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# Cultivated land and food supply in China

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**Abstract**

The study utilizes official statistics at the national and provincial level to examine changes in cultivated land in China during the past two decades. The environmental impact of the changes and the consequent effect on China's short- and long-term food supply are tackled. The study finds that while the decline in cultivated land was a trend evident at the national level, a provincial investigation reveals that this was mainly the result of a drastic reduction of fertile land in the southeast areas. The conversion of cultivated land to other types of agricultural uses and the encroachment of various constructions were the major causes of the loss there. Cultivated land increased in some northwest and frontier provinces, which partially offset the loss in the southeast. Reclamation was the primary source of the increase. This gain, however, has been made at the expense of environment, indicated by a substantial abandonment of damaged land in the major reclaiming provinces. The study argues that under the current land management system, the enforcement of the strategy of maintaining a dynamic balance of cultivated land can only intensify the existing regional trend. To this end, the strategy could potentially do more harm than good to China's long-term food security. 

*Keywords:* China; Cultivated land; Reclamation; Environment; Food supply

## Introduction

China is a country with vast population and scarce land per capita. This basic characteristic has determined the preciousness of cultivated land to its people. Partly for this reason, the 'land reform' campaign launched by the communist party during the 1930s and 1940s had helped it win the grassroots support, and eventually the power of the state. The economic reform, incepted in the late 1970s, again has started from assigning land and farm work to individual households in rural areas. Indeed, land issue has always been a central concern of the Chinese government and people. With the continuous increase in population and an ever-growing demand for food, the pressure on cultivated land is also mounting. In recent years, a debate on China's ability to feed itself has further heightened the concern.

Concomitant to the annual GDP growth averaged at around 10% during the past two decades, the country's cultivated land has been diminishing. Between 1978 and 1996, total cultivated land decreased by 4.73 million hectares (See Table 1). Most of the loss had occurred in coastal and central provinces, where land is relatively fertile and the multiple cropping index is high. The rapid decline in cultivated land drew initial attention in the middle 1980s. There were calls for protecting cultivated land. The first 'Land Management Ordinance' was promulgated in 1986 (ECCLY, 1997). Nevertheless, a serious concern about the cultivated land losses has mainly arisen since the mid-1990s. Two factors triggered the change. One was the grain-market crisis which erupted at the end of 1993 and in 1994. A shortage of rice supply in some southern areas ignited price hikes. The panic rapidly spread to the north and became a nationwide grain shock (Cui, 1995; Ke and Tang, 1996; Yang, 1999). The second factor was the publication of Lester Brown's query '*Who Will Feed China?*' in 1995. Based primarily on his observation of the rapid decline in cultivated land, Brown predicted that by 2030, China would not be able to feed itself. The surplus of the rest of the world would also not be enough to fill China's grain shortfalls (1995). Although Brown's projection has received intense criticism both within China and abroad, it brought the concern of the loss of cultivated land and China's food security to an all-time high. A series of policy measures were

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stipulated to stabilize the domestic food supply and to halt the decline in cultivated land. The Governor Responsibility System for grain supply was introduced in early 1995. Grain-sown area and output plans, which were more or less phased out in the previous years, were restored in many areas to ensure the fulfillment of the output targets (Cui, 1995; Wang, 1996). To halt the decline in cultivated land, a strategy named 'maintaining a dynamic balance of cultivated land' was initiated in 1996 (Zou, 1997). The strategy was later formally written in the amended 'Land Management Ordinance' in 1998. Provincial governments are required to take the responsibility to maintain a dynamic balance of cultivated land in their jurisdictions. Losses of cultivated land have to be compensated by reclaiming new land and other means (mainly rehabilitating damaged land and reusing deserted land). In the provinces where no reclaimable land is available, the reclamation (to compensate the loss) has to be made in other provinces under the arrangement and supervision of the State Council (Zhang, 1998). It has been generally believed that this strategy is imperative for China to stabilize food supply and sustain food security (Zou, 1997; Lin Fanglei, 1998; Liu, 1998).

Indeed, in a country where cultivated land is scarce in relation to its population and a high level of food self-sufficiency is ideologically upheld, protecting cultivated land from further decline is necessary. The strategy may be seen as a compromise between the modernization urge and a desirable grain production growth. However, questions have to be asked. Can this strategy necessarily benefit grain production? Is it really conducive to food security? Worse, could it have adverse effects on grain production and food security? So far, little empirical and scholarly research has been conducted to assess the overall impact of the strategy. Environmental implications behind this strategy are far from clear. Yet, without a clear idea about its impact, the enforcement of the strategy could be dangerous. As is elaborated in this paper, under the current land management system, the strategy renders a high risk for a consequence that is opposite to what it is designed for.

Despite the preciousness of cultivated land in China, systematic studies of this matter were relatively few in number in the literature before the 1980s.[1] Part of the reason was the inadequacy and inaccuracy of the statistical data.[2] In *China's Statistical Yearbook*, an official annual publication of the State Statistical Bureau, the cultivated land figure was reported as roughly 95 million hectares. However, it is noted in the yearbook that 'the cultivated areas are underestimated and the actual figure must be further verified'. The data problem has more or less deterred systematic studies of changes in cultivated land in China.

Since the late 1980s, nevertheless, there have been some large-scale land surveys conducted by government departments and academic institutions. The aim is to acquire more accurate figures for China's cultivated land resources. Based on these surveys and with the assistance of remote-sensing techniques, general agreement has now been reached that the actual cultivated land in China is 30–40% higher than the officially published figure. This brings the total cultivated land to about 130–140 million hectares (CISNAR, 1991; Ash and Edmonds, 1998; Smil, 1999). The Chinese government has accepted this estimate in principle but is reluctant to change the cultivated land figure in official publications. The reason is simple. The alteration of the cultivated land figure will lead to a consequent rewriting of all the statistics relating to or based on cultivated land. Not to mention the enormous work this may involve, the elapse of the years may have made the correction of historical statistics virtually impossible. As a compromise to this perplexity, starting from 1996, the cultivated land figure has been dropped from *China's Statistical Yearbook*. However, in statistics of individual provinces, also published by the State Statistical Bureau, cultivated land figures for 1996 were presented.

Recognizing the underestimation of cultivated land in the official statistics, however, does not alter the fact that China is scarce in cultivated land. The figure for per capita cultivated land remains extremely small. Meanwhile, the loss of cultivated land has continued in many places despite the implementation of various land-protection measures. Thus, there is an urgency to study China's cultivated land resources and investigate environmental and economic impacts of cultivated land changes over the years. Before proceeding further, however, the validity of such study in the presence of underestimation needs to be reconciled. The argument is that the underestimation in the official data is systematic. It exists in the entire statistical series. The magnitude of the underestimation is expected to be consistent over the years. A time-series analysis of changes in cultivated land, therefore, is feasible because the systematic underestimation would not significantly affect the conclusion. This point has also been made by other authors, including Ash and Edmonds (1998) and Smil (1999), in their studies of the land issue. Accepting this premise is of importance as it is the foundation underlying numerous studies of China's agricultural economy using official statistics of cultivated land, either directly or indirectly.

[1] A notable exception is the study by Buck (1937) who conducted a pioneer survey amongst 16,786 farms covering twenty-two provinces in China in the 1930s. Since the founding of the People's Republic of China, large scale land surveys had been absent until the late 1980s.

[2] The data problem is partly stemmed from the incentives of underreporting of cultivated land. Underreporting cultivated land has been used as a means by local officials to evade taxes (Hill, 1997). Meanwhile, underreporting has also been encouraged by political motivations. Given the volume of output (the figure itself may be underreported), underreporting cultivated land can derive a higher yield, a criterion for evaluating cadres' achievement in rural areas.

Before 1987, the State and Provincial Statistical Bureau (SSB, hereafter) were the main official agencies for collecting and publishing land statistics. Data published by SSB have been regarded as the most authoritative statistics. In 1986, The State Land Administration (SLA, hereafter) was established as a statutory body under the State Council to monitor and report the change of cultivated land.[3] SLA had published statistics between 1988 and 1995, detailing sources of changes in cultivated land.

This study examines changes in cultivated land during the past 20 yr. Regional disparities are highlighted. It aims to gain an in-depth understanding of the environment impact of the strategy of maintaining a dynamic balance of cultivated land and its implications for China's short- and long-term food security. Policy suggestions in dealing with cultivated land and food supply are addressed. The data used are primarily from SSB and SLA. The SLA data contain detailed information about the sources of the increase and the destinations of the loss of cultivated land. However, this data set only covers the period from 1988 to 1995. In contrast, the data from SSB have a longer length but lack details of the causes of the changes. Meanwhile, there are some inconsistencies between the two data sets due possibly to statistical errors, different definitions and time lagging (Fischer et al., 1998; Lin Fanglei, 1998). It is thus inappropriate to combine these two data sets in a time-series analysis. In this paper, we use the data from SSB to examine historical changes in cultivated land at the national level. The data from SLA are used to investigate sources of cumulative gains and losses of cultivated land in individual provinces during the period 1988–1995.[4]

The rest of the paper is organized as follows. The following section investigates the magnitude of changes in total cultivated land and variations across provinces. Further we deal with the sources of cultivated land changes. The environmental impacts of the cultivated land changes are elaborated and also the analysis of the effect of cultivated land changes on grain production is conducted. Implications for the sustainability of China's grain production and long-term food security are addressed. Concluding remarks and policy implications form the final section.

## An overview of changes in cultivated land

### *Changes in total cultivated land at the national level*

In China's official statistics, cultivated land refers to those lands which are planted with crops, newly reclaimed land and the land fallow for less than three years.[5] However, it excludes perennial plantations, such as orchards, mulberry fields, tea plantations and tropical crop plantations. During the last two decades, China has experienced an unprecedented economic growth. The rapid increase in incomes, together with the continuous growth in population, has meant a rigid expansion of the demand for food. However, cultivated land has declined. Fig. 1 illustrates changes in total cultivated land between 1978 and 1996.

During the period studied, total cultivated land decreased by approximately 4.7 million hectares, or about 4.45%. On the absolute terms, the decline was huge. On the relative terms, however, the decline seems not as drastic as one would have perceived. Does this mean the magnitude of the decline in cultivated land has been somehow exaggerated and, the actual effect of the decline on grain production has not been as substantial as one had expected? We leave the answer to this question to the succeeding sections. Here, we concentrate on the changes in quantity of cultivated land. Fig. 1 shows that the decline was uneven over the years. The early period of the reform saw a faster decline. This was particularly so between 1983 and 1987, when the total reduction exceeded 2.4 million hectares, 50% of the total decrease during the entire period observed. In the later years, the decline slowed. Between 1988 and 1991, the figure was fairly stable. In 1995 and 1996 the figure even increased slightly. This coincided with the implementation of the Governor Responsibility System and the strategy of maintaining a dynamic balance of cultivated land in these years.

The general trend in cultivated land changes exhibited in Fig. 1 gives an impression that the decline has been halted in the later years. If so, the worry about the effect of the loss of cultivated land on food supply could be eased. The situation is seemingly a good sign. However, the environmental impacts and their implications for the sustainability of food production have not been so optimistic. Instead, as the following analysis will demonstrate, food production capacity has continuously been reduced by the loss of cultivated land. In the meantime, the reclamation of cultivated land in the marginal areas has exerted serious impacts on the fragile ecosystem.

### *Regional and provincial disparities*

Since the reform, economic growth in different regions has varied substantially. In general, coastal provinces have benefited tremendously from their location when China's door opened to the outside world (Fan, 1995).

[3] In 1998, the State Land Administration was merged with several other departments to form the Ministry of Land Resource in accordance with the administrative restructuring of the State Council.

[4] In some years, the difference between the two data sets is substantial. The following analysis will notify the difference whenever it may affect the analytical result.

[5] Cultivated land is different from sown area. Multiple cropping is widely practiced in China, particularly in southeastern areas. Sown area counts land cropping and harvest more than once in a year.

The economy has experienced a vigorous growth, typified as a boom of non-agricultural sectors. In interior provinces, particularly those in the western areas, the growth has been slow and the development of non-agricultural sectors has been retarded. Accompanying this spatially uneven economic growth has been a varying magnitude of the changes in cultivated land across regions and provinces.

To observe the spatial patterns of the changes in cultivated land, we divide provinces into three regions: Coastal, Central and Western-Border. The division of the regions is based primarily on their spatial location, an important factor that has determined the level of economic development during the reform period (Fan, 1995; Wei, 1998). This regional division is slightly different from the conventional 'three-region' concept in which Sichuan, Guizhou and Shaanxi are regarded as western provinces. We put these provinces in the Central region for their central location in China. The *western-border* region in this study encompasses all inland border provinces, as well as the interior northwestern provinces of Gansu, Qinghai and Ningxia. Map 1 illustrates the

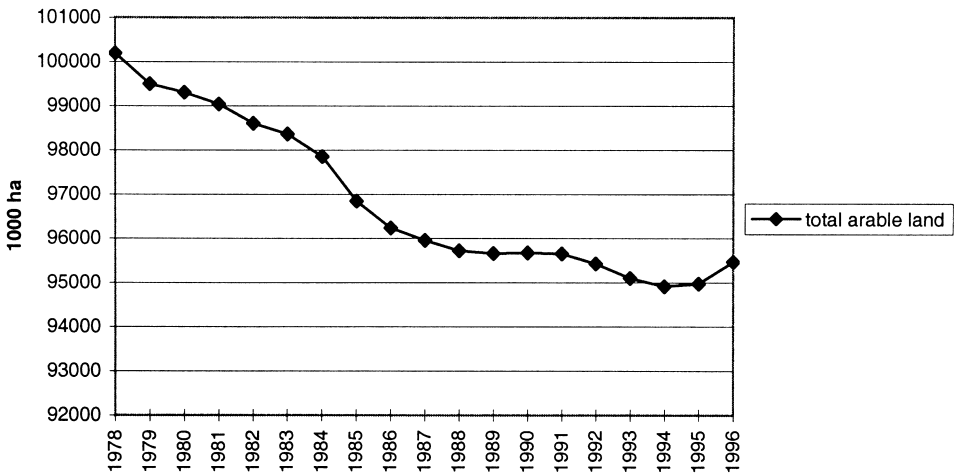
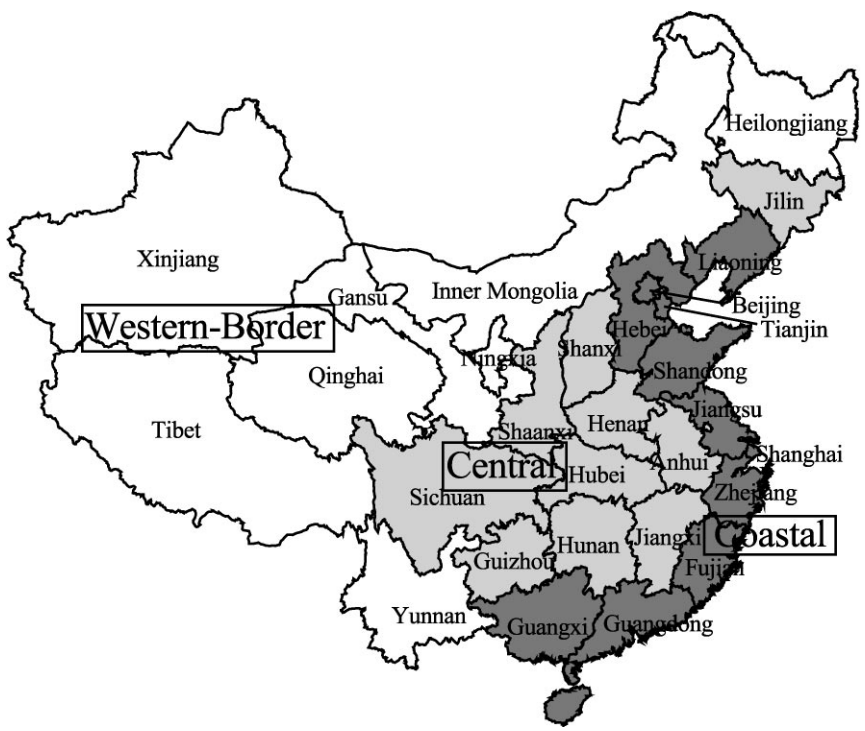



Fig. 1. Changes in arable land, 1978–1996.
*Source*: Data for 1978-1984 are from USDA, 1991. Data for 1985–1995 are from SSB, ZNTN, 1986–1996. Data for 1996 are from ECCAY, ZNN, 1997.




MAP. 1. Spatial location of regions and provinces

Table 1
Changes in Cultivated Land by Regions and Provinces[a]

| | 1978–1996 | % | 1978–1987 | % | 1987–1996 | % |
|---|---|---|---|---|---|---|
| Nation | − 4728.5 | − 4.7 | − 4306.3 | − 4.3 | − 422.2 | − 0.4 |
| *Coastal* | − 2232.9 | − 7.5 | − 1170.2 | − 3.9 | − 1062.7 | − 3.6 |
| Beijing | − 31.1 | − 7.3 | − 9.3 | − 2.2 | − 21.8 | − 5.2 |
| Tianjin | − 41.2 | − 8.8 | − 28.5 | − 6.1 | − 12.7 | − 2.9 |
| Hebei | − 166.2 | − 2.5 | − 88.5 | − 1.3 | − 77.7 | − 1.2 |
| Liaoning | − 295.3 | − 8.0 | − 186.7 | − 5.1 | − 108.6 | − 3.1 |
| Shanghai | − 70.7 | − 19.7 | − 27.1 | − 7.6 | − 43.6 | − 13.2 |
| Jiangsu | − 213.6 | − 4.6 | − 69.2 | − 1.5 | − 144.4 | − 3.2 |
| Zhejiang | − 214.2 | − 11.7 | − 83.1 | − 4.5 | − 131.1 | − 7.5 |
| Fujian | − 94.8 | − 7.3 | − 47.1 | − 3.6 | − 47.7 | − 3.8 |
| Shangdong | − 611.6 | − 8.4 | − 366.7 | − 5.0 | − 244.9 | − 3.5 |
| Guangdong | − 494.2 | − 15.3 | − 264.1 | − 8.2 | − 230.2 | − 7.8 |
| Guangxi | 69.3 | 2.7 | 1.9 | 0.1 | 67.4 | 2.6 |
| *Central* | − 2780.1 | − 6.7 | − 1690.2 | − 4.1 | − 1089.9 | − 2.6 |
| Jilin | − 87.5 | − 2.2 | − 85.5 | − 2.1 | − 2.0 | − 0.1 |
| Anhui | − 179.7 | − 4.0 | − 63.1 | − 1.4 | − 116.6 | − 2.7 |
| Jiangxi | − 221.3 | − 8.8 | − 161.1 | − 6.4 | − 60.1 | − 2.5 |
| Henan | − 365.7 | − 5.1 | − 179.4 | − 2.5 | − 186.3 | − 2.7 |
| Hubei | − 415.8 | − 11.0 | − 247.0 | − 6.6 | − 168.8 | − 4.8 |
| Hunan | − 197.6 | − 5.7 | − 119.0 | − 3.5 | − 78.6 | − 2.4 |
| Sichuan | − 479.8 | − 7.2 | − 319.4 | − 4.8 | − 160.4 | − 2.5 |
| Guizhou | − 57.6 | − 3.0 | − 39.7 | − 2.1 | − 17.9 | − 1.0 |
| Shanxi | − 290.0 | − 7.4 | − 194.7 | − 5.0 | − 95.3 | − 2.6 |
| Shaanxi | − 485.1 | − 12.6 | − 281.3 | − 7.3 | − 203.8 | − 5.7 |
| *Western-Border* | 284.4 | 1.0 | − 1445.9 | − 5.1 | 1730.3 | 6.0 |
| Inner Mongolia | 191.6 | 3.3 | − 881.1 | − 15.4 | 1072.7 | 22.1 |
| Heilongjiang | 6.6 | 0.1 | − 309.3 | − 3.4 | 315.9 | 3.6 |
| Yunnan | 167.4 | 6.1 | 68.9 | 2.5 | 98.5 | 3.5 |
| Tibet | 8.9 | 4.1 | 3.0 | 1.4 | 5.9 | 2.7 |
| Gansu | − 69.6 | − 2.0 | − 76.9 | − 2.2 | 7.3 | 0.2 |
| Qinghai | − 6.1 | − 1.0 | − 31.4 | − 5.3 | 25.3 | 4.5 |
| Ningxia | − 80.5 | − 9.0 | − 103.1 | − 11.5 | 22.6 | 2.9 |
| Xinjiang | − 3.2 | − 0.1 | − 118.0 | − 3.7 | 114.8 | 3.8 |

[a] *Source*: Same as Fig. 1.

spatial location of the three regions and the provinces included.[6]

Table 1 presents the absolute and proportional changes in cultivated land across provinces with reference to the regions defined. The period 1978–1996 is further divided into two sub-periods: 1978–1987 and 1987–1996. The division is based on the general trend exhibited in Fig. 1. Between 1978 and 1987, the decline in cultivated land was drastic. The period 1987–1996 had seen a deceleration in the reduction. Meanwhile, the division also takes into consideration the pace of regional economic development. During the early years of the reform, economic growth in all provinces was relatively rapid and regional income gaps narrowed (Fan, 1995). However, since the late 1980s, regional gaps have widened. The Coastal provinces have experienced a much faster advance, whereas the growth in the interior and frontier provinces has been rather slow (Wei, 1998; Ying, 1999)

Between 1978 and 1996, the aggregate declines in the Coastal and Central regions were 7.5 and 6.7%, respectively. The figures are significantly higher than the national average. In contrast, cultivated land in the *western-border* region did not decline, but increased by 1%. Down to the provincial level, except for Guangxi, cultivated land declined in all provinces in the Coastal and Central regions. The reduction exceeded 10% in Shanghai, Zhejiang, Guangdong, Hubei and Shaanxi. In other provinces, the figure was mostly over 7 percent. There were only six provinces where the cultivated land figures increased or hardly changed. These were Heilongjiang, Inner Mongolia, Tibet, Yunnan, Guangxi and Xinjiang.

[6] Hainan was separated from Guangdong in 1988. Chongqing was separated from Sichuan in 1997. For the sake of data consistence, in this study Guangdong includes Hainan and Sichuan includes Chongqing.

All but Guangxi are located in the *western-border* region and all but Heilongjiang are the major habitats of minority Chinese nationalities. The changes in cultivated land over the period studied demonstrate significant provincial disparities with distinct regional patterns. In general, the loss was entirely caused by the Coastal and Central regions. The *western-border* made a small gain in the cultivated land.

Regional patterns can be seen more clearly when dividing the whole period into two sub-periods. During the period 1978–1987, cultivated land in the Coastal region declined by 3.9%, or 1.17 million hectares. The decline in the second sub-period was 3.4% or 1.06 million hectares, not much different to the first sub-period. In Shanghai and Beijing, the loss even accelerated. This situation is in contrast to the national trend, in which the reduction in the second sub-period was rather modest.

In the Central region, the decrease was large in both absolute and relative terms during the first sub-period. Cultivated land declined by 1.69 million hectares. The proportional decrease was 4.1%, similar to the national average. The decline in the second sub-period was 2.6%. The absolute loss, 1.09 million hectares, remained large.

The situation in the *western-border* region differs from the other two regions. During the first sub-period, cultivated land decreased by 5.1%, the highest percentage drop amongst the three regions. However, in the second sub-period, cultivated land increased by 6%. A notable feature is that the increase was evident in all the provinces in the region. Inner Mongolia recorded an exceptionally large increase, 22.1%. The increase in the *western-border* region partially offset the decrease in the Coastal and Central regions. This had been the major reason for the slowed reduction in cultivated land at the national level during the second sub-period.

The above examination shows substantial regional variations in cultivated land changes. In most Coastal and Central provinces, the decline was drastic. The gain was mainly made in a few northwest and frontier provinces. This result is more or less expected. It has been well known that the rapid development in non-agricultural sectors in the Coastal and Central regions had taken away a large amount of farmland for other uses. Accordingly, the slower development in the *western-border* region would mean a lower speed in the loss of cultivated land. However, the increase in cultivated land in the region is rather peculiar.

So far, we have only looked at the net losses and gains across regions and provinces. In reality, while cultivated land is being taken away for other uses, land is also being brought into cultivation. This can happen at national, regional and provincial levels. Different sources of gains and destinations of losses can impose varying impacts on environment and grain production. For this reason, it is necessary to conduct a thorough scrutiny into the details of gains and losses of cultivated land at respective levels.

## Where had the cultivated land come and gone?

### *Sources of the increase and decrease in cultivated land*

In China's official statistics, sources of the increase in cultivated land are classified into following categories:

- reclamation;[7]
- drainage from shallow sea, lake, swamp and/or waterlogged land;
- rehabilitation and reuse of areas previously discarded due to disasters, mining, construction, etc.;
- conversion of land from forestry, grassland, or horticulture to cultivated land through adjustments of agricultural structure.

Destinations of the lost cultivated land are grouped into five categories, namely:

- capital construction;
- construction by rural collectives;
- peasant housing;
- conversion of cultivated land to other agricultural land-use types, such as horticulture, forest, pastureland, or fish ponds;
- loss due to disasters (such as flooding, mud flow, gully erosion, landslides, sand encroachment, etc.) and abandonment of cultivation.

Comparing the sources of gains with the destinations of losses of cultivated land, it is not difficult to find that some of the items in these two groups are convertible. For example, cultivated land can be converted to horticulture land, and vice versa. Reclamation can occur on pastureland and forests. This, in turn, may cause land degradation and eventual abandonment. Cultivated land lost to disasters and abandonment may be rehabilitated and reused.[8] Nevertheless, for the land lost to various types of constructions, i.e., capital construction, rural-collective construction and peasant housing, the reversal is difficult, if not impossible. This type of loss is therefore more or less permanent in nature.

It should be pointed out that gains and losses of cultivated land specified above all have direct and/or potential impact on environment. The impact can be positive or negative. In terms of the gains of cultivated land, except for the rehabilitation of discarded land and the reuse of it that is likely to be conducive to the

[7] According to the definition in the Chinese official statistics, reclaimed land refers to newly cultivated land, which is plowed and planted with crops in the current year. It includes reused farmland that has not been cultivated or left fallow for more than three years. It, however, does not include areas idle for less than three years.

[8] This is not always possible. Reclamation may lead to a permanent damage of land, such as desertification. This situation is common in the arid and semi-arid areas in Northwest China (Office of Desertification Prevention and Management, 1998).

environment, all other actions can have detrimental impacts. For example, the conversion of forests and pastureland to cultivated land can cause soil erosion and land degradation. Land acquired from drainage involves filling lakes and rivers and destroying coastal wetlands. The environmental consequence is often negative. One result would be an increase in flood frequency and intensity. The 1998 summer flood on the Yangtze River was a typical example.[9] As for the losses of cultivated land, the effects are mixed. The environmental impact of various types of construction is often uncertain. The conversion of cultivated land to horticulture land and fish ponds does not necessarily cause environmental damage. Returning cultivated land to forests and pastureland can protect soil from erosion, hence is benign to the environment. Nevertheless, losses to the disasters and abandonment are the result of environmental degradation. Human abuse of land resources has been a major cause of such losses.

*A national perspective*

Due to the lack of detailed statistics in the SSB data set, we cannot separate each individual source of the gains and destination of the losses of cultivated land for the period in question. We aggregate the sources into two categories, reclamation and others. The category 'others' includes drainage, reuse of previously discarded land and conversion of non-crop land to crop uses. For the destinations of the losses of cultivated land, three categories are defined: construction, conversion and others. Here, cultivated land losses to all types of construction are aggregated into one category.

Fig. 2a shows the sources of the gains in cultivated land in absolute terms. It can be seen clearly that reclamation is a main contributor. In most of the years, it accounted for more than 50% of the total gain. In 1985, the proportion was as high as 80%.

Fig. 2b presents the destinations of the losses of cultivated land. On average, various types of construction took away about 200,000 hectares of cultivated land annually. This is about 20–40% of the total loss, though the actual proportion varies from year to year. The absolute changes over the years had been closely related to the national macro-economic situation. As demonstrated in Sun and Li's study (1997), the ups and downs of the curve of the losses to various constructions are highly consistent with the total investment in fixed assets. Whenever the economic growth is fast, the loss of cultivated land to construction expands. This trend indicates an extensive use of cultivated land in non-agricultural sectors. Considering the permanent nature of such losses, tighter control over construction on cultivated land is necessary.

The category 'others' includes all the other sources of losses. However, in 1985 and 1987–1992, the conversion of cultivated land to other types of agricultural uses is separated from this category. From the data of these several years, we can see that the conversion accounted for a large share of the total loss. In 1985, the proportion was above 50%. From the environmental protection point of view, this conversion is necessary if it occurs in areas where natural conditions are not suitable for crop farming. The SSB data set did not give separate figures for the conversion before 1985 and after 1992. However, from the SLA data in which details are given, we can see that the conversion was also a major reason for the cultivated land losses after 1992.

Referring to the destinations of the losses of cultivated land specified in the section sources of the increase and decrease in cultivated land, we know that the category 'others' for the years when the conversion is extracted contains only the loss to disasters and abandonment. Fig. 2b shows that this loss is substantial, even exceeded the total loss to the constructions in some years. This situation is alarming to China's environment and food production.

*A regional perspective*

To investigate the spatial distributions of gains and losses of cultivated land across provinces, we present cumulative figures for the changes in individual provinces in Figs. 3 and 4. The data used are from SLA, which contain details of the sources of cultivated land changes, but cover only the period 1988–1995.

Fig. 3 shows that the gains of cultivated land were mainly from Inner Mongolia, Heilongjiang, Yunnan, Xinjiang and Guangxi. The gains in these five provinces accounted for 52% of the total increase. Reclamation was the predominant source, accounting for approximately 90% of their gains, and contributed 57% to the total reclaimed land in the nation during the period. This feature indicates that China's reclaimable land reserve is mainly concentrated in the frontier and border areas. The result is understandable given the fact that these areas have had a relatively short history of crop farming and natural environment is generally harsh, which constrains farming practice. In contrast, reclamation is limited in most of the Coastal and Central provinces. The long history of agriculture and the high density of population have left little potentially reclaimable land in these areas. Under the 'dynamic balance' strategy, one would expect that part of the compensation to the lost land in these provinces would have to be conducted in the Western-Border provinces where reclaimable land is available.

[9] For years, reclamation has been conducted around the Dongting and Boyang lacks on the Yangtze River. It has caused a substantial reduction in the water holding capacity of the lakes. This, in turn, has lowered their capacity to cushion the intensity of floods.

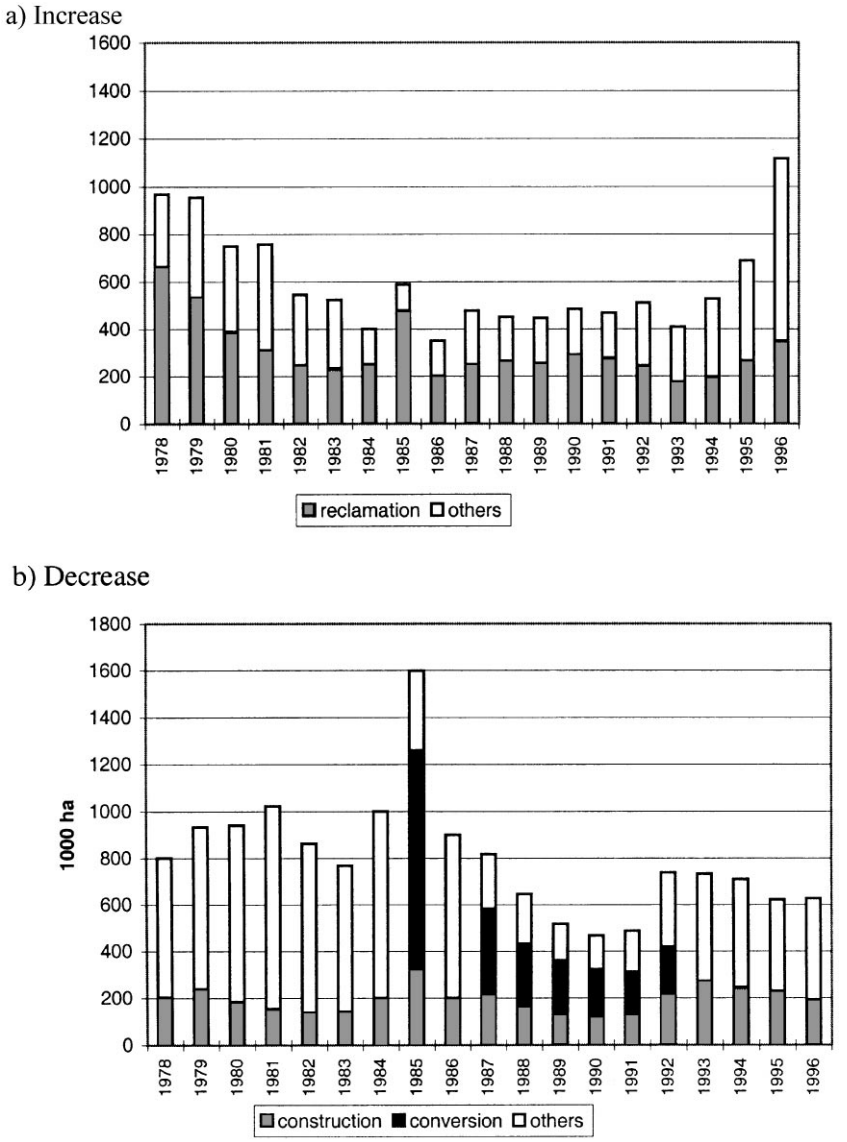



Fig. 2. Sources of changes in cultivated land, 1978–1996.
*Source*: Data for 1978–1990 are from the Ministry of Agriculture, ZNTZ, 1979–1991. Data for 1991–1996 are from ECCAY, ZNN, 1992–1997.

The category 'conversion' refers to the cultivated land converted from forests, pastureland and horticulture as well as fish ponds. The proportion under this category is relatively small in most of the provinces. This seems to suggest that limited forests and pastureland have been converted to cropland. However, the following analysis will reveal an opposite situation.

Fig. 4 shows the composition of cumulative losses of cultivated land across provinces. The conversion of cropland to other types of agricultural uses is an important reason for the loss of cultivated land in most provinces. In this aspect, there are no clear regional patterns. However, as specified in the section sources of the increase and decrease in cultivated land, this category consists of different types of conversion. The actual destinations of the lost land under this category vary greatly in accordance to the natural and economic conditions in different regions and individual provinces.

Cultivated land lost to construction is relatively small in comparison to that lost to conversion and disasters in most of provinces. Compared with the data from SSB, exhibited in Fig. 2, the figures in SLA under this category are somewhat smaller. This had been said to be partly attributable to the inconsistent definition of statistics, which underestimated cultivated land losses in the SLA data set (Fischer et al., 1998; Lin Fanglei, 1998).

It is noted that cultivated land lost to disasters and abandonment is large in the Western-Border provinces. In Inner Mongolia, the cumulative figure accounted for more than 16% of its total loss, indicating a serious

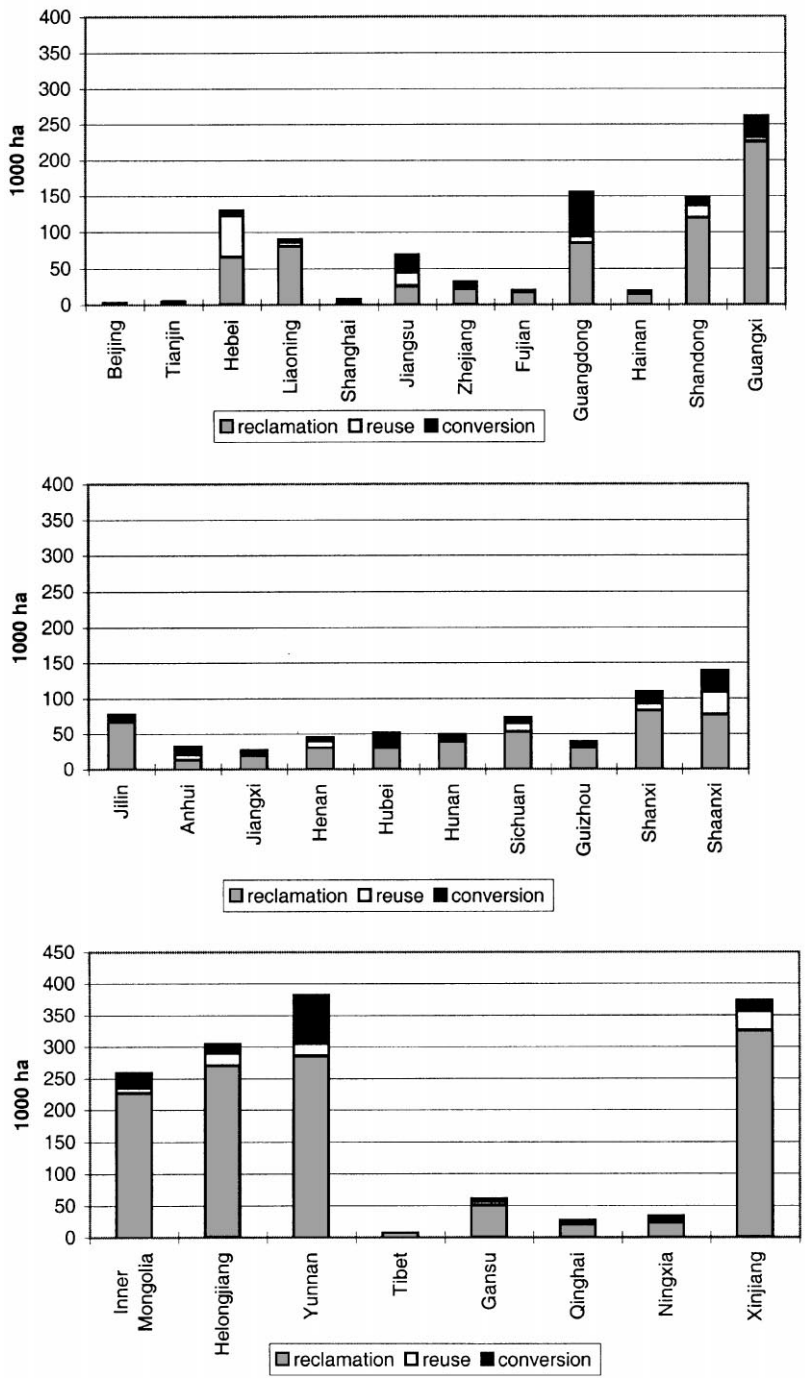



Fig. 3. Composition of cumulative gains of cultivated land, 1988–1995.
*Source*: SLA, 1997.

environmental degradation. Comparing Fig. 3 with Fig. 4, one can easily find that there is a high degree of spatial correlation between reclamation and losses to disasters and abandonment. In the provinces where the reclaimed land is larger, the land lost to disasters and abandonment is also greater. There comes a question. Can China sustain its food supply on the basis of such 'dynamic balance' of cultivated land?

## A further analysis of caltivated land changes and their environmetal impacts

The above examination shows that conversion of cultivated land to other agricultural uses is the most important reason for the losses of cultivated land. The following analysis focuses on examining various types of conversion and exploring their environment

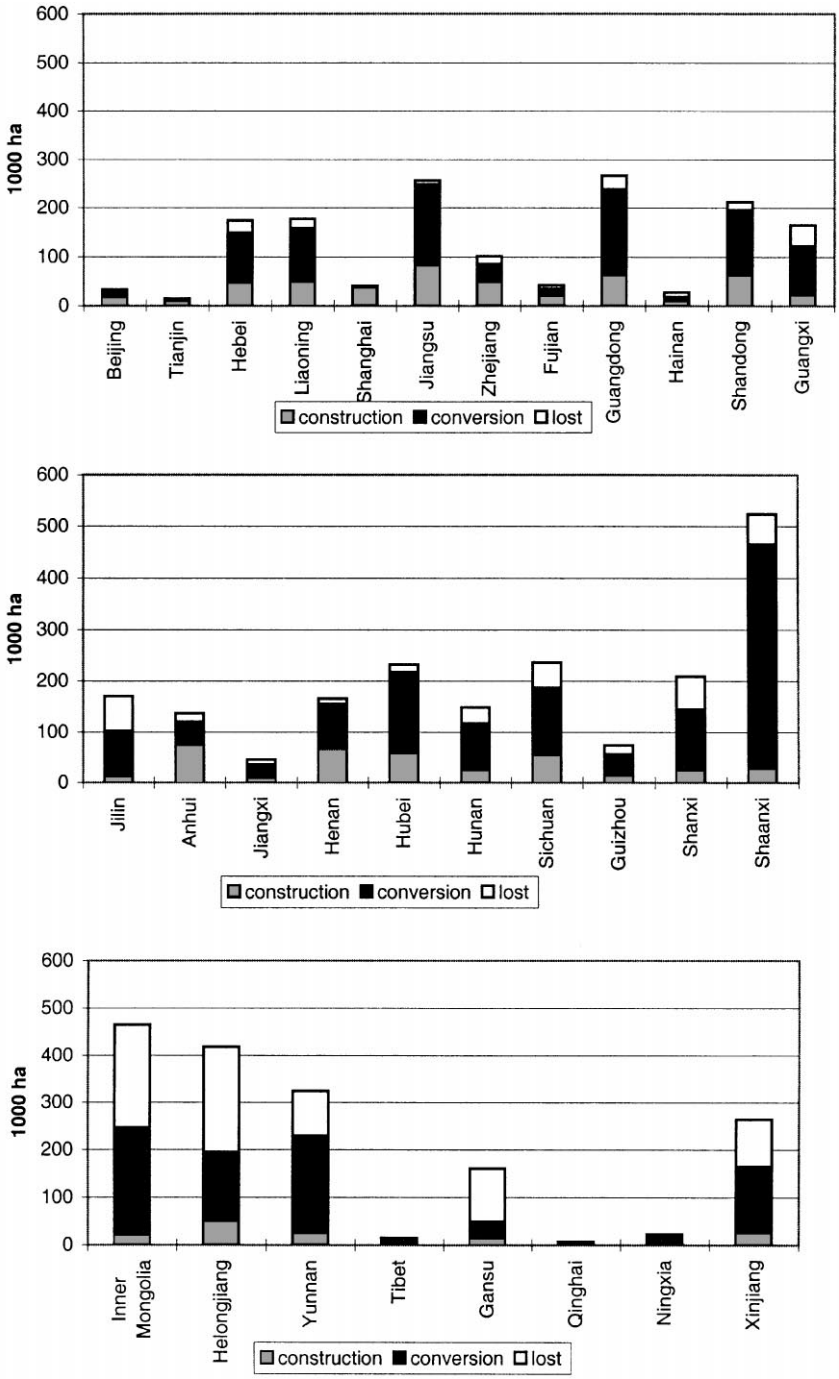



Fig. 4. Composition of cumulative losses of cultivated land, 1988-1995.
*Source*: SLA, 1997.

impacts and the implications for China's long-term food security.

Table 2 provides the detail of the destinations of the conversion. In many Coastal and Central provinces, a large proportion of the lost cultivated land had gone to horticulture and fish ponds. This is apparently a response to the increasing demand for fruits and aquatic products with the rise in incomes. In Jiangsu, Zhejiang, Anhui, Guangdong, Shandong and Shaanxi, the expansion of horticulture took more than 70% of the total converted land. For farmers, such conversion has been profit-driven (Sun and Li, 1997). It is well known that in China, crop farming is a poor-return sector due in part to the state control over production and marketing (Yang, 1998a). Nevertheless, this type of conversion does not necessarily cause land degradation or soil erosion. Instead, the

Table 2
Components of converted land, 1988–1995[a]

| | Total converted cultivated land | To | | | |
|---|---|---|---|---|---|
| | 1000 ha | Horticulture (%) | Forestry (%) | Grassland (%) | Fish pond (%) |
| *Coastal* | | | | | |
| Beijing | 14.0 | 44.3 | 46.4 | 0.0 | 7.9 |
| Tianjin | 5.2 | 42.3 | 3.8 | 0.0 | 51.9 |
| Hebei | 100.9 | 46.6 | 30.6 | 22.7 | 0.3 |
| Liaoning | 108.5 | 65.3 | 22.8 | 10.6 | 1.7 |
| Shanghai | 1.4 | 14.3 | 0.0 | 42.9 | 35.7 |
| Jiangsu | 165.9 | 69.9 | 9.0 | 0.3 | 20.7 |
| Zhejiang | 36.5 | 71.8 | 12.1 | 0.5 | 15.6 |
| Fujian | 13.5 | 61.5 | 8.1 | 0.7 | 29.6 |
| Guangdong | 175.7 | 48.3 | 7.3 | 1.1 | 43.2 |
| Hainan | 7.3 | 39.7 | 30.1 | 8.2 | 17.8 |
| Shandong | 132.1 | 83.3 | 15.7 | 0.2 | 1.0 |
| Guangxi | 99.2 | 21.0 | 65.4 | 7.4 | 6.3 |
| *Central* | | | | | |
| Jilin | 90.4 | 9.1 | 67.8 | 21.1 | 2.0 |
| Anhui | 46.6 | 78.1 | 11.2 | 0.0 | 10.7 |
| Jiangxi | 26.3 | 58.9 | 22.8 | 1.1 | 17.9 |
| Henan | 86.9 | 76.9 | 20.1 | 0.6 | 2.4 |
| Hubei | 159.1 | 33.8 | 43.2 | 1.1 | 21.9 |
| Hunan | 92.4 | 35.5 | 39.9 | 0.6 | 23.9 |
| Sichuan | 132.8 | 64.6 | 26.3 | 5.3 | 3.8 |
| Guizhou | 41.7 | 21.8 | 61.9 | 13.7 | 2.2 |
| Shanxi | 120.5 | 55.3 | 29.9 | 14.7 | 0.1 |
| Shaanxi | 437.0 | 62.9 | 25.7 | 11.0 | 0.4 |
| *Western-Border* | | | | | |
| Inner Mongolia | 324.7 | 0.5 | 39.5 | 59.3 | 0.7 |
| Helongjiang | 145.1 | 5.8 | 48.7 | 41.6 | 4.0 |
| Yunnan | 203.3 | 9.5 | 49.6 | 39.9 | 0.9 |
| Tibet | 8.8 | 0.0 | 0.0 | 100.0 | 0.0 |
| Gansu | 35.2 | 62.2 | 11.4 | 26.1 | 0.3 |
| Qinghai | 3.5 | 2.9 | 2.9 | 97.1 | 0.0 |
| Ningxia | 11.6 | 8.6 | 28.4 | 62.1 | 0.0 |
| Xinjiang | | 18.3 | 52.1 | 28.4 | 1.1 |
| China total | 2967.6 | 41.2 | 32.7 | 18.5 | 7.6 |

[a] *Source*: Same as Fig. 4.

higher profits in horticulture may provide incentives for farmers to protect the soil from erosion and degradation.

In the *western-border* region, few provinces have a significant figure for conversion to horticulture and fish ponds. The major destinations are forests and pastureland. This is particularly so in Inner Mongolia, Heilongjiang, Xinjiang and Yunnan. Knowledge of China's physical geography and natural conditions tells us that such conversion is likely to be beneficial to the environment. Hence, the loss of cultivated land to forests and pastureland may be considered as a necessary tradeoff.

There has been some debate over the economic rationale of the conversion. Some people are relaxed about the loss of cultivated land. They argue that much of the loss in the southeast regions is converted to orchards and fish ponds. Such conversion increased the output value of per unit of land. It is an economically rational adjustment in line with the comparative advantage and thus need not be regretted (Ash and Edmonds, 1998; Lu, 1998; Smil, 1999). Others, mainly Chinese themselves, are worried about the conversion. They believe that it is of strategic importance for China to maintain a fairly high level of grain self-sufficiency to safeguard its political stability and national unity. It is not the intention for this study to expand the discussion on the debate. We concentrate on the investigation of the conversion in the *western-border* region and argue that the reclamation has been a major

cause of the abandonment of damaged land and environmental degradation.

Since the 1980s, some land-conservation projects have been carried out in arid and semi-arid areas in China. The most important one is the 'Three-north Forest Protection Belt Program', which involves reforestation and conversion of cropland to pastureland in northwestern, northern and northeast provinces. The scales of other land conservation projects are smaller and locally based. The momentum of the conservation projects occurred in the early 1980s, resulting in a large decline in cultivated land in many Western-Border provinces at the time, as shown in Table 1. The situation after the mid-1980 was rather complex. Table 2 shows that the conversion to pastureland and forests remained the single most reason for the lost cultivated land in the region between 1988 and 1995. However, perusing the total forest and pasture figures in provinces where the conservation projects are being carried out, we hardly see any increase in such areas. On the contrary, a decrease has often been the case. For example, in Inner Mongolia, the figure for pastureland was 79.1 million hectares in 1989. In 1995, the figure became 78.8 million hectares (SSB, 1990, 1997). In Heilongjiang, where a large figure for the conversion to forests was recorded in Table 2, no increase in the total forest areas is found in the provincial statistical yearbook. Recalling the figures in Table 1, we know that during this period there was a significant increase in cultivated land in these provinces. The bulk of the increase, as shown in Fig. 3, was from reclamation.

How can we comprehend the situation after the mid-1980s? It is not very difficult. In reality, the following situation is common. On the one hand, in many arid and semi-arid areas, poor land quality often leaves farmers with no choice but to fallow cultivated land or abandon it completely. Motivated by political incentives, however, local cadres are likely to report this as conversion to pastureland and forests.[10] This would have resulted in an overstated figure for the conversion of cultivated land to pastureland and forests in Fig. 4. On the other hand, the increasing population and the rising demand for food (as well as policy encouragement) have led to more reclamation for crop farming. Part of the reclamation has been conducted on forests and pastureland. Such practice is inevitable so long as the costs of conversion are lower than those of reclaiming marginal land. Many empirical studies have found that the conversion of pastureland and forests to cultivated land has been prevalent in the Western-Border provinces. A large proportion of reclaimed land there had come from this source. According to a study by Song et al. (1998), between 1986 and 1996, 640,000 hectares of pastureland were converted to cultivated land in Inner Mongolia. Reclamation from the so-called 'usable wild land' was only 102 thousand hectares. The same source also revealed that in Heilongjiang, a large area of forests was brought into crop uses. Similar findings are also seen in many other studies (Smil, 1993; Edmonds, 1994; Sun and Li, 1997; Rivera, 1997; Office of Desertification Prevention and Management, 1998; Yin, 1998). However, the massive conversion of forests and pastureland to cultivated land is often not reported. This resulted in a small conversion figure in Fig. 3.

Up to this point, the reason for the consistency between reclamation and the loss to disasters and abandonment would have been clear. It is the inappropriate use of land that has created a vicious circle: reclamation (conversion of pastureland and forests to cultivated land) – land degradation – abandonment (due to the loss of productivity) – reclamation (reuse the abandoned land or more conversion).

The above analysis reveals serious environmental consequences of the reclamation. Under the current land-management system, the trend of transferring cultivated land to other more lucrative uses in the southeastern fast-developing areas is unlikely to be halted. The enforcement of a dynamic balance of cultivated land could lead these provinces to seek reclamation in the Western-Border provinces. The Western-Border provinces may even be willing to shoulder the loss in the southeast provinces if such reclamation involves some kind of compensation. Hence, maintaining a dynamic balance of cultivated land through reclamation could only intensify the degradation of the environment in the *western-border* region.

It must be pointed out that there is an intrinsic absurdity in the strategy of maintaining a dynamic balance in cultivated land. Common sense tells us that the natural condition of the reclaimable land is often worse than the cultivated land returned to pastureland and forests. This is because the land of better condition should have been reclaimed first. Should the cultivated land returned to pastureland and forests be compensated? If so, why should the return be carried out in the first place? Reclaiming more marginal land can only cause more abandonment of damaged land, and aggravate environmental degradation. If not, then the total cultivated land figure could decline in the *western-border* region. The dynamic balance of cultivated land is impossible.

Putting aside doubt as to the realization of a dynamic balance of cultivated land, the above analysis has suggested that any policy aiming to uphold the land quantity has to be incorporated with the protection of environment and land productivity. Solely emphasizing a dynamic balance of cultivated land could intensify environmental damage, and hence potentially do more harm than good to the long-term food security. To this end,

[10] Land conservation and reclamation are both encouraged by the government. Thus, there is incentive for local cadres to underreport the figure for converting pastureland and forests to cultivated land while overstate the figure for the inverse conversion. This can help them win political kudos.

protecting cultivated land in southeastern areas where natural conditions are favorable to grain production and land productivity is high would be more effective and sustainable to achieve a desirable food supply, though this does not necessarily mean a high grain self-sufficiency.[11]

## Land productivity losses and their impact on food supply

China's agriculture has a characteristic of high intensity. Wherever the natural condition allows, multiple cropping is practiced. Thanks to the relatively high temperature and abundant rainfall, multiple cropping index in southeastern areas is high. The index declines with increasing distance from the coastal line. In the northwestern part of the country, multiple cropping is constrained by low temperature and scarce rainfall. The different level of multiple cropping across provinces means that a same amount of losses of cultivated land can result in a different amount of decline in sown acreage. More precisely, a given loss of cultivated land has a larger impact on grain production in the southeast than that in the northwest.

The level of yields per crop is more or less consistent with the level of multiple cropping in different regions. For example, the aggregate grain yields per crop in the Coastal, Central and *western-border* regions were 5071, 4502 and 3686 kg/ha, respectively (SSB, 1997). This is related to two factors. One is the different spatial distribution of individual crops. Rice is highly concentrated in the southeastern areas, and wheat and maize as well as coarse grains are mainly grown in the northern and northwestern areas. As rice has a relatively high yield in comparison to many other crops, particularly coarse grains, the average yield per crop in the Coastal and Central regions is relatively high. By the same token, the average yield in the Western-Border areas is low. Another factor is that for the same type of crop, the average yield in the Coastal and Central areas is usually higher than that in the northwest arid and semi-arid areas due to the favorable natural conditions in the former areas.

The high level of multiple cropping index and yield in the Coastal and Central regions amplifies the effect of cultivated land losses on grain output. Given the crudeness of the data for cultivated land and consequent skews of the yield level, it is impossible to get an accurate estimate of the output losses. The main purpose of the following estimation is to contribute to the assessment of the impact of losses of cultivated land on China's food supply. Based on this estimation, some comments on the strategy of maintaining a dynamic balance of total cultivated land are raised.

Table 3 shows the multiple cropping index and average yield per crop across provinces and regions. The estimated loss/gain of grain output caused by cultivated land changes is presented in the last column of the table. For the nation as a whole, the average multiple cropping index is 160. At the regional level, the index is high in the Coastal and Central regions, at 167 and 180 respectively. In the *western-border* region, the index is much lower. In Inner Mongolia, Heilongjiang and Xinjiang, the major contributors to the reclaimed land, the multiple cropping index is below 100, reflecting the harsh natural conditions. In Inner Mongolia, more than 10% of its total cultivated land is left fallow each year. The uncovered land during the fallow period is subject to a great danger of soil erosion.

The estimate of output changes is derived from multiplying the changes in cultivated land by multiple cropping index and average yield per crop. For the sake of simplicity, we only estimate the total loss/gain of grain output in 1996 as a result of the loss/gain of cultivated land between 1987 and 1996. The result shows that the output loss in the Coastal region was 7.59 million tons. In the Central region, the reduction was 6.19 million tons. In the Western region, cultivated land increased significantly during this period, offsetting about 80% of the loss occurred in the Coastal and Central regions. However, the gain in grain output was less than 5 million tons, compensating only 36% of the reduced grain output in the other two regions.

Adding the figures for output changes in the three regions, we get a net output loss of 8.89 million tons in 1996 as a result of the loss of cultivated land during the period 1987–1996 at the national level. Large as it is, this figure, however, is underestimated because it ignores intra-provincial variations in yield and multiple cropping index. Given the large size of each province, social, economic and natural conditions vary in different areas. In some circumstances, the variations can be substantial. More developed areas within a province are usually in the plains and river-delta areas where land is fertile. The yield level and the multiple cropping index are higher, and the loss of cultivated land is greater. Hence, the real loss of grain output in a province is higher than the estimate based on the aggregate loss of cultivated land and average level of yield in the province. According to a study by Li (1999), in which the estimation is based on county-level data, the volume of the reduction is

[11] Many people have pointed out that the scarcity of cultivated land has meant a comparative disadvantage in crop farming in China. China thus should utilize the resources of the world. That is to increase the reliance upon the international market for its food supply. However, the Chinese government has so far determined to maintain a fairly high level of self-sufficiency for fear of food insecurity to rely on the international market. For further discussion on the issue, see Yang and Zhang (1998). Here, the authors would like to emphasize that no matter to what degree that China will rely on the international market, a relatively stable domestic food production and supply are nevertheless necessary.

Table 3
Multiple cropping index, average yield and changes in cultivated land and grain output[a]

| | Multiple-cropping index 1996 | Average Yield (kg/ha) 1996 | Land loss/gain (1000 ha) 1987–1996 | Esimated output loss/gain (1000 tons) 1996 |
|---|---|---|---|---|
| *Coastal* | 167.1 | 5071 | − 1062.7 | − 7593.3 |
| Beijing | 136.0 | 5559 | − 21.8 | − 130.9 |
| Tianjin | 134.7 | 4584 | − 12.7 | − 61.6 |
| Hebei | 136.5 | 3908 | − 77.7 | − 333.6 |
| Liaoning | 107.2 | 5401 | − 108.6 | − 532.5 |
| Shanghai | 189.9 | 6331 | − 43.6 | − 343.1 |
| Jiangsu | 178.4 | 5914 | − 144.4 | − 1131.6 |
| Zhejiang | 245.6 | 5271 | − 131.1 | − 1232.4 |
| Fujian | 247.9 | 4686 | − 47.7 | − 379.9 |
| Guangdong | 236.0 | 5218 | − 244.9 | − 1954.8 |
| Shandong | 164.3 | 5259 | − 230.2 | − 1492.8 |
| Guangxi | 228.3 | 4070 | 67.4 | 386.2 |
| *Central* | 180.1 | 4502 | − 1089.9 | − 6185.1 |
| Jilin | 102.6 | 6419 | − 2.0 | − 12.0 |
| Anhui | 195.4 | 4435 | − 116.6 | − 728.6 |
| Jiangxi | 261.3 | 4946 | − 60.1 | − 461.3 |
| Henan | 180.6 | 4283 | − 186.3 | − 1054.1 |
| Hubei | 226.3 | 5090 | − 168.8 | − 1252.0 |
| Hunan | 144.7 | 5262 | − 78.6 | − 387.6 |
| Sichuan | 210.6 | 4483 | − 160.4 | − 1169.5 |
| Guizhou | 235.1 | 3503 | − 17.9 | − 98.3 |
| Shanxi | 108.9 | 3321 | − 95.3 | − 283.3 |
| Shaanxi | 142.2 | 3003 | − 203.8 | − 738.3 |
| *Western* | 113.0 | 3686 | 1730.3 | 4892.9 |
| Inner Mongolia | 89.3 | 3470 | 1072.7 | 2780.0 |
| Helongjiang | 96.8 | 3916 | 315.9 | 1048.8 |
| Yunnan | 176.7 | 3370 | 98.5 | 425.0 |
| Tibet | 98.7 | 4012 | 5.9 | 19.9 |
| Gansu | 108.0 | 2804 | 7.3 | 17.3 |
| Qinghai | 95.7 | 3136 | 25.3 | 53.1 |
| Ningxia | 120.2 | 3298 | 22.6 | 71.5 |
| Xinjiang | 97.0 | 4849 | 114.8 | 291.1 |
| *China total* | 159.7 | 4482 | − 422.2 | − 8886.5 |

[a] *Source*: Data for multiple-cropping index and provincial average grain yield are from ECCAY, ZNN, 1997. Data for cultivated land changes are from Table 1.

substantially larger than the figure shown in Table 3. Although the difference may partially stem from the different data sources (Li used the SSB data set), the result does suggest that the actual loss of grain output caused by the reduction in cultivated land is more substantial than the estimate using the provincial aggregate data.

The expansion of cultivated land in the Western-Border provinces and the decline in the southeastern provinces has partially contributed to the difference in output growth. During the period 1987–1996, grain output in the Coastal, Central and *western-border* regions increased by 18.7, 34.6 and 46.8%, respectively (SSB, 1988, 1997). The faster growth in the *western-border* region increased its share in the national grain production. According to a study by Yang (1998b), the intensity of weather fluctuations in the Western-Border provinces is generally higher than that in the Coastal and Central provinces. Thus, the shift of the grain production towards the northwest would increase the volatility of China's domestic grain output and market supply.

The above estimation, in spite of the crudeness, has important implications. It shows that a 'dynamic balance' of total cultivated land, without taking into consideration the quality and spatial distribution of losses and gains, cannot sustain the level of land productivity. In other words, even China could maintain a dynamic balance of total cultivated land, grain output would still fall

as a result of substituting fertile land by marginal land. This again suggests that policies aimed at protecting the quantity of cultivated land have to be integrated with the protection of land productivity. The latter is more economically and environmentally viable for China's long-term food security.

One challenge facing China's food supply is the low relative profitability of the grain sector. It has caused a reduction of investment in the grain sector and has been partially responsible for the large transfer of cultivated land to non-crop uses. This has also constrained the improvement in yield. Empirical studies show that there is considerable room for increasing yield when the policy is right (Huang and Kalirajan, 1997; Lin Justin, 1998). Meanwhile, as suggested by Huang and Rozelle's (1998) study, returns to the investment in R&D and improving technologies in the grain sector are promising. Therefore, stimulating the investment in R&D is of significance for the sustainability of grain production. Considering the limitation of the potentially reclaimable cultivated land resources and the fact that China is in the process of fast industrialization and urbanization, the decline in cultivated land is almost inevitable. Policies aimed at protecting environment and improving land productivity are urgently needed.

## Concluding remarks and policy implications

This study examines the changes in cultivated land during the last two decades. National and provincial data are used to investigate sources of gains and destinations of losses of cultivated land. It highlighted the adverse impact of the strategy of maintaining a dynamic balance of cultivated land on environment and grain production in China.

During the period studied, the decline in cultivated land had been a trend evident at the national level. However, a scrutiny revealed that the decline mainly occurred in the Coastal and Central provinces where land is relatively fertile and land productivity is high. For the *western-border* region as a whole, cultivated land did not decline but increased. The increase, however, was engendered primarily from a few frontier provinces where the natural conditions are harsh.

The study conducted a thorough investigation into sources of gains and destinations of losses of cultivated land. It was found that the factors reducing cultivated land in the southeast provinces were predominately the conversion of cropland to orchards and fish ponds, and the loss to construction. In Western-Border provinces, the main factor is the loss to disasters and abandonment. As for the increase in cultivated land, reclamation in a few Western-Border provinces had been the major source. The increase partially offset the losses occurred in the Coastal and Central provinces. However, such gain had been made at the expense of the ecosystem. The spatial correlation between the reclamation and the loss to disasters and abandonment in the Western-Border provinces has been the result of the environmental degradation.

The higher yield and multiple cropping index in the Coastal and Central regions have amplified the effect of the lost cultivated land on grain production. In contrast, the newly reclaimed land is poor in quality and is located in the areas where the ecosystem is fragile. Both yield and multiple cropping index are low. Substituting such land for more fertile land in the southeast cannot sustain grain output.

Two concluding points can be drawn from this study. One is that it is environmentally damaging and not economically feasible to rely on reclamation in the *western-border* region to balance the quantity of China's cultivated land. The serious environmental degradation undermines China's resource basis and consequently the long-term food security. The second conclusion is that merely maintaining cultivated land in quantity cannot prevent the reduction in land productivity and grain-production capacity. The shift of food production to the *western-border* region also increases the volatility of domestic food output. Improving land productivity is more effective for sustaining a desirable food supply. The prospect of this direction is rather promising as there is relatively large room for increasing yields and the returns of the investment to R&D are high. Policy makers should stimulate measures that can provide incentives to the protection of fertile land and the improvement in land productivity. Ameliorating the profitability of grain production and increasing investment in R&D are two key aspects that deserve much more consideration.

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## References

Ash, R., Edmonds, R.L., 1998. Land resources, environment and agricultural production. The China Quarterly (156), 836–879.

Brown, Lester 1995. Who Will Feed China: Wake up Call for A Small Planet. W.W. Norton and Company, New York.

Buck, J.L., 1937. Land Utilization in China: a study of 16,786 farms in 168 localities, and 32,256 farm families in 22 provinces in China, 1929–1933. Commercial Press, Shanghai.

Commission of Integrated Survey for Natural Resources of Chinese Academy of Science (CISNAR), 1991. Research on Land Resource Productivity and Population Carrying Capacity. People's University of China Press, Beijing.

Cui, X., 1995. Dui midaizi shengzhang zerenzhi de jidian zhengcexing sikao (Some policy thoughts on the provincial governmor responsibility system). Nongcun Diaojan (Rural Investigation) (10), 10–15.

Editorial Committee of China's Land Yearbook (ECCLY), 1997. Land Yearbook of China (ZTDN). China Land Publishing House, Beijing.

Editorial Committee of China's Agricultural Yearbook (ECCAY), 1997. Zhongguo Nongye Nianjian (ZNN) (Agricultural Yearbook of China). Agricultural Publishing House, Beijing.

Edmonds, R., 1994. Patterns of China's lost harmony: a survey of the country's environmental degradation and protection. Routledge, London.

Fan, C., 1995. Of belts and ladders: state policy and uneven regional development in post-Mao China. Annals of the Association of American Geography 85 (3), 421–449.

Fischer, G., Chen, Y., Sun, L., 1998. The balance of cultivated land in China during 1988-1995. Publications Catolog, International Institute for Applied Systems Analysis, No. IR-98-047.

Hill, R.D., 1997. Questions for Chinese agriculture. Land Use Policy 14 (4), 335–336.

Huang, Y., Kalirajan, K.P., 1997. Potential of China's grain production: evidence from the household data. Agricultural Economics 17, 191–199.

Huang, J., Rozelle, S., 1998. China's Food Economy towards the 21st Century. China Agriculture Publishing House, Beijing.

Ke, B., Tang, R., 1996. Price spiral of agricultural products, inflation and macroeconomic control. Chinese Agricultural Economics 7, 3–8.

Li, X., 1999. Zhongguo jin 20 nian gengdi mianji de bianhua jiqi zhengce qishi (Change in arable land area in China during the past 20 years and its policy implications). Ziran Ziyuan (Natural Resources) 14 (4), 329–333.

Lin Fanglei, 1998. Kongzhi gongdi zongliang de nandian ji duice (Difficulties and counter-policies in controlling total quantity of land supply. Zhongguo Tudi (China Land). (7), 7–9.

Lin, J.Y., 1998. China's grain supply capacity: the past and the future. Strategy and Management 4, 82–90 (in Chinese).

Liu, C., 1998. Shizian Kechixu fazhan de biran xuanze (A necessary measure for realizing sustainable development). Shongguo Tudi (China Land) (7), 15–19.

Lu Feng 1998. Grain versus food: a hidden issue in China's food policy debate. World Development 26 (9), 1641–1652.

Ministry of Agriculture of China, 1979–1991, Zhongguo Nongye Tongji Ziliao (ZNTZ) (Tabulations of Chinese Agriculture). Agricultural Publishing House, Beijing.

Office of Desertification Prevention and Management 1998. Zhongguo huangmohua zai tudi liyong leixing fangmian de biaoxian yu fenxi (Characteristics and analysis of desertification in China's land use patterns). Zhongguo Tudi (China Land) (1), 44–46.

Rivera, W., 1997. China on the road to unsustainability: agriculture and natural resources in the Northwest. American Journal of Chinese Studies 4, 198–208.

Smil, V., 1993. China's Environmental Crisis: An Inquiry Into the Limits of National Development. M.E. Sharpe, New York.

Smil, V., 1999. China's agricultural land. The China Quarterly (158), 414–429.

Song, J., Cai, Y., Guo, H., Liu, H., 1998. Xiyou canban shuo shinian: beifang sishengqu tudi kaifa liyong diaocha (Half relieved and half worried 10 years: a survey of land reclamation and utilization in four northern provinces). Zhongguo Tudi (China Land) (11), 21–24.

State Land Administration (SLA), 1997. Land Statistical Data of China. State Land Administration, Beijing.

State Statistical Bureau (SSB), 1990, 1997. Neimenggu Tongji Nianjian (NTN) (Statistical Yearbook of Inner Mongolia). Chinese Statistical Publishing House, Beijing.

State Statistical Bureau (SSB), 1997. Zhongguo Nongcun Tongji Nianjian (ZNTN) (Rural Statistical Yearbook of China). Chinese Statistical Publishing House, Beijing.

State Statistical Bureau (SSB), 1998 and 1997. Zhongguo Tongji Nianjian (ZTN) (Statistical Yearbook of China). Chinese Statistical Publishing House, Beijing.

Sun, L., Li, X., 1997. Driving forces of cultivated land conversion in China. Publications Catalog, International Institute for Applied Systems Analysis, No. IR-97-076.

United States Department of Agriculture (USDA), 1991. Agricultural Statistics of the People's Republic of China, 1949–1990. Database of U.S. Department of Agriculture.

Wang, Z., 1996. Analysis of China's regional grain production. Paper presented at the ACIAR Grain Workshop, Beijing, 4–5 October, 1996.

Wei, Y., 1998. Regional inequality of industrial output in China, 1952–1990. Geographiska Annaler 80B (1), 1–15.

Yang, H., 1998a. Trends in China's regional grain production and their implications. Agricultural Economics 19, 309–325.

Yang, H., 1998b. Maize production in China: spatial distribution, output fluctuation and trade implications. China Report 34 (2), 213–229.

Yang, H., 1999. Growth of China's grain production 1978–1997: a disaggregate analysis. World Development 27 (12), 2137–2154.

Yang, H., Zhang, X., 1998. Can China feed itself? vs how should China feed itself?. China Newsletter (136), 2–7.

Yin, R., 1998. Forestry and the environment in China: the current situation and strategic choices. World Development 26 (12), 2153–2167.

Ying, L., 1999. China's changing regional disparities during the reform period. Economic Geography 75 (1), 59–70.

Zhang, F., 1998. Gengdi zongliang dongtai pingheng yingzhuyi de jige wenti (Several questions in maintaining a dynamic balance of total cultivated land). Zhongguo Tudi (China Land) (11), 28–30.

Zou, Y., 1997. Shixian gendi zongliang pingheng cuji guomin jingji chixu, kuaisu, jiankang fazhan (Realizing a dynamic balance of total cultivated land to support a continuous, fast and healthy development of the national economy). In: Zhongguo Tudi Nianjian (China Land Yearbook). China Dadi Press, Beijing.