gansu province, the western semiarid zone, and the eastern semiarid zone of Northern China (Figure 2). Each dry period persisted approximately 50 years and usually occurred in the first half of each century. The climatic condition in the Hexi region and the western semiarid zone in the latest 50 years were slightly above the 500-year averages but was not severely dry in comparison with other drought periods. The drought frequency in the eastern semiarid zones in the recent 50 years was lower than the 500-year average (Wang et al., 2004). Thus, the climatic condition in the past 50 years was not particularly favorable to inducing severe aeolian desertification.

The annual anomaly series of temperature, precipitation and drought index (DI) during the recent 120 years are shown in Figure 3. Northern China experienced two periods of high temperature. The first period of higher temperature was from 1920s to 1940s and the second lasted from 1980s to 2000. The period with the highest MAT (mean annual temperature) appeared from the late 1930s to 1940s. Since 1980s, the temperature has gradually increased, but the MAT did not exceed the average in 1940s. Precipitation fluctuated more frequently than temperature did. It was below the 120-year average during the period from 1890s and 1920s but above the average during the 1880s and from 1940s to 1950s. The drought index during the 1980s~1990s in the region was relatively high but did not exceed the highest one during the 1920s~1940s. Thus, climatic condition since 1980 appeared to moderately favor desertification but was still less severe than that in the 1920s~1940s in comparison to the average climate in the past 120 years.

### 5. The impact of human activity on aeolian desertification

Increases in population and changes in land-use practices often resulted in the aeolian desertification in Northern China. Historically, the aeolian desertification
FIGURE 5  Changes in drought frequency, dryness index, sizes of human population, number of livestock equivalents, and major changes in China’s State policies that affected land-use in Northern China. Bars indicate aeolian desertification areas in 1955, 1973, 1987, and 2000. Desertification in the Northern China was primarily driven by increases in human population and livestock, and changes in State policy. The data of animal production (sheep equivalents) in Northwest China are from the Statistical Yearbook (1949~2000) of the five provinces, namely, Gansu province, Qinghai province, Inner Mongolia Autonomous Region, Nixia Hui Autonomous Region, and Xinjiang Uygur Autonomous Region. State policies are shown by numbers 1 and 2 for “Great Leap Forward” and “Take Grain as the Key Link”, respectively, number 3 for “Household Contract Responsibility System in Rural Areas”, and number 4 for “Grain for green”
occurred in the marginal areas of Taklimakan Desert in Xinjiang and Alashan Desert in Inner Mongolia during the Han Dynasty about 2,000 years ago. Aeolian desertification also took place in Mu Us Sandy Land during the Tang Dynasty 1,400 years ago and in Horqin Sandy Land during the Qing Dynasty in the middle of 17th century. The aeolian desertification has extended with an accelerating rate in the past 50~100 years to 0.386 million km$^2$ in 2000 (Figure 5c). The expansion of aeolian desertification during different historical periods was related to growth of human population and changes in land-use patterns.

The human population in the five provinces or autonomic regions (i.e., Inner Mongolia, Xinjiang, Ningxia, Shaanxi, and Qinghai) of Northern China increased rapidly since 1750, reached nearly 24 millions in 1950 and 78.5 millions in 2000 (Figure 5c). The annual growth rate of population was, on average, 24.1‰. The increase in population was mainly occurred in the agro-pastoral ecotones where the annual growth rate of population reached 30.8‰ during the period of 1950s to 1980s. The rapid growth of population resulted from natural growth and migration due to the China’s State policy that encouraged immigration for exploiting less populated grasslands in Northern China. From 1949 to 1978, the immigrants totaled 3.76 million in Inner Mongolia, 3.14 million in Xinjiang, and more than 1.0 million in Qinghai and Ningxia. In 2000, approximately 32 million people lived in the aeolian desertified areas in Northern China.

Rapid expansion of population has resulted in increases in population density, especially in areas with the agro-pastoral ecotones. For example, the population density was 73 persons/km$^2$ in the Songnen Sandy Land, 43 persons/km$^2$ in the Horqin Sandy Land, and 48 persons/km$^2$ in the Kubqqi Sandy Land in 2000. The average population density increased from 10 persons/km$^2$ to 50 persons/km$^2$, and even to 80 persons/km$^2$ in some aeolian desertified areas. The population density in the desertified lands in Northern China was several-fold higher than the critical index defined by the United Nations, which is 7 persons/km$^2$ in arid regions and 20 persons/km$^2$ in semiarid regions. The high population density exerted severe stresses on lands. The livestock, which was indicated by sheep equivalents, increased from 79.6 millions in 1949 to 249.6 millions in 2000 in the five provinces (Figure 5c). The increased population also accelerated reclamation of grasslands for cropping. In Inner Mongolia alone, for example, reclamation converted 4.68 million km$^2$ of grasslands and woodlands into croplands from 1949 to 2000. As a consequence, conversion extended the farmland northwards and pushed the north boundary of the agro-pastoral ecotones 180~220 km northwards into locations of typical steppe or desert steppe since 1760 (Figure 4). Therefore, the human-induced changes in the land-use patterns created favorable conditions for soil erosion by wind and aeolian desertification (Zhu, 1998).

The rapid population expansion and resultant aeolian desertification was partly attributable to changes in some of the State policies. For example, after a period of rapid population growth from 1760s to 1840s, Qing Dynasty encouraged migration to north of the Great Wall to cultivate grasslands. In the late 1950s, China’s State policies encouraged reclamation of natural grasslands under the “Great Leap Forward” and “Take Grain as the Key Link” policies. The State policy on “Household Contract Responsibility System in Rural Areas” leased lands to individual peasant households, without appropriate land conservation and management guidance, since 1978. The State policy encouraged the peasant to pursue short-term economic gain via over-grazing, over-cropping, and over-logging in the state-owned lands, resulting in severe aeolian desertification.

6. The impact of aeolian desertification on ecosystems

The aeolian desertification induced by the excessive human activities involved degradation of both vegetation and soil, leading to reduction in species diversity, vegetation cover, biomass production, and soil organic carbon (SOC), and nutrient accumulation (Li et al, 2008). In the Horqin region, the total loss of
biomass from the aeolian desertified grasslands was 0.22 Pg C during the last 41 years by 2000 (Wang et al., 2005). Estimates from the present SOC content in aeolian desertified lands indicate that wind erosion has resulted in a great amount of SOC loss (2.17 Pg C) from the surface soil during the last 40 years (1950~1990) in Northern China, representing 35.8% of the organic C in the soil profile of 0~1.0 m (Feng et al., 2004). In 1990s, the wind erosion rate of SOC was 75 Tg C/yr in the region (Yan et al., 2005), which is about 2.2 times as the SOC loss across the continental USA (34 ± 10 Tg C/yr) (Smith, 2005). Besides SOC, soil clay, nitrogen, microbial diversity, and fauna richness also declined with the expansion of desert. Manipulative experiments in the Horqin region showed that plant diversity, vegetation coverage, plant height, and primary productivity under continuous overgrazing for 5 years were only 12.1%, 17.9%, 6.0%, and 43.0% of that in the un-grazing plots (Zhao et al., 2004). The degradation in both vegetation and soil caused by desertification leads to accelerated soil erosion by wind (Li et al., 2003, 2005).

Wind erosion also varies with soil type and wind speed. Our analysis indicates that number of windy days and wind speeds in spring were highest in 1960s and, since then, gradually decreased. Decreased windy days and wind speeds in spring did not favor dust storms. On the other hand, occurrence of dust storms also depends on vegetation covers, soil types, and destroyed soil surface ratio (DSR – ratio of destroyed soil surface to the total area in tunnel experiments). There are five major types of soils in Northern China, which are known as Chestnut soil, Brown soil, Sierozem, Chernozem, and Aeolian sandy soil. All of the soil types are prone to be eroded after their surface vegetation cover was decreased or removed (Li et al., 2005; Zhao, 2006). Our wind tunnel experiments showed that the wind erosion is accelerated with wind speed, especially when it reaches 16 m/s or higher (Figure 6b). The wind erosion rate exponentially increases with DSR, and exponentially decreases with vegetation coverage (Figure 6c and Figure 6d). Our data from tunnel studies and wind field analysis indicated that aeolian desertification was primarily caused by disturbance of land surface by human activities in recent decades.

### 7. Can aeolian desertification be reversible?

To reduce desertification and dust storms, China developed a policy “Grain for Green” in 1999. Since then, desertification has been reversed in several local areas (Figure 4) although the overall desertified areas kept increasing in Northern China. We studied spatial changes of aeolian desertification in the Horqin region during the past 50 years. The aeolian desertified area increased from 42,300 km² in 1959 to 51,384 km² in 1975 and 61,008 km² in 1987. The desertified areas decreased by 10,810 km² or 17.7% from 1987 to 2000 (Table 2). Of the desertified land, very severely and slightly desertified land areas increased by 393 km² and 1,749 km², respectively, while severely and moderately desertified areas decreased by 488 and 12,463 km², respectively. The reversion of aeolian desertification in the Horqin region was caused by use of a series of the China’s State policies such as “Grain for Green” and “Limitation of Grazing in Grasslands”, which were designed to combat aeolian desertification and reduce dust storms. Under these policies, grasslands and forests had to be restored from farmlands, and grazing intensity had to be reduced according to the carrying capacity of grasslands with financial subsidy to farmers. As a consequence, soil fertility and vegetation cover were partially restored. The aeolian desertification was effectively curbed and even reversed in the region and some of the other local agro-pastoral areas (Su et al, 2005; Su et al, 2006).

### 8. Conclusion

Although the climatic variation in the past 50 years has been in favorable for desertification in Northern China, drought index was still lower than the severest one in 1920s~1940s. Without excessive human
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FIGURE 6 Change in spring wind speed and windy days in Northern China. (a) relationships of wind erosion rate with soil types; (b) destroyed soil surface ratio (DSR); (c) and vegetation coverage ratio; (d) under different wind speed. DSR is a ratio of destroyed areas over the total soil surface of the soil monoliths used in the wind tunnel studies. The destroyed area is the sum of several rectangular areas created by random methods. Windy day is the day with wind speed larger than 17.2 m/s.

TABLE 2 Changes in desertified land in the Horqin region in four categories of severity in aeolian desertification from 1959 to 2000

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Area (km$^2$)</th>
<th>Very severe (km$^2$)</th>
<th>Severe (km$^2$)</th>
<th>Moderate (km$^2$)</th>
<th>Slight (km$^2$)</th>
<th>Changes relative to previous stages (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1959</td>
<td>42,300</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1975</td>
<td>51,384</td>
<td>2,829</td>
<td>7,885</td>
<td>22,495</td>
<td>18,175</td>
<td>+21.47</td>
</tr>
<tr>
<td>1987</td>
<td>61,008</td>
<td>5,162</td>
<td>5,422</td>
<td>21,472</td>
<td>28,950</td>
<td>+18.72</td>
</tr>
<tr>
<td>2000</td>
<td>50,198</td>
<td>4,674</td>
<td>5,815</td>
<td>9,009</td>
<td>30,699</td>
<td>-17.72</td>
</tr>
</tbody>
</table>

Disturbance, aeolian desertification could not occur so severely in such vast areas. Human activities most likely tilted balances of the vulnerable arid and semiarid ecosystems and accelerated degradation of grasslands into deserts. Naturally, even if there is a clear drought trend, the climate-induced changes in vegetation cover usually occur gradually over a long period of time. The rapid reduction in vegetation cover and resultant aeolian desertification in the vast areas of Northern China in the past few decades were clearly indicative of human impacts. Human activities under the increased pressure of population growth and economic benefits can dramatically change land-use patterns and abruptly destroy land cover within a short
period. Destroyed land cover greatly favored wind erosion (Figure 6c) and accelerated the development of aeolian desertification.

Overall, our analyses of climate data, soil surface property, policy shift, and social-economic change evaluated the relative importance of natural and human factors in aeolian desertification development in Northern China. The time series data sets over the past 500 and 120 years showed that the climate condition in the recent 50 years was still within the range of natural climate variability in the past 500 years. The drought index in 1990s was still lower than that in 1920s~1940s, and wind speeds and windy days in spring showed declining trends since 1960s. The past 50 years, however, witnessed the rapid expansion of aeolian desertification in Northern China. During that period, human population and livestock each tripled in the regions. Rapid growth of human population and livestock, together with land mismanagement and overuses resulted in accelerated soil erosion and degradation. In particular, China’s State policies on land management have shifted several times, leading to acceleration of land degradation. Based on analysis of several lines of evidence, we conclude that the human activities were the major factor leading to the rapid development of aeolian desertification. If human activities are appropriately regulated by developing ecologically sound land-use practice, the aeolian desertification in Northern China could be curbed and even reversed.

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