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Soil Degradation and Food Security Coupled with Global Climate Change in Northeastern China

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Abstract: The northeastern China is an important commodity grain region in China, as well as a notable corn belt and major soybean producing area. It thus plays a significant role in the national food security system. However, large-scale land reclamation and non-optimum farming practices give rise to soil degradation in the region. This study analyzed the food security issues coupled with global climate change in the northeastern China during 1980–2000, which is the period of modern agriculture. The results of statistical data show that the arable land area shrank markedly in 1992, and then increased slowly, while food production generally continually increased. The stable grain yield was due to the increase of applied fertilizer and irrigated areas. Soil degradation in the northeastern China includes severe soil erosion, reduced soil nutrients, a thinner black soil layer, and deterioration of soil physical properties. The sustainable development of the northeastern China is influenced by natural-artificial binary disturbance factors which consist of meteorological conditions, climate changes, and terrain factors as well as soil physical and chemical properties. Interactions between the increasing temperature and decreasing precipitation in the region led to reduced accumulation of soil organic matter, which results in poor soil fertility. Human-induced factors, such as large-scale land reclamation and non-optimum farming practices, unsuitable cultivation systems, dredging, road building, illegal land occupation, and extensive use of fertilizers and pesticides, have led to increasingly severe soil erosion and destruction. Solutions to several problems of soil degradation in this region requiring urgent settlement are proposed. A need for clear and systematic recognition and recording of land use changes, land degradation, food production and climate change conditions is suggested, which would provide a reference for food security studies in the northeastern China.

Keywords: food security; soil degradation; climate change; northeastern China; black soil region

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1 Introduction

The global food system will encounter an unprecedented convergence of pressures over the next few decades. Estimation results from the Food and Agriculture Organization of the United Nations (FAO) show that agricultural production will need to increase by more than 70% to feed over 9×10^9 persons by year 2050. Food production has increased because of improved technology, application of pesticides and introduction of high-yielding crop varieties. However, global arable land yields have declined due to climate change and poor farming methods, among which soil degradation is considered to be one of the major causes of stagnating

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growth in productivity. FAO found that 1.60 × 10^{11} U.S. dollar will be required by 2050 for the prevention of soil erosion and flood control (FAO, 2011).

Due to its complex and multi-faceted nature, soil degradation can not be measured by a single quantitative indicator (Bindraban *et al*., 2012). Few large-scale assessments that account for the impact of soil degradation on agricultural production are available (Nkonya *et al*., 2011). Bindraban *et al*. (2012) illustrated the considerable impact of soil degradation on crop production in China and Sub Saharan Africa. The study pointed out that the need for solutions were dependent on location specific agro-ecological conditions and farming systems.

China feeds 22% of the world population with only 7% of the arable land, and the sustainable development of agriculture in the northeastern China occupies an important strategic position with respect to China′s and even the world′s food security. The total grain yield in the northeastern China was 117.79 × 10^6 t in 2010, accounting for 21.6% of the total for the whole nation. Food production has increased about 7.4 times in the past 60 years. However, predatory exploitation has resulted in a continuous decline of black soil resources. Extrapolating from the current loss rate, 9.3 × 10^5 ha of cultivated black soil in the northeastern China would be totally lost by the year 2058 (Sun, 2010). In addition, the increase of soil carbon emissions and the loss of organic matter as well as the decline of soil fertility will further influence food security in this region under the effects of global climate change. It is estimated that the population of China will reach 1.6 × 10^9 in 2030 and the demands for grain will be 6.40 × 10^7 t (http://www.cicete.org/tzgg/lhgxm/716664.shtml). Following from its current significance for supplying the nation′s grain, the northeastern China will be the likely base for providing a large amount of grain. Based upon this fact, Gong (2011) considered that China can meet the needs of its growing population without importing grain from elsewhere.

In recent years, a shortage of water arising from industrial pollution, agricultural and domestic water wastage has become increasingly serious in the northeastern China. The concept of virtual water (Allan, 1996) has not only brought about a totally new perspective to water management, but also provided new thoughts for strategic adjustment about trade policies with respect to agricultural products. As a rule, virtual water trade theory, such as with respect to trading grain, can be used to alleviate water stress conditions in regions with scarce water resources. The grains produced in the northeastern China are mostly water-saving crops with a high self-sufficient rate. Food export from Northeast China (including Heilongjiang, Jilin and Liaoning provinces) accounts for a significant proportion of that for the whole of China and the export of virtual water flow is considerably higher than the import of it in Northeast China (Liu and Li, 2009; Huang *et al*., 2011)

Currently, soil degradation has become the major factor restricting the sustainable development of the northeastern China. In the aspect of natural conditions, the northeastern China is erosion-prone because of its undulating terrain. Also, large-scale land reclamation and non-optimum farming practices are primary reasons resulting in soil degradation in the northeastern China since 1958, when the large-scale development of ′the Great Northern Wilderness′ began. Compared with other countries, China is still lagging behind in various aspects of cropping systems, land use policies, water and soil conservation funding, propaganda, education and scientific experiments on soil erosion control (Fan *et al*., 2005). Although Chinese researchers have been actively studying and exploring soil erosion problems, there is still a long way to go before they devise effective way for water conservation and management measures in the northeastern China (Wang Jiangshan *et al*., 2009; Cheng *et al*., 2010; Xu *et al*., 2010; Liu *et al*., 2011; Zhang *et al*., 2011). Therefore, to maintain steady food production under the influence of global climate change, control of water shortage, soil erosion and degradation will play vital practical and strategic roles in the sustainable development of agriculture in the northeastern China (Liu and Yan, 2009; Wang Zhiqiang *et al*., 2009).

This paper selects the northeastern China as the study area and analyzes food security issues during 1980–2000, the modern agriculture period, under the background of global climate change.

2 Study Area and Data Sources

2.1 Study area

The northeastern China, selected as the study area, occupies an area of approximately 1.24 × 10^8 ha and includes Heilongjiang, Jilin, and Liaoning provinces, as well as the eastern part of Inner Mongolia Autonomous Region. It has a total population of 1.19×10^8. The climate in the northeastern China varies from humid in the east to semi-humid monsoon in the west, with the average annual precipitation ranging from 400 mm in the northwest to 800 mm in the southeast, and the average annual temperature ranging from –7℃ to 11℃. In January the average temperature is below –20℃, while in July the average temperature is over 18℃. According to the Genetic Soil Classification of China (GSCC), primary soil types in this region include dark brown soil, bleached Baijiang soil, chernozem soil, meadow soil, and black soil (Duan *et al*., 2011) (Fig. 1).

The black soil region of the northeastern China, the Mississippi Valley of the United States, and the Great Plains of Ukraine are known as the world's three major black soil zones. Due to the porous characteristics and high organic matter contents of the black soil, these three major black soil zones are primary bases of food production. The generalized black soil region in the northeastern China is characterized by areas with black topsoil, covering an area of 1.03×10^8 ha and over 83% of the northeastern China, excluding the western Liaoning, and Chifeng City, the south of Tongliao City and the western Hulun Buir City of Inner Mongolia (the right figure in Fig. 1). The main forming process of black soil is characterized by the accumulation of humus and organic matter with a thickness of 40–70 cm which occupies about 6%, even more than 10% of the total soil weight in certain areas in the natural status. Because of its high organic matter content, soil fertility, loose soil structure and permeability, and its neutral or slightly alkaline soil pH, the black soils are very suitable for farming (Wang and Shen, 2012). The Chinese Soil Database (National Soil Survey Office, 1995) lists 23 black soil series in this region, which are classified into three categories: black soil, meadow black soil and albic black soil. The primary crops grown in the northeastern China are corn, soybean and wheat. Most cropland there has been used for agriculture since the early 20th century (Zhang *et al*., 2006).

Agricultural reclamation and ecosystem structure in the northeastern China have developed along with the stage of historical development. During the period of shift-plow agriculture (before 1910), farmland was reclaimed with slash-and-burn cultivation and only a

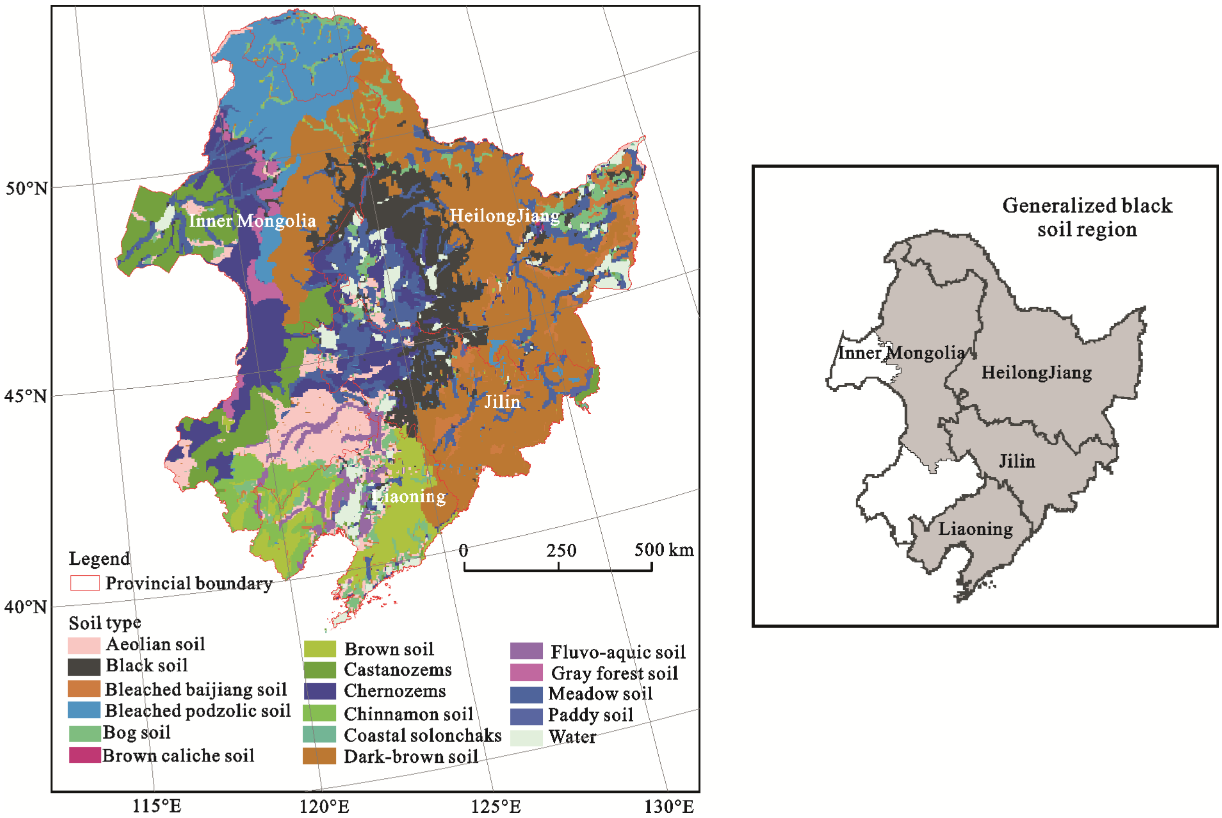

Fig. 1 Soil type map in northeastern China (Duan *et al*., 2011)

small quantity of grain was planted. Then the traditional agricultural period (1910–1960) was dominated by a self-sufficient mode of operation, which mainly produced grain crops. The following was the pre-industrial agricultural period (1960–1980), during which agriculture had entered a commodity era and the nation required a large amount of food to meet the needs of growing population. At this stage, the region provided 70% of commodity grain for the country each year, while soil desertification became an inevitable trend. The last was the modern agricultural period (after 1980). Although people started to realize the relationship between irrational farming and soil erosion, and made certain adjustments in agricultural structures, land use and farming methods, still traditional small-peasant economy and conventional farming practices were not eradicated completely, resulting in continuous soil erosion (Liu, 2010). Remote sensing satellites have been adopted for monitoring land surface in large areas synchronously since the early 1970s.

2.2 Data sources

The data used in this study including the land use data for analyzing the arable land spatial changes, temperature and precipitation data used for describing the climate changes, together with statistic data including the arable land area, grain yields, amounts of fertilizer used, effective irrigated area and population from *China Statistical Yearbook* for describing the time serious trend.

National 1 km × 1 km Gridded Land Use Data were downloaded from the Data Sharing Infrastructure of Earth System Science portal (http://www.geodata.cn/Portal/index.jsp), and the units of land use data are area percentage proportion. The map of soil erosion in the northeastern China at a scale of 1∶15 000 000 was from http://erodata.iswc.ac.cn/Portal/index.jsp. Data from the China Meteorological Data Sharing Service System was available at: http://cdc.cma.gov.cn/index.jsp. The arable land area, grain yield, amount of fertilizer use and effective irrigated area in the three provinces, including Heilongjiang, Jilin and Liaoning, from 1985 to 2010 were obtained from the *China Statistical Yearbook* (1985–2010) (National Bureau of Statistic of China, 1985–2010) (The yearbook uses provinces as its statistical unit and there are no statistical data for the eastern part of Inner Mongolia Region. Data from the other three provinces basically represent the northeastern China). Since Northeast China is the granary of China, the whole population of China from *China Statistical Yearbook* (National Bureau of Statistic of China, 1985–2010), not only that of Northeast China, was counted from 1985–2010.

3 Results and Analyses

3.1 Changes in arable land area and food production

The data in Table 1 showing the proportion and changes of paddy and dry land in the year 1980 and 2000 indicated that the arable land accounted for 27.01% in 1980 and 29.78% in 2000, representing an increase of 2.76% over those 21 years. The spatial distribution of farmland is presented in Fig. 2, and the results show that the main farming system was dry land, mainly located in the Sanjiang Plain, the Songnen Plain and the Liaohe Plain. Compared with dry land, the area of paddy field was relatively smaller, being mainly in the areas surrounding the Songhua River, the Nenjiang River and the Liaohe River.

According to the investigation results of Sun Honglie (http://www.mwr.gov.cn/ztbd/sbkkzt/20060329/69462.asp), in 2004, 16.35% of the total grains in China were produced in the northeastern China, and the grains produced in the northeastern China accounted for 30.52%, 55.69% and 9.60% of the national corn, soybean, and rice production respectively. The population was approximately 1.19×10^8 and per capita production of grain exceeded 1000 kg annually, of which nearly 60% was for commercial use.

From Fig. 3, it can be found that the area of arable

Table 1 Arable land area in northeastern China in 1980 and 2000

	1980		2000		Change during 1980–2000	
	Area (km^2)	Percentage (%)	Area (km^2)	Percentage (%)	Area (km^2)	Percentage (%)
Dry land	298286.62	24.02	324738.08	26.15	26451.46	2.13
Paddy	37115.27	2.99	44954.92	3.62	7839.65	0.63
Total	335401.89	27.01	369693.00	29.78	34291.11	2.76

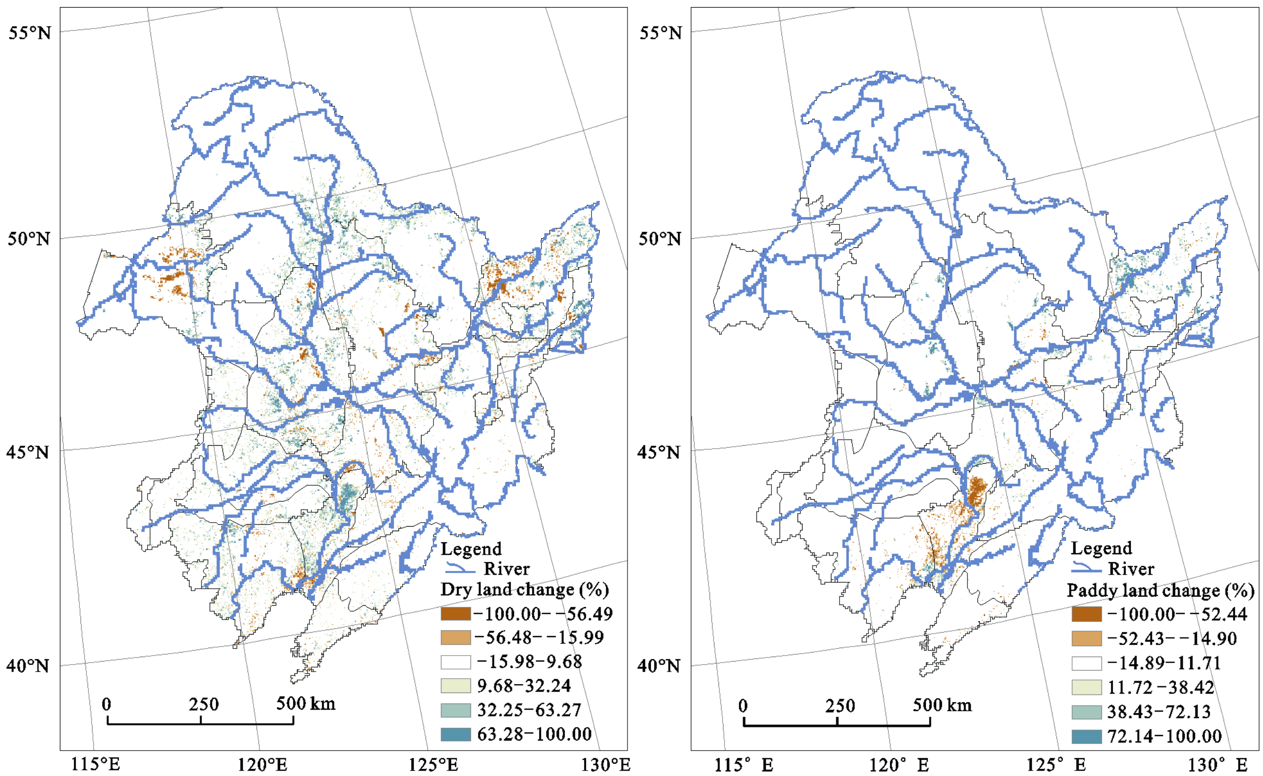

Fig. 2 Distribution maps for dry land and paddy land changes in northeastern China from 1980 to 2000

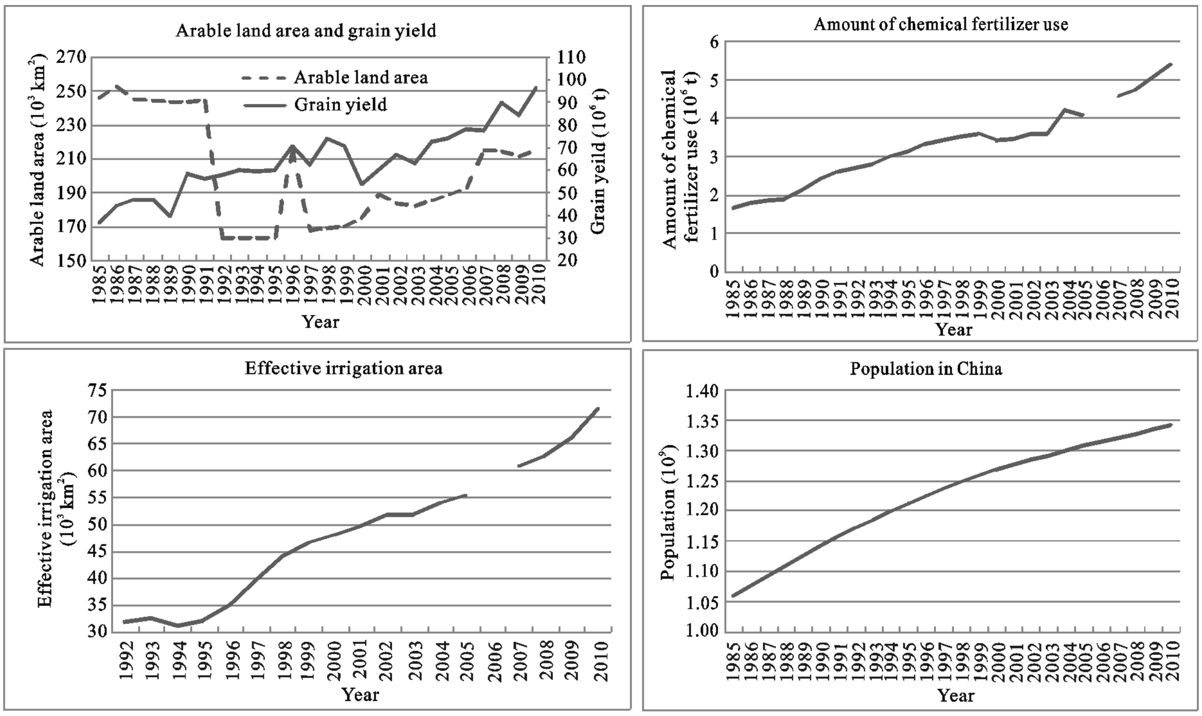

Fig. 3 Arable land area, grain yield, amount of chemical fertilizer use, and effective irrigation area in northeastern China and population in China (The irrigation area, not the effective irrigation area, was surveyed before 1992 for the China Statistical Yearbook. Data for 2006 are missing.)

land dropped significantly in 1992, and then increased slowly, while grain yield have been increased continually. During 1980s, although the arable land area was larger, yet with a small yield per unit area, and so grain yield was maintained at a low level. Intensified use of chemical fertilizer contributed to the steady increase of food production every year, which nearly tripled in volume over the 25 years. During the almost 20 years, effective irrigation areas were doubled by increasing irrigated land, and transforming dry land into paddy land. Human intervention therefore weakened the negative effects arising from climate change and soil degradation, which finally ensured continuing growth in grain production. Also, national population data showed a straight line of continuing-increase, from 1.05×10^9 in 1985 to 1.34×10^9 in 2010.

3.2 Status quo of soil degradation

Soils, especially black soil, are an important global natural resource. However, issues such as soil erosion, environmental pollution, cultivated land conversion and arable land degradation, are the major causes impeding the sustainable development of the northeastern China. Although soil is renewable resource, unlimited cultivation and improper land utilization have been placing strong pressure on it. Soil degeneration is becoming increasingly serious, and restricting the economic development in the northeastern China and grain production in China.

Soil degeneration in the northeastern China includes severe soil erosion, reduced soil nutrients, a thinner soil layer, and deterioration of soil physical properties. The various major types of soil erosion consisting of water, wind, freeze-thaw and gravity erosion are generally intertwined. Figure 4 shows that water erosion, mainly in the eastern and central regions, is the most serious in the northeastern China, followed by wind erosion, mainly in the western part of the region. The most severe soil erosion is in the eastern tableland plain, with an annual erosion modulus of about 6000 t/km^2, reaching 7000 t/km^2 in Keshan and Baiquan counties in Heilongjiang Province, equivalent to that of the Loess Plateau in central Gansu Province. The annual wind erosion modulus in the western Tongyu County in Jilin Province reaches

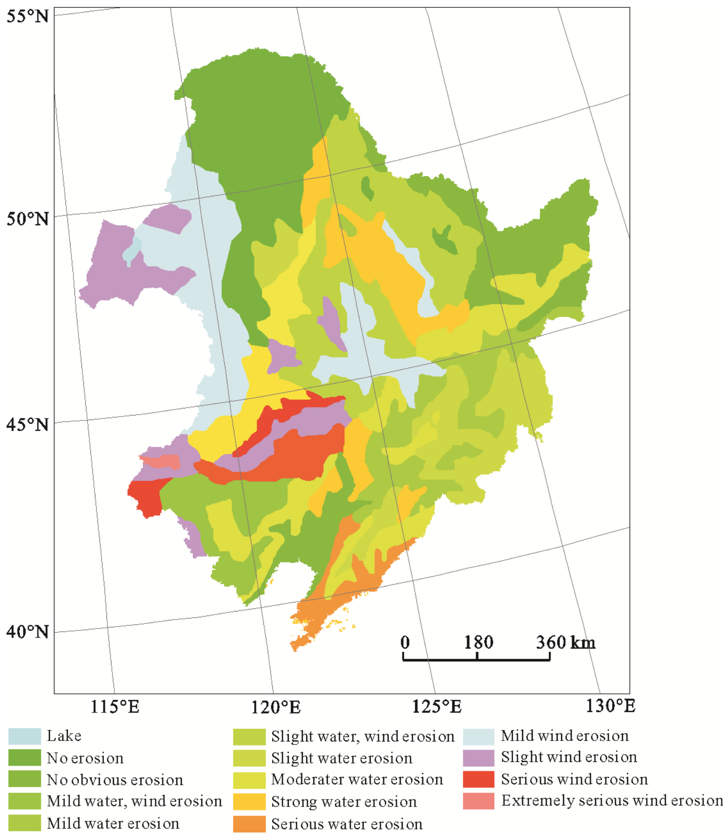

Fig. 4 Soil erosion map of northeastern China (Erosion levels gradually increase from mild, slight, strong, serious to extremely serious erosion. http://erodata.iswc.ac.cn/Portal/index.jsp)

4000–8000 t/km^2. The original thickness of the black soil layer is 60–80 cm, and the deepest soil may reach thickness of up to 100 cm. However, currently, the layer has become thinner, with some having only a thin layer of the epidermis. Soil compaction worsens, soil structure deteriorates, and the color changes from dark to yellow. It has been estimated that about 0.4–0.7 cm of the topsoil was lost annually due to erosion, while the formation of 1 cm of black soil takes 400 years. Black land is a gift of nature, which should be protected with great efforts for there will be no possibility of regeneration once damaged (Sun, 2010).

In addition, snowmelt is another possible factor leading to soil erosion in that the sticky characteristic of the black soil facilitates the erosion gullies formation in spring in the northeastern China. According to the result of a survey, there are 250 000 erosion gullies in this region, engulfing 4.83×10^7 ha of the cultivated land, with a total loss of 3.623×10^6 t grain annually, assuming annual corn production of 7500 kg/ha (The Ministry of Water Resources of the People′s Republic of China *et al*., 2010). Liu and Yan (2009) pointed out that the soil erosion area occupied nearly 17% of the total area, while more than 30% area of the northeastern China is currently facing this problem. Soil erosion scenes in the northeastern China are shown in Fig. 5.

Soil erosion impairs soil quality, the fundamental reason for which lies in a reduction of the soil organic matter content. Organic matter concentrations were 8%–12% following the initial reclamation but have now reduced to only 2%–3%. The results of statistics show that in parts of the Songnen Plain, organic matter, porosity, and water holding capacity have already declined at different degrees, while the soil bulk density has increased proportionally. Through analyzing spatio-temporal variability of soil quality in typical black soil area in Northeast China from 1980 to 2000, Wang *et al*. (2007) found that soil pH, organic matter and available K had decreased significantly during the past 20 years, while available P had increased with the highest variation coefficient and the soil pH the least. Areas rated as being first and second grades with respect to soil fertility quality were over 80% in the 1980s, whereas more than 98% were rated as being second and third grades at the beginning of the 21st century. Thus soil fertility quality has declined, probably because of the intensive cultivation and lack of maintenance, and other issues such as river siltation, reduction of soil water storage capacity, and increased numbers of droughts and floods (Wang *et al*., 2007).

4 Discussion

4.1 Impact of natural and geographical factors on soil erosion and food security

Soil erosion is a complex process affected by meteorological conditions, topographical factors, and soil physicochemical properties (Cui *et al.*, 2007). Precipitation and wind are the key natural forces contributing to soil erosion. The average annual precipitation is 450–550 mm in the eastern water erosion region, of which 70%–80% is concentrated in June–September with heavy rainfall accounting for 40%–60% of the annual precipitation. During this period, serious soil erosion is likely to occur caused by excess infiltration flow.

Topographic and geomorphic features of this region are the natural cause for soil erosion. For example, some open black soil areas have undulating topographic features with wide and long slope. Prolonged rainfall is likely to converge in these areas, which will result in

Fig. 5 Soil erosion scenes in northeastern China

concentrated runoff and increasing scouring force. Black soil farmland, with loose topsoil, sticky subsoil, and weak corrosion resistance, are readily eroded by such kinds of natural forces. Moreover, extensive cultivation intensifies soil erosion, especially in the sloping farmland. Soil erosion can eliminate surface soil, destroy soil structure and reduce soil fertility. Per capita arable land of China is far below the world average, and there are obvious contradictions between the number of people and the arable land area, which are aggravated by serious soil erosion. As a consequence, soil erosion is directly and closely related to the security of national ecology, flood control, and the supply of food and drinking water (Yan and Tang, 2005).

4.2 Impact of climate change on soil degradation and food security

The northeastern China is part of the eastern monsoon region, characterized by having heat and precipitation at the same time. With global climate change, droughts are worsening, and the temperature increases while precipitation decreases. It can be verified from the analysis of changes in temperature and precipitation in the northeastern China from 1980 to 2000. Annual temperature and precipitation in 1980 and 2000 were used to analyze regional climate changes. There are 94 meteorological stations in total in the study area, and spatial distribution maps of climate indexes were generated by spatial interpolation (Fig. 6). A significant warming trend is presented during the 21 years, and the fluctuation ranged from –0.2987℃ to 1.6000℃. Warming region accounted for 99.41% of the total area, with a temperature decrease only in the northern Heilongjiang Province. During the same period, precipitation fluctuation ranged from –394.6 mm to 417.8 mm, with a reduction in 72.68% of the region, and an increase in the remaining 27.32% of the region.

Climate warming-drying trend has both positive and negative influences on agricultural production. Increase in accumulated temperature will improve the conditions of crop heat, while a reduction in cold damage is conducive to maintaining high and stable yield. Changes in hydrothermal conditions have prompted the transformation of agricultural production and cropping patterns. For example, substantial dry land has been transformed into paddy land in Heilongjiang Province. The increase

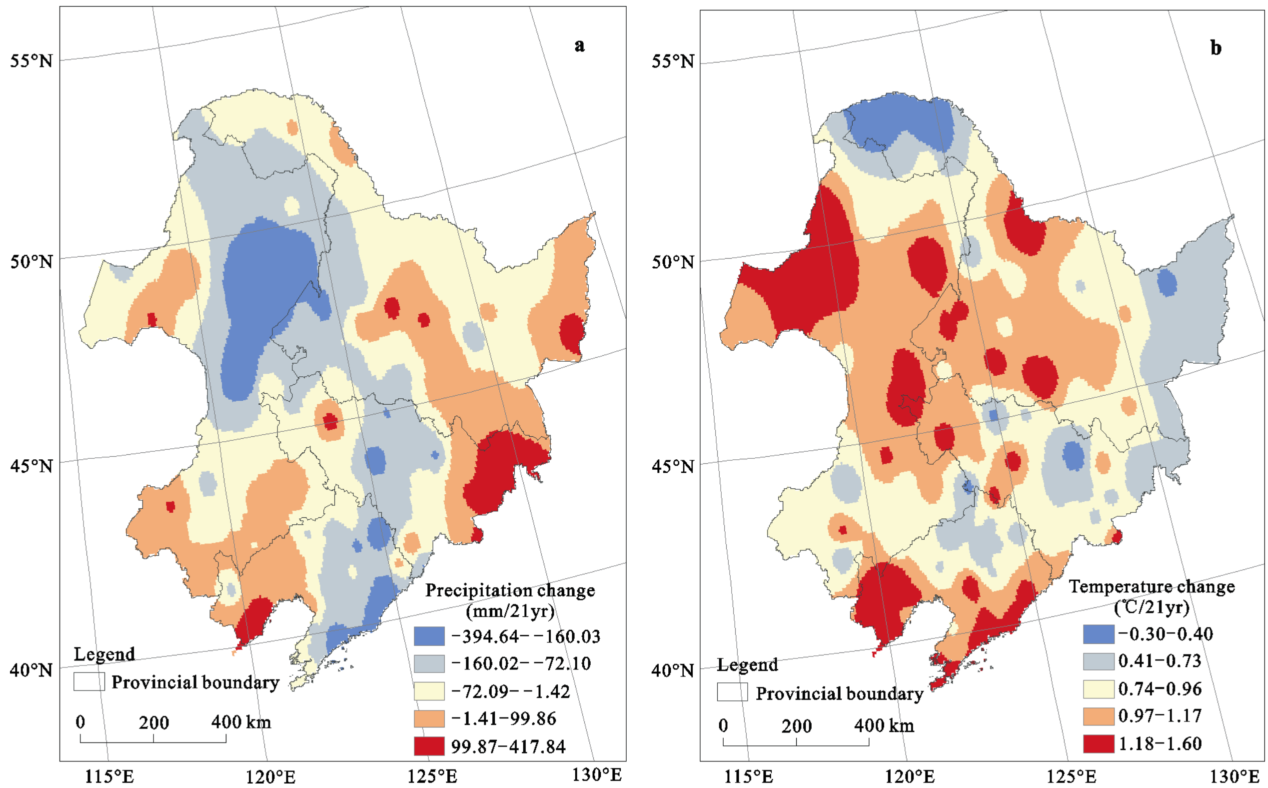

Fig. 6 Changes of average annual precipitation (a) and average annual temperature (b) in northeastern China from 1980 to 2000

in global carbon dioxide concentrations promotes photosynthesis, which may help improve crop yields. However, sea level rise and frequent extreme weather events such as drought, lead directly to frequent sandstorms and loss of topsoil. Possibly an even worse effect is that pest disasters caused by warm winter will counteract the positive factors, resulting in uncertainty over food production. In general, there are more harmful than beneficial impacts of climate change on agricultural production in the northeastern China (Wang Jiangshan *et al*., 2009).

This paper is focused only on the impact of climate change on soil quality and further on food production. The fundamental reason for a decline in soil quality is typically a reduction in the soil organic matter content. Gao *et al.* (2005) found that the increase in soil organic carbon benefits from a temperature drop or a precipitation increase. A temperature increase accelerates the respiration rate of soil microorganisms in high latitudes, which leads to increased release of soil carbon into the atmosphere as CO_2, thus reducing the soil organic matter content. Bai (2005) thought that the distribution of soil organic carbon content in the Songnen Basin (located in the northeast part of the northeastern China, mainly including the Songhua River and the Nenjiang River) was related to the longstanding weather conditions. Thus a conclusion can be drawn that climate change is one reason for the degradation of the soils in the Songnen Basin. A temperature increase and precipitation decrease influence each other, which slows down the accumulation of soil organic matter, leading to increasingly poorer soil quality.

4.3 Impact of artificial factors on soil degradation and food security

Apart from the impacts of natural geographical factors and climate change on soil degradation and food security, humans activities are responsible for much soil destruction, with the consequences of improper development and ignorance of soil and water conservation being the most severe. Before reclamation, soil degradation was typically minimal because of good vegetation cover and the self-restoration ability of soils. With the expansion of land reclamation, a large amount of woodland and grassland was converted into cultivated land, which greatly undermined natural protective barriers. Improper cultivation damaged natural soil structures, and also led to deterioration in soil quality. Take the transformation from dry land into paddy land, for example. The area of dry land is larger than the paddy land in the northeastern China, but the productive output of the paddy land is far higher than that from dry land. Yields of rice, corn, and soybean were 7010.77 kg/ha, 6122.79 kg/ha, and 2020.41 kg/ha, respectively, in 2004 (He *et al.*, 2006). As a result, farmers transformed considerable areas of dry land into paddy land, which resulted in increasing demands for water. The multi-year average of total water resources in the northeastern China is 1.987×10^{11} m^3, of which 70% is consumed by agriculture. There are about 5.3×10^6 ha of effective irrigation area, in which arable land irrigation only accounts for 21%, while the rain-fed agricultural land accounts for 79% (http://www.neigae.ac.cn/xwzx/zhxw/201010/t20101029_2998862.htm). Therefore, if a large amount of dry land is changed into paddy land, the output is bound to be affected because of a lack of water. On the other hand, if dry land is first changed into paddy land, and then changed back, food production will be generally reduced because of low soil temperature. In general, corn tends to catch a kind of top-rot disease if planted in dry land switched from paddy fields, which can lead to its death in severe cases.

Another serious issue, due to a lack of ecological awareness, as well as errors in agricultural policy, is that some local governments, regardless of resource destruction and environmental pollution, such as mining, dredging, road construction, deforestation, and construction through illegal occupation of arable land, only pursue temporary and partial interests. It is irrational exploitation and shows a poor awareness of soil and water conservation that exacerbates soil erosion in the region.

In recent years, despite that fertilizers and pesticides have promoted food production, the excessive use have exerted negative effects on food security, mainly in the quantity and quality of food. First, fertilizer, especially the long-term use of nitrogen fertilizer, results in the degradation of soil quality, such as soil compaction and soil fertility decline, leading to the reduction of food production. Second, several varieties of phosphate chemical fertilizers contain heavy metals, and most of them are absorbed by crops and eventually enter human body and endanger human health because they can only be consumed little by soil once they are poured into the land in a great amount (Guo *et al.*, 2003; Zhang *et al.*, 2010). Environmental changes resulted from climatic variation exacerbate prevalence of pests and spread of weeds. Winter warming makes it easy for many northern pests and pathogens to overwinter, which results in the increase of application rate of pesticide. Consequently, the agricultural industry is confronted with more threats from pest and disease damage.

4.4 Countermeasures

Though soil degradation can not be completely prevented, it can be reduced to an acceptable level or soil loss tolerance. Soil degradation prevention relies on selecting appropriate strategies for soil conservation. The severity of soil degradation in the northeastern China have been realized, and a lot of work on water and soil conservation, such as installing terraces on sloping land, planting ridge crops, building check dams, and planting soil and water conservation forests to minimize soil degradation, has been carried out in some areas. The scenes of countermeasures implementation for soil and water conservation from 'The report of soil erosion monitoring in key black soil regions of the northeastern China in 2011(from School of Urban and Environmental Sciences, Northeast Normal University, 2011)' were shown in Fig. 7.

For more effective protection on soil and national food security, and accelerating the sustainable development of land-water resources, the research on soil degradation in the northeastern China has been a longstanding and important concern of experts both in China and abroad. Several problems in the northeastern China requiring urgent settlement are proposed through consideration of overseas erosion control research and practices. There is a need for legislation concerning degradation prevention measures which addresses the need for precise agricultural information to be mapped out, erosion gully and sloping farmland controlled, and fertilizers applied appropriately. First of all, laws are required to strengthen the protection of cultivated land, and appropriate administrative policies need to be developed. Second, databases incorporating soil physical and chemical properties in the region should be developed as a basis for identifying and conveniently making use of those properties. Third, a soil fertility monitoring network for the northeastern China should be established to identify long-term trends in soil fertility, and then on the basis of these trends in soil fertility and its characteristics, corresponding fertility measures should be taken, such as tillage, crop rotation, fertilization, and growing appropriate plant species. Also, the regulation of sloping lands and gullies should be strengthened and more trees planted. Last, there should be integration of measures such as increasing organic manure application, returning straw to fields, and combining of deep tillage and proper no-tillage to maintain soil fertility in the northeastern China.

5 Conclusions

Selecting the northeastern China as the study area, this paper mainly analyzes food security issues in the 21-

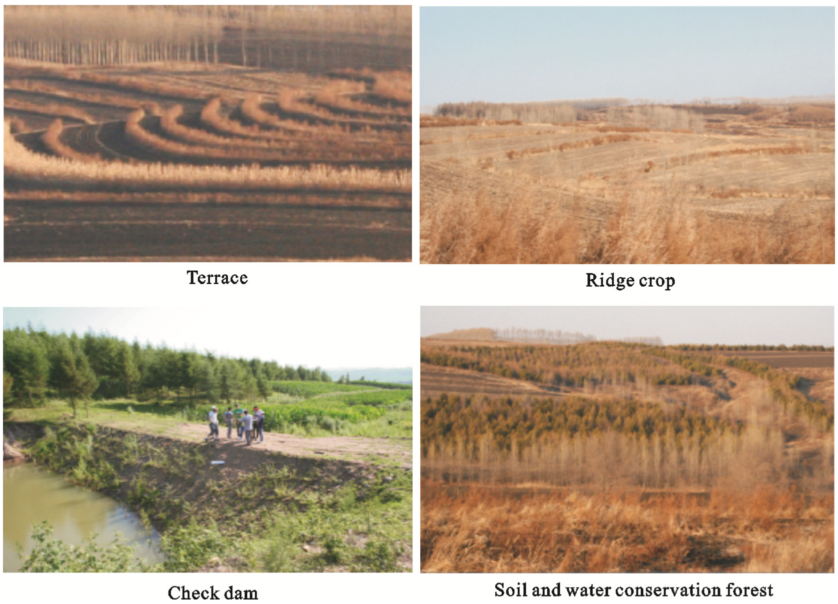

Fig. 7 Soil and water conservation measures

year modern agriculture period after 1980, under the background of global climate change. The conclusions are as the follows:

(1) Arable land area accounted for 27.01% of the total land area in 1980 and 29.78% in 2000, which represents an increase of 2.76% over the 21 years. Dry land is domainated, mainly located in the Sanjiang Plain, the Songnen Plain and the Liaohe Plain. Compared to dry land, paddy land area was relatively smaller, mainly distributed in the surroundings of the Songhua River, the Nenjiang River and the Liaohe River.

(2) The cultivated land area decreased significantly in 1992, and then increased slowly, while food production increased continually. Continually increasing use of chemical fertilizers contributed to the steadily increasing food production every year. During the 21 years of the modern agricultural period, effective irrigation areas doubled. Human intervention weakened the negative effects caused by climate change and soil degradation, which had the end result of ensuring growth in grain production.

(3) The sustainable development of the northeastern China is influenced by natural-human binary disturbance factors. Precipitation and wind are the key natural forces responsible for soil erosion. Topographic and geomorphic features of this region are the natural background factors affecting soil erosion. Annual temperature and precipitation in 1980 and 2000 indicated a significant warming trend over the 21 years. In general, there are more harmful than beneficial impacts of climate change on agricultural production in the northeastern China. Artificial factors, such as large-scale land reclamation and unsuitable farming practices, improper cultivation systems, dredging, road building, illegal land occupation, extensive use of fertilizers and pesticides, intensified soil degradation and destruction. Several problems in the northeastern China requiring urgent settlement are proposed, including improving legislation in the protection of soil degradation, such as controlling erosion gully and sloping farmland, developing incorporating soil physical and chemical properties databases, corresponding fertilizers applied appropriately on the basis of soil characteristics databases, integration of measures such as increasing organic manure application, returning straw to fields, and using combinations of deep tillage and proper no-tillage to maintain soil fertility in the northeastern China.

Most of the data in this paper came from statistic yearbook, land use dataset and meteorological data, being lack of recent data, while the remote sensing images can give more detail information on monitoring soil degradation and crop growth, and there will be huge workload in such large study area what we will do as the following work.

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