

# Chapter 13

## Economics of Land Degradation in China

Xiangzheng Deng and Zhihui Li

**Abstract** Land degradation is a complex process that involves both the natural ecosystem and the socioeconomic system, among which climate and land use changes are the two predominant driving factors. We reviewed the status of degradation in grasslands, forests and cultivated lands in China, as well as the major drivers of land degradation in the North China Plain. The previous research shows that an increase in rainfall and temperature would significantly and positively contribute to land improvement. The conversion from cultivated land to grassland and forest land showed positive relationship with land improvement, while conversion to built-up area is associated with land degradation. In addition, human agricultural intensification may help improve the land quality. The overall economic development may exert positive impacts on land quality, while the increased agricultural production may exert negative impacts on land. Infrastructure construction would modify the land surface and further result in land degradation. Finally, our analysis of the costs of actions to address land degradation in China shows that the annual costs of land degradation due to land use and cover change (LUCC) is equal to about 24.5 billion USD. In addition, the cost of grassland degradation, without shifts in LUCC, is estimated to equal about 0.49 billion USD due to losses in livestock productivity resulting from grassland degradation. Moreover, the costs of cropland degradation for three crops: wheat, maize and rice, is estimated to be about 12 billion USD annually. The total cost of land degradation due to LUCC and using land degrading management practices on cropland and grazing land is 2007 US\$37 billion or 1 % of China's 2007 GDP. Finally, the analysis shows that the costs of the rehabilitation of the lands degraded due to LUCC are significantly lower than the costs of inaction, with the returns of up to 4.7 times for every yuan invested over a 30-year period. This underscores the need to take action against land degradation. This is particularly important given China's

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new sustainable development and green economy approach reflected in its five year plan (2011–15) and other environmental policies. Results of this study will inform policy makers on the key areas for addressing land degradation.

**Keywords** Land degradation · Land use change · Climate change · NDVI · China

## Introduction

Land degradation means a significant reduction of the productive capacity of land. It is a complex process involving various causal factors, among which climate changes, land use/cover changes and human dominated land management play a dominant role (Barbier 1997; Sivakumar and Ndiang’Ui 2007; Symeonakis et al. 2007; Bajocco et al. 2012). There are two interlocking complex systems involved in the land degradation process, i.e. the natural ecosystem and the human social system, and both changes in biophysical natural ecosystem and socioeconomic conditions will affect the land degradation process (MEA 2005). Natural forces affect land degradation through periodic stresses exerted by extreme and persistent climatic events, while human activities contribute to land degradation through (1) deforestation, removal of natural vegetation and urban sprawl which lead to land use/cover changes, (2) unsustainable agricultural land management practices, such as use and abuse of fertilizers, pesticides and heavy machinery, (3) and overgrazing, improper crop rotation and poor irrigation practices etc. (Sivakumar and Ndiang’Ui 2007).

In comparison to other regions, land degradation afflicts China more seriously in terms of the extent, intensity, socio-economic impacts and the number of affected population (Bai and Dent 2009). With just 7.2 % of the world’s cultivated land area, China needs to feed 22 % of the world’s population, thus agricultural production is a critical issue related with national economy and livelihood of its citizens in China (Deng et al. 2008). However, rapid population growth and urbanization, unreasonable human utilization and influence of natural factors, have caused degradation of 5.392 million km<sup>2</sup> land, accounting for about 56.2 % of the total national area, among which the area of land degradation resulting from soil erosion and water loss, desertification, soil salinization, pasture degradation and soil pollution is 1.80, 0.334, 0.9913, 2.00 and 0.267 million km<sup>2</sup>, respectively (Long 2013). The suitable land for agricultural production is only about 1.3 million km<sup>2</sup>, accounting for 14 % of the total land area in China. In addition, more than 50 % of the total cultivated land has experienced land degradation, which further exerts more pressure on the economic benefits of agricultural production and food security. Besides, as cultivated land degradation will directly affect the potential land productivity, more inputs such as fertilizer and irrigation water will be needed in order to get the same production and yield level, which will increase the production costs (Li et al. 2011). In addition, the land use structural change and pattern succession resulting from

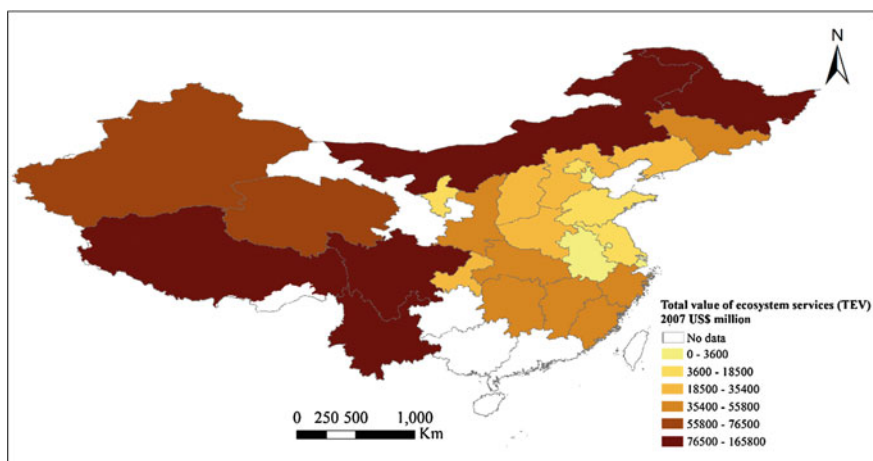
land conversions will definitely affect the suitability and quality of land and directly influence land productivity (Deng et al. 2006). Hence, for the long-term sustainable development of agricultural economy, it's critical to take sustainable productive land management measures.

China is a large country with significant spatial variation of natural/climatic conditions and diverse socioeconomic characteristics. For example, the eastern, central and western parts of China have different population densities, industrial structure, per capita incomes, etc. The difference among regions will affect land use, leading to differences in the ways and extent of economic use of land resources. In this chapter, we review three types of land degradation, including grassland degradation, forest degradation and cultivated land degradation, and also assessment of the driving causes of land degradation. Finally, we estimate the costs of land degradation in China and compare them with the costs of inaction.

## Review of Land Degradation Assessments in China

Distribution of ecosystems and their total economic value (TEV) is shown in Fig. 13.1. The highest TEV is in the northeastern area, where about 29 % of forest cover is located (Deng et al. 2010) and the south-western region, which is also endowed with both natural and planted forests.

The northwestern area is endowed with grasslands—which also have high value, while the densely populated and urbanized eastern region has the lowest TEV. As it will be seen in the cost of land degradation section, the highest cost of land degradation is found in areas with highest TEV.



**Fig. 13.1** Total economic value of ecosystem services of major biomes, 2001. *Source* Authors' data

Land degradation in China is an increasingly serious economic, social and environmental problem. With the continuously serious land degradation leading to the reduction of agricultural yields, China may face critical food security problems. To clarify the conditions of land degradation in China, it is necessary to carry out comprehensive analyses of the differences among regions and the heterogeneity of different types of land degradation in different regions considering the environmental, social and economic conditions. A comprehensive analysis of the typical spectral characteristics of various types of land degradation can be conducted on the basis of previous studies, field investigations, and remote sensing data of a variety of spatial and temporal resolutions in combination with the application of the RS and GIS techniques.

**Grassland degradation** indicates the deterioration of ecological function of grassland ecosystem. It is a process accompanied by the decline of grass quality and primary productivity, the loss of bio-diversity and complexity, and the deterioration of resilience and recovery functions (Yang et al. 2007; Jiang et al. 2011). The grassland, with an area of 400 million km<sup>2</sup> and covering more than 40 % of China (Ren et al. 2008), supports the development of animal husbandry, is one of the most important terrestrial ecosystems in China. Grassland ecosystem can provide significant ecological benefits and economic benefits for humans, including forage, milk, meat, wool and pelts etc. However, with grassland degradation, the average grassland productivity level of China is much lower than that of other parts in the world.

There have been many studies to identify and assess grassland degradation in China. With assistance of RS and GIS, the vegetation pattern is regarded as a good indicator to monitor vegetation dynamics and assess grassland degradation (Li et al. 2012). Based on a landscape-scale approach, Tong et al. (2004) combined the field survey data, vegetation maps, and RS data to assess the degradation degree of different steppe communities at the local scale and analyze the spatial pattern at the landscape scale. Further, a steppe degradation index (SDI) that integrates the spatial extent and steppe degradation severity information was developed to quantify the spatio-temporal grassland ecosystem degradation. Similarly, with Landsat Thematic Mapper (TM) image conjunct with 1 m<sup>2</sup> plot sampled percent grass cover and proportion (by weight) of unpalatable grasses (PUG) information, Liu et al. (2004) assessed the grassland degradation and conducted regression analyses, the results showed that NDVI is the most reliable indicator of grass cover and PUG. Furthermore, Liu et al. (2008) used Multispectral Scanner Sensor (MSS) images and TM images to spatially and temporally analyze the grassland degradation degree in the Three-River Headwaters Region. Also, Li et al. (2012) estimated the regional vegetation fractional coverage (VFC) based on the Gutman model (Gutman 1987), which is one of the most widely used models to estimate VFC based on NDVI.

Grassland has a wide distribution in China and shows significant regional heterogeneity. The NPP in the eastern China was higher than that in the western region, and with higher value in the southern region than in the northern region. Overall, from northwest to southeast China, except the Tibetan Plateau, the NPP

showed an increasing trend with some fluctuations, and reached the highest value in the southwest karst area with a value of 1000 gC/m<sup>2</sup> in 2010 (Wu et al. 2013).

Researchers have identified many causes of grassland degradation, including overgrazing, improper cultivation methods, unreasonable harvest of herbs for medicine, and damages induced by rodent activities. Besides, there have been many studies showing that climate changes have great impacts on the grassland productivity, especially in the arid and semi-arid regions (Baldocchi 2011; Qi et al. 2012). In addition, a key issue is how natural and anthropogenic causes influence grassland degradation. Li et al. (2012) carried out an in-depth empirical analyses on the natural and anthropogenic drivers and mechanisms of grassland degradation, ten biophysical and socioeconomic factors, including precipitation, temperature, population density, sheep unit density, etc., were chosen to analyze the impacts on the observed patterns of steppe degradation on the basis of econometric analysis. Their results show that the higher altitude, rainfall amounts, distance to markets and sustainable land management measures, such as fencing, are associated with less grassland degradation (ibid.).

Wu et al. (2013) also find that the climate factors and geographical factors have great impacts on grassland productivity. The precipitation and temperature play a more important role than sunshine duration. The soil phosphorus has significant positive effects on net primary productivity (NPP), indicating that the increase of soil nitrogen and phosphorus will improve the grassland productivity (ibid.). Moreover, Wu et al. (2013) find that elevation exerts significantly negative impacts on NPP, while the percentage of plain area plays a positive role in NPP. As to the socioeconomic factors, both the population and the demand for meat show significantly positive relationship with NPP. The higher share of agricultural production in the total GDP has been found to have negative effects on NPP, indicating that the expansion of the agricultural production will exert more pressure on the grassland and further result in the decline of grassland productivity (ibid.). The population shows significantly positive impacts on NPP. Wu et al. (2013) find that when population increases by ten thousand, the grassland NPP would increase by 0.03 %. With the growth of population, more labor inputs might be devoted into the sustainable grassland production and management (ibid.).

**Deforestation** is a complicated transformation process with temporal dynamics and spatial heterogeneity. The current studies of land degradation in China mainly focus on grassland productivity and cropland degradation. However, research on deforestation began late and mainly focuses on the soil fertility decline caused by continuous crop production in deforested areas. There is still no general consensus on how to correctly assess deforestation, which is a complex process, and there are many difficulties to overcome, such as how to define deforestation, how to improve the reliability and availability of the deforestation data, how to deal with the limited time-series data, and how to map deforestation with higher spatial resolution satellite images at the global level, and, how to identify the particular drivers of deforestation dynamics. It is still a challenge to get reliable estimates of forest degradation in China (Gao et al. 2011), and there is a lot yet to be advanced on the assessment method of deforestation.

Jiang et al. (2011) study deforestation in Northeast China, which accounts for 28.9 % of the total forest land area in China (Deng et al. 2010), and the forest stock accounts for 27.8 % of the national total (SFA 2005). This makes the Northeast China an important forest production base and plays an important role in sustaining the ecological and socio-economic development in China. Jiang et al. (2011) find that due to the long-term exploitation, the forests in Northeast China have shrunk dramatically, with monotonous and juvenile forest age structures and less forest resources to be exploited. According to the national forest resources survey, the ripe forests decreased by 49 % during 1981–1988, and 0.61 million ha of forests continually disappeared in the next decade (Xiao et al. 2002). Although the complementation of the Grain for Green Project, the Logging Ban Program, and other ecological restoration projects have made some achievements in the Northeast China, the forest shrinkage and degradation still continue (Wang et al. 2003; Zhao et al. 2006; Shen et al. 2006; Peng et al. 2007).

The analysis by Jiang et al. (2011) shows that the average slope and elevation has significant impacts on forestry production and forest conversion, with higher forest coverage in the areas with steeper slopes and higher elevation. Besides, in the regions with habitats where crop cultivation is forbidden and the urbanization and industrialization levels are low, the open forests and other land uses are converted to the closed forest to some extent. As to the climate change impacts on the forestry area, the estimation results by Jiang et al. (2011) show that temperature and precipitation only have significant impacts on the forestry production, but not on the forest conversion. The distance to the nearest water area is found to be positively associated with forest production (*ibid.*). The socioeconomic factors are the major factors that affect forest production and the spatial pattern of forest coverage. With more dense populations, there might be more damages to the forests, which leads to a relatively lower gross output value of forest production and constraints land use conversions to the closed forest (*ibid.*). However, with the increase in agricultural population, the conversion amount from other land uses into the closed forest may increase (*ibid.*). The increase in gross output value of forestry sector may stimulate the expansion of the closed forest (*ibid.*).

**Cropland degradation** is an important problem in China. With a large population and relatively limited cultivated land, food security is always an important issue concerning the economic development and citizens' livelihood (Deng et al. 2008). Along with rapid population growth and urbanization, the cultivated land degradation due to unreasonable utilization and conversion from cultivated land to other lands exerts more pressure on the economic benefits of agricultural production and food security. Besides, as the cultivated land degradation directly affects the potential land productivity, more inputs such as fertilizer and irrigation water will be needed in order to get the same production and yield level, which will increase the production cost (Li et al. 2011).

In the analysis of cropland degradation in the North China Plain, Li et al. (2015) find that higher temperature and rainfall are positively related with increases in

cropland NDVI. Moreover, the agricultural intensification proxied by fertilizer utilization, is significantly positively related with land improvement, as fertilizer application will make soil carbon increase (Vlek et al. 2004), which further lead to an increase in NDVI. In addition, increases in the share of the primary industry (Agriculture, Animal, Husbandry and Fishery) in GDP are associated with lower NDVI values. In addition, geographic and topographic factors were also found to affect land degradation (Li et al. 2015). Steeper slopes are found to lead to land degradation, as steep slope regions are more vulnerable to severe water-induced soil erosion (ibid.). Besides, the distances to highways are significantly positively related with land improvement, which suggest that larger distances to a road network means there is less human disturbance, less infrastructure development and fewer land use changes, which will exert less impacts on the land degradation (ibid.).

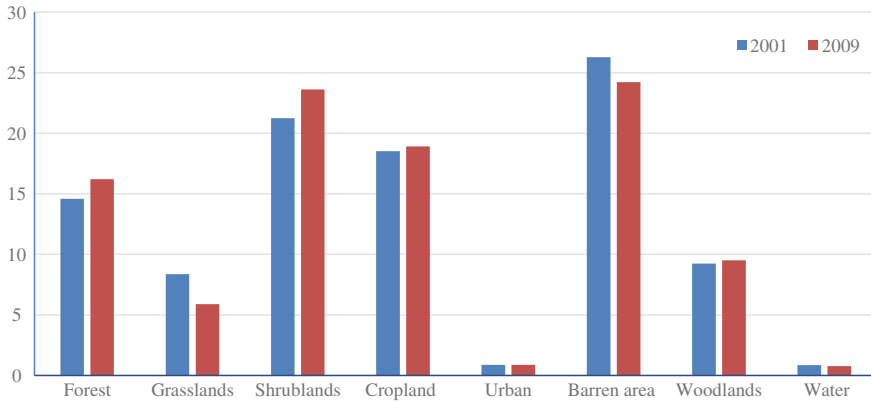
## **Cost of Land Degradation and Cost of Action and Inaction Against Land Degradation Due to Land Use/Cover Change in China**

We follow the methods discussed in Chap. 6 to determine the cost of land degradation and the cost of action and inaction against land degradation.

To take action to control land degradation, the awareness about urgent conditions in regard of the loss of economic opportunities and livelihoods should be raised, then an assessment of the economic consequences of land degradation and the costs of related inaction, compared against the costs of action for sustainable land use, is required. In this section, we aim to assess the cost of land degradation due to land use/cover changes, and compare the cost of action and inaction.

Land use/cover changes (LUCC) are a major driver of land degradation, which replace the high value biomes with low value biomes (Nkonya et al. 2014). In this section, we used the 1-km resolution Moderate Resolution Imaging Spectroradiometer (MODIS) land cover data to analyze LUCC (Fig. 13.2). Accordingly, the grasslands covered about 8.37 % of land area in China in 2001, then decreased to 5.88 % in 2009. Shrublands and woodlands covered about 21.25 and 9.23 % respectively of land area in 2001, and the extent of shrublands and woodlands increased to 23.62 and 9.51 % respectively in 2009. Forestland covered only 14.60 % of land area in 2001 and its extent increased to 16.20 % of the land area in 2009. The increase was mainly due to the Grain for Green Project in China, which was launched in 1999. Cropland area increased from 18.52 to 18.91 %.

The costs related to land degradation as a result of LUCC for China are shown in Table 13.1. Based on the MODIS land use data of year 2001 and year 2009, along with the application of the total economic value (TEV) approach (see Chap. 6), the total cost of land degradation due to LUCC for the period between 2001 and 2009 is



**Fig. 13.2** Extent of land uses in China, 2001 and 2009

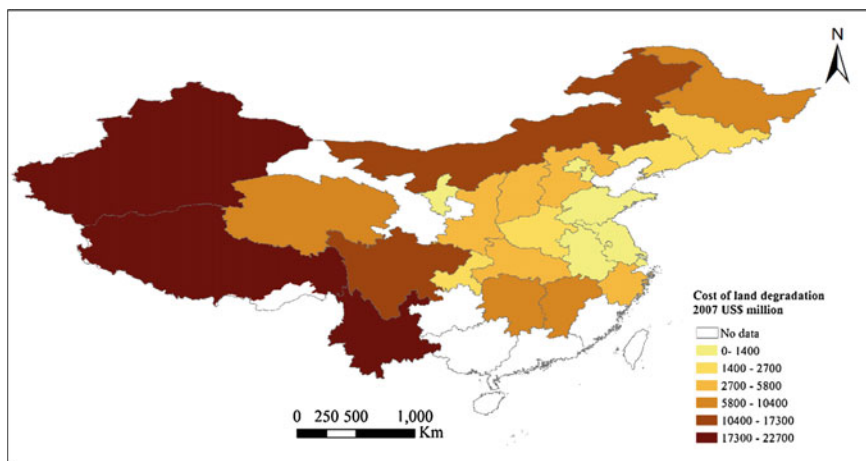
**Table 13.1** The cost of land degradation due to LUCC for the period of 2001–2009 and cost of action and inaction in China across degraded biomes

	Agroecological zone			Total
	Arid and semi-arid	Sub-humid	Humid	
	2007 US\$ billion			
<i>Cost of land degradation</i>				
• TEV	103.37	24.94	67.44	195.75
• Provisioning services	49.91	9.12	25.63	84.66
• Loss of provisioning services as % of TEV	48.28	36.57	38.01	43.25
<i>Cost of restoration of degraded biomes</i>				
• Forest	25.55	21.71	64.59	111.85
• Grassland	68.08	5.64	7.71	81.43
• Shrublands	12.70	4.22	7.49	24.41
• Woodlands	4.33	9.92	23.51	37.76
<i>Total cost of</i>				
• Action	110.66	41.50	103.29	255.45
• Inaction	608.57	175.55	423.95	1208.08
MRR of taking action	5.5	4.2	4.1	4.7

Note: *MRR* Marginal rate of return

Source Authors' data





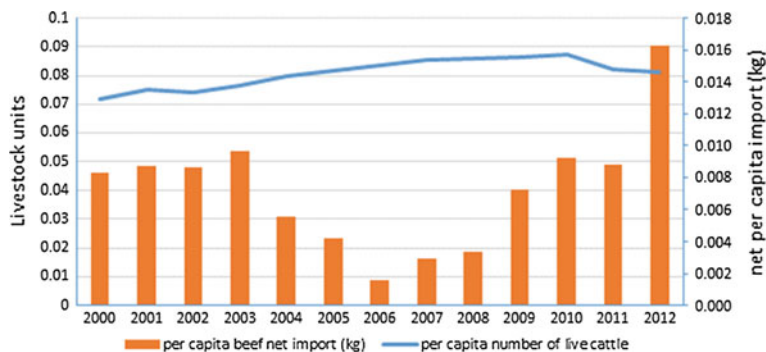
**Fig. 13.3** Cost of land degradation due to LUCC for the period of 2001–2009 (million US\$). *Source* Authors' data

estimated to be about 2007 US\$ 195.747 billion,<sup>1</sup> which is about 5.4 % of Chinese 2007 GDP. This means that annually between 2001 and 2009, the costs of land degradation due to LUCC in China were about 24.5 billion USD. The cost is highest in the arid and semi-arid area (Table 13.1; Fig. 13.3). We calculated the cost of taking action against land degradation, the cost of establishing and maintaining degraded biomes. The results showed that in order to completely rehabilitate the land degraded due to LUCC between 2001 and 2009 in China, a total amount of US \$ 255.45 billion will be required during a 30 year period (Table 13.1). While, if action is not taken to rehabilitate these degraded lands, China will incur a loss of US \$ 1208.08 billion during the same period. The marginal rate of return for investment in restoration of degraded land is above 4—suggesting very high payoff for taking action. Restoration of degraded forest accounts for the largest cost. This is followed by restoration of degraded grasslands—especially in the arid and semi-arid areas in northwestern China.

China is has already started a reforestation program and has been the world's leading country in afforestation and reforestation programs that involved payment for ecosystem (PES) or other strategies (FAO 2010). For example in 2005, China accounted for 90 % of the global afforested area of 4.9 million ha (Ibid).<sup>2</sup>

<sup>1</sup>These costs do not include the losses due to land degradation on static land use, such as croplands and grazing lands—which are discussed below.

<sup>2</sup>Afforestation is planting of forest on an area previously under non-forest biome.



**Fig. 13.4** China's growing demand for livestock products. *Source* Calculated from FAOSTAT (2012)

## Cost of Land Degradation on Grazing Land

The livestock sector accounted for 34 % of the agricultural sector, which in turn accounted for 14 % of the China's GDP in 2005 (FAO 2005). The livestock sector has been growing with growing income and change in consumer tastes and preferences (Ibid). Consequently, per capita number of livestock increased by 21 % from 0.071 in 2000 to 0.087 in 2010 (FAOSTAT 2012). Net import per capita of beef doubled from 0.008 kg in 2000 to 0.016 kg in 2012 (Fig. 13.4).

The increasing livestock population density and over-exploitation of grazing resources in response to the increasing demand for livestock products has resulted in land degradation. Following analytical approaches discussed in Chap. 8, the cost of land degradation on static grazing lands was US\$491 million (Table 13.2).

**Table 13.2** Cost of land degradation on grazing land (2007 US\$ million)

AEZ	Milk loss cost	Meat loss cost	Total cost	Percent of total cost
Subtropic-cool/semi-arid	20.59	21.74	42.33	8.6
Subtropic-cool/arid	10.53	11.55	22.08	4.5
Subtropic-cool/humid	0.12	0.04	0.16	0.0
Subtropic-cool/sub-humid	10.01	5.05	15.06	3.1
Temperate/semi-arid	33.26	33.48	66.75	13.6
Temperate/arid	100.56	230.03	330.59	67.3
Temperate/sub-humid	0.43	0.40	0.83	0.2
Tropic-cool/sub-humid	0.91	0.12	1.03	0.2
Tropic-warm/humid	5.61	0.86	6.46	1.3
Tropic-warm/sub-humid	5.09	0.63	5.72	1.2
Total	187.11	303.90	491.00	

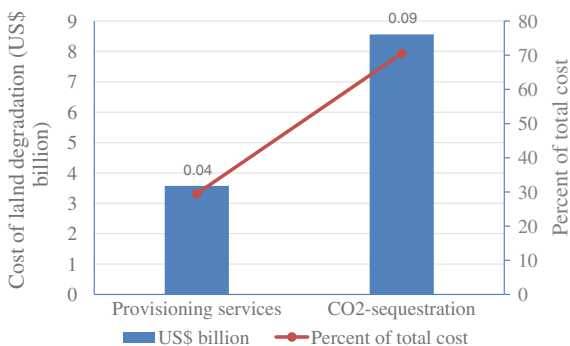
The loss accounts for only milk and meat production. This suggests other losses—especially carbon sequestration, are not taken into account. The temperate arid area in the northwestern region accounted for two thirds of the loss. Meat loss also accounted for 62 % of the loss. This is due to the fact that livestock production in temperate rangeland in the northwestern China is largely for meat production.

The high cost of degradation on grazing lands coupled with the increasing demand for livestock products underscores the need to take action to address land degradation on grazing lands.

### Land Degradation on Static Cropland

Crop production accounted for 12.3 % of China’s GDP in 2004 (CNBS 2010). The number of farmers in China is aging and rapidly dropping with growing urbanization. For example, the share of rural population as the share of total population dropped from about 82 % in 1978 to about 47 % in 2012 (Yang 2013). Yet China still has a large number of crop farmers and therefore need to address cropland degradation. China is among the countries that uses the highest rate of fertilizer in the world. China accounts for a third of the global consumption of inorganic nitrogen fertilizer (Kahrl et al. 2012), though its cropland area accounts for only about 8 % of the global cropland (FAOSTAT 2013). The high rate of inorganic fertilizer application is leading to eutrophication and other environment consequences. For example, concentration of nitrate in groundwater in northern China was about 30 times U.S. EPA-allowed levels (Kahrl et al. 2012). Adoption rate of organic inputs and integrated soil fertility management (ISFM) is limited. Using analytical methods discussed in Chap. 6 and focusing on maize, rice and wheat only, the cost of land degradation on static cropland is about US\$12 billion. Due to limited use of organic inputs and continuous cropping, loss of carbon sequestration accounts for the largest share of total cost (Fig. 13.5).

**Fig. 13.5** Cost of land degradation due to using land degrading management practices on cropland



**Table 13.3** The annual cost of land degradation due to LUCC and land degrading management practices on static cropland and grazing lands

Type of land degradation	Total cost (TEV)	Provisioning services	Cost of land degradation as % of GDP of 2007 US\$3494.06 billion	
	2007 US\$ billion		Total cost (TEV)	Provisioning services
LUCC	24.46	10.58	0.70	0.30
Livestock	0.49	0.49	0.01	0.01
Cropland	12.13	3.57	0.35	0.10
Total annual cost	37.09	14.64	1.06	0.42

## Summary

The total annual cost of land degradation reported in Table 13.3 is US\$ 37.09 billion in China or about 1 % of China's GDP in 2007. This is an enormous loss that calls for action—especially given that the returns to taking action are high and China's new sustainable development and green economy approach reflected in its five year plan (2011–15) and other environmental policies (He et al. 2012). The rapid economic development and the consequent natural resource degradation is posing a challenge in the country's human health and welfare in general. The results of this study will inform policy makers on the key areas for addressing land degradation.

## Conclusions and Policy Implications

Land degradation is a serious potential threat to food production and rural livelihoods. Land degradation or improvement is an outcome of many proximate and underlying causes. The changes of land quality are the result of many highly inter-linked factors including natural, socioeconomic and also policy and related agricultural practices. In China, many types of land degradation are occurring, such as grassland degradation, deforestation, and cultivated land degradation. In this chapter, we conduct a revisit to the researches on the assessment and driving mechanism of degradation in grasslands, forests and cultivated lands in China and the North China Plain. The results show that degraded areas have been expanding in the northern part of the North China Plain, while many parts of the North China Plain show land improvement, and the increases in temperature and rainfall corresponded to the increase in NDVI in most parts of the North China Plain, agricultural intensification and soil organic matter will benefit the land quality, while rural economic and agricultural development may lead to land degradation. As the rural economic and agricultural production growth exerted negative impacts on land quality, which means the development of rural economy and agricultural production

led to land degradation. The increases in rural farmers' per capita income and primary production value ratio did not result in the improvement of land quality, which may be due to the overexploitation of land with insufficient investment into the land conservation. In this regard, an effective response to land degradation calls for increasing the incentives of farmers to conserve their cultivated land and improving their access to the knowledge and inputs required for proper conservation. Promotion of such land improvements should be a development policy priority. During the process to promote rural economic development, the governments should also focus on the monitoring and assessment of land quality and make measures to improve land quality, and such improvement measures should be designed together with farmers to meet their prior needs and use appropriate techniques according to the local economic and social conditions. In addition, access to infrastructures may also have negative effects on land quality. Infrastructure development is the basis for regional prosperity, and a booming economy will result in more construction of infrastructure such as new commercial and industrial buildings. The expansion of basic transport infrastructure such as roads, railways and airports can further occupy land resources and further lead to land overexploitation and degradation. Soil sealing resulted from the urban development and infrastructure construction means the soil surface being covered by impervious materials. If the impervious surfaces replace the natural, semi-natural and cultivated land, this will degrade soil functions or cause their loss. To reduce the impacts of infrastructure construction on land quality, the local government should take the assessment of land degradation into consideration during the construction of infrastructures.

Further, the cost of land degradation due to land use/cover changes, and cost of action and inaction were computed. The results show that, in China, the cost of taking action against land degradation is lower than the cost of inaction even just considering the first 6 years of rehabilitation. The opportunity cost of taking action accounts for the largest share of the cost.

Based on the above analysis results, to achieve sustainable land management, climate changes should be monitored so as to make adaptation measures to mitigate the impacts of climate changes on land quality. Along with the socioeconomic development, investments and better land management for improving land quality should be encouraged through appropriate policy measures. Human activities that change the land surface, such as infrastructure constructions, should be regulated on the basis of the assessment of impacts on land quality, and corresponding land conservation measures should be taken during the construction process. Government strategies should be developed that give incentives to take positive action to manage lands sustainably.

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