Expansion of China's Cities and Agricultural Production

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Abstract

In China, there is a growing debate on the role of cultivated land conversion on food security. This paper examines the changes of the area of cultivated land and its potential agricultural productivity in China using satellite images. We find that between 1986 and 2000, China recorded a net increase of cultivated land (+1.9%), which almost offset the decrease in average potential productivity, or *bioproductivity* (-2.2%). Therefore, we conclude that conversion of cultivated land did not hurt China's national food security. We also show that more recent change in cultivated area also should have little adverse effect on food security.

Keywords: Cultivated land, land use changes, potential agricultural productivity, China

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Land is a critical input that is needed to keep the development process moving, allowing for the shift of people from the rural to the urban sector. However, it is possible that as cultivated land is converted to built-up area, it will conflict with national food security goals. While little was heard about this conflict in the late 1990s through late 2003, as grain prices rose through the early part of 2004, policy makers and scholars began to debate the role of cultivated land conversions in the rise of prices. On the one hand, local leaders and developers in many parts of coastal China and in suburban areas around inland cities are in the middle of a period in which they have already committed large amounts of capital to development zones, factories and housing projects and argue that they need access to land so their plans can be fulfilled. Tens of millions of jobs in construction in the short run and hundreds of millions of jobs in the longer run depend on completing these projects and continuing on with more in the future. On the other hand, others have labeled the conversion as an irreversible destruction of cultivated land that will hurt national food security.

Is the rate of cultivated area conversion in China normal or is it occurring at such a rapid pace that it is threatening national food security? That is the question that is at the core of the food security versus growth debate. International experience shows that rapid economic growth is often accompanied with a large shift of land from agriculture to industry, infrastructure and residential use. Countries in East Asia, North America and Europe have all lost considerable levels of cultivated land during their periods of economic development (Uchida et al., 2004).

Although economic growth started later than many other nations, China has grown rapidly in recent years. Since 1978 China's economy doubled itself three times. By 2002 the economy was about 8.5 times greater than at the beginning of the economic reforms (CNBS, 2003). Such rapid economic growth has significantly improved the livelihood of China's population. Between 1978 and 2002, gross domestic product (GDP) grew at an average annual rate of about 9 percent. During the 25 year period, agriculture also increased substantially, with agricultural GDP rising by around 5 percent per year. Since the population growth rate during the period was only 1.2 percent, food availability also improved. Hence, according to many indicators, rising income and food production has considerably improved China's food security and substantially reduced the rate and severity of poverty. The rise of food output improved so dramatically that between 1983 and 2003, China was a net food exporter during every year. After the mid-1990s, the nation also was a net exporter of grain (Anderson et al., 2004).

Despite the achievements, concern over national food security remains as leaders worry that economic growth both increases the demand for land and can weaken incentives for agricultural production. Since the late 1980s, structural change allowing the emergence of cash crops, new export opportunities for labor-intensive fruits and vegetables and rising wages encouraged some of China's farmers to move out of grain production . Likewise, urbanization and industrialization began to accelerate and cultivated land began to be converted to nonagricultural uses, such as for industrialization, the building of residences and the construction of infrastructure (Naughton, forthcoming). Such trends are expected to continue into the future as China's growth is expected to double the nation's economic output once again during the first decade of the 21st century (World Bank, 2002).

Although food security concerns have always been part of the agricultural policy making equation, at no time in the past decade have they surfaced as they did in 2004. Triggered by five successive years of fallings in grain sown area and production, food security once again has moved onto the agenda of national agricultural policy makers (ARDTF, 2004a). Food security concerns rose as the price of China's major grains began to rise in late 2003. Among other actions, in the early part of 2004 the State Council came out with strongly worded directives about the importance of slowing down the conversion of cultivated land to built-up area (ARDTF, 2004b). When the price rises continued in February 2004, a directive came from the top leadership in March 2004 banning any further conversion, except for under several extreme conditions. The issue of land conversion also immediately became a topic of intense debate. Interviews with local leaders and commentaries in local and national periodicals show that different sets of actors have had strong reactions favoring and opposing the strong measures against continuing with the conversion of built-up area. Some researchers believe it is unnecessary and could cripple economic growth (Huang et al., 2004). Another group of scholars claim the move is critical to maintaining national food security (Brown, 1995, Lin, 1998, Yang and Li, 2000, Verburg et al., 2000, Zou, 1997).

Surprisingly, although the issue is so important and has such far-reaching potential consequences, there is almost no empirical research effort studying the economic consequences of land conversion in China. Several key questions are in need of being addressed. During the reform era, how much cultivated land has been shifted for non-agricultural use? Of the cultivated area that has been lost, how much has been due to urbanization and industrialization? While land is being converted out of cultivated area, how much land has been converted into built-up area? What are the implications of cultivated land changes to nation's food security in the past and in the future?

Answers to the above questions are critical for China to be able to formulate appropriate policies that can ensure both food security and high economic growth in the coming decades. The overall goal of this study is to answer these questions by examining the changes in cultivated land base, the effect on productivity and its ultimate impact on food security. To meet the goal, changes in China's cultivated area over time and its conversion to built-up area and other uses due to urbanization, industrialization and rural settlement expansion are compared the experiences of other countries in the world and are examined based on Landsat TM/ETM digital imagines covering China's entire territorial area during the past 15 years. After identifying areas that have changed from cultivated areas to built-up areas, we then calculate the corresponding changes in the potential productivity of the agricultural land(henceforth, *bioproductivity*), using a methodology called Agro-Ecological Zones (AEZ).

Our study finds that, contrary to popular perceptions, there was not a large shift of land from agricultural to non-agricultural uses. In fact, although a large area of cultivated land was converted to built-up area, China's farmers and others converted even more land into land that could be used for cultivation. Hence, in a net sense, China's cultivated land actually increased between 1986 and 2000. Because of differential qualities between land converted into and out of cultivated area, we do find that there was a fall in the bioproductivity of China's cultivated land. It is important to note, however, that the net decline in bioproductivity over the study period was so small that the rise in total cultivated area was large enough to almost offset it. In the end there was only a very slight decrease (-0.3 percent) in total agricultural potential output, which is a measure that capture change on both cultivated areas and average bioproductivity. Based on this, it can be said with certainty that there was no adverse effect on food security from land conversion between 1986 and 2000. A final section also examines briefly the situation since 2000 and likewise concludes that land conversion has not had a major negative effect on food security.

Cultivated Land Conversion in an International Perspective

While many scholars and policy makers in China often discuss the loss of cultivated land as if it were happening in China due to its weak property rights, a review of the international literature shows that land conversion is not only occurring in China. In fact, land conversions happen in all countries, especially those that are rapidly developing. For example, in Japan, cropland has been declining during the last three decades. In the 1990s Japan lost at a rate of one percent per year – with losses both to development but also to abandoned cultivated land due to low profitability. A similar trend is found in South Korea since the 1970s. The US is losing its agricultural land with a range of 0.1 to 0.3 percent per year to development and conservation set aside. In most European countries, the utilized agricultural area declined slightly between 1975 and 1995. The national figures show trends ranging from -12% (United Kingdom) to -1.5% (Luxembourg).

While we (and others) have presented these trends in a way that make them often appear to be comparable, there should be a note of caution. Creating series of conversion losses are inherently difficult to calculate. They are even more difficult to compare. The difficulties in calculations and comparisons are mainly due to differences across nations and over time in definitions of cultivated land, orchards, the base (either cropland or cropland+rangeland/pasture) and other factors. However, regardless of the exact definition, few would argue that most or all countries, as they develop, lose cultivated land.

In addition to the quantity of land being converted, a common concern in Japan, South Korea, Europe, and the U.S. is that the quality of land also is being compromised by development (Uchida et al., 2004). Policy makers and scholars often express their worry that some of the most productive agricultural land is being lost due to urbanization. In fact, this is intuitive because productive agricultural land is usually flat and often relatively rich land (which is also where urbanization is likely to occur). While of concern, it is also recognized that the productivity of such land when it is put into urban uses is more productive and more highly valued (ARDTF, 2004b, Verburg et al., 1999). Hence, given China's development path in the past and expected growth in the future, it is rational that policy makers and scholars should both expect changes in the cultivated area as well as maintain concern about both the trends of quantity and quality of cultivated land conversion.

Methodology

In trying to assess the trends in the quantity and quality of China's cultivate land, some researches have relied on secondary data collected by those in the bureaucratic hierarchy of China's land administration (Tong et al., 2003, Crook, 1993, Fischer et al., 1998, Smil, 1999, Smil, 1995, Zhang et al., 2000). Unfortunately, for a number of reasons there are many reasons to view with skepticism the quality of the statistical system's land conversion data. Local officials, who benefit from land sales, have an incentive to misreport land conversions—either on the up- or down-sides. Existing data series frequently include inconceivable trends. Such inconsistencies should not be surprising given the fact that during the past three decades a number of different agencies have had responsibility for managing China's land. Moreover, until recently there has been little reason to carefully track land changes, so one should not even think series prior to the mid-1990s were constructed in order to identify trends in land conversions—neither in terms of quantity of converted land nor quality.

Without access to data from traditional statistical databases, we rely on methods that use Landsat TM/ETM data to generate estimates of changes in land quantity and quality. In fact, given several of the characteristics of the data and the methodologies that we use with them, even compared to the best estimates from enumeration-based series, our approach has many features that make it a relatively effective way to study land conversion. In this section we introduce the methods that we use to track land conversion, first by describing how land uses are detected in the different time periods for which we have data (which will give us measures of changes in land quantity) and second how the data are transferred into measures of potential agricultural productivity (which will give us measures of land quality). In the next section we discuss the data that are used with these methods.

Detection models of Land Use Change (LUC), 1-km area percentage data models

The vector data model and the raster data model are two of the most widely used models in spatial data analyses (Lin and Kao, 1998, Wicks et al., 2002). In a vector data model, each location or point is recorded as a single coordinate (x, y). A line is a series of ordered coordinates. Areas are recorded as a series of coordinates defining line segments that enclose an area. The term polygon in our analysis means a many-sided figure (Chen et al., 1999, Felleman, 1990, Xu and G., 1994). Vector data models represent each surface as a series of isolines. For example, elevation is represented as a series of contours. While the vector data model is useful for displaying information, its disadvantage is that it is not a convenient platform for analyzing land surfaces with more than two characteristics, such as slope and elevation along with some other aspect (Chen et al., 1999).

An alternative to the vector data model, the raster data model is more like a photograph than a map. In a raster data model, each location is represented as a cell. The matrix of cells, organized into rows and columns, is called a grid. Each row contains a group of cells with values representing some geographic phenomenon (Chen et al., 1999). Cell values are numbers, which represent nominal data such as land use types and measures of light intensity.

Although there are other choices, vector and raster data models each have a number of advantages (Chen et al., 1999, Felleman, 1990, Xu and G., 1994). By combining the best features of these two types of data models, Liu et al. further developed a 1-km area percentage data model (1-km APDM), or 1-km area with different land uses model, to detect and represent the land use changes on a 1 km x 1km grid scale (Liu et al., 2002, Liu et al., 2003). This model has been widely used in the past to analyze spatial and inter-temporal characteristics of land use change in China (Albersen et al., 2002, Deng et al., 2002, Deng et al., 2003, Liu et al., 2002, Liu et al., 2003).

Based on the prototype of the 1-km APDM, we develop a set of programs to generate 1-km area percentage data. The generated 1-km area percentage data are based on map-algebra concepts, a data manipulation language designed specifically for geographic cell-based systems (Albersen, 2000, Deng et al., 2002, Deng et al., 2003, Liu et al., 2003, Liu et al., 2002). The procedures to generate the 1-km area percentage data are conducted in five steps. The first step is to generate land use maps during the study periods at the scale of 1:100,000. This is done by man-computer interpretation in the ArcGIS 8.02 software environment (Albersen, 2000, Deng et al., 2002, Deng et al., 2003, Liu et al., 2003, Liu et al., 2002). The second step is to generate a 1-km FISHNET vector map geo-referenced to a China boundary map at the scale of 1:10,000. The third step is to intersect the land-use change map with a 1-km FISHNET vector map. This is followed by aggregating the conversion areas for each LUT in each 1-km grid identified by 1-km FISHNET vector cell IDs in the TABLE module of Arc/Info 8.02. Finally, the area percentage vector data are transformed into grid raster data to identify the conversion direction and intensification. The design and experienced data handling procedures ensure that there is no loss in area and produces the basic data that are used for monitoring LUC (the encroachment of urban land onto cultivated land).

Agro-ecological Zones (AEZ) methodology

In addition to estimates of the quantity of the cultivated land conversions, there are several ways to estimate the changes in the quality of cultivated land. One way is to estimated changes in the potential productivity of cultivated land. As with any of the alternative methods, a number of assumptions are needed about the crops or mix of crops that can be produced on each plot of land.[1] Other assumptions are needed to estimate the acceptable level of output, the social acceptance of land-cover

[1] Ultimately, what is desired, is a measure of foregone yields from land converted out of cultivated land and increased yields from land converted into cultivated area. The problem with using data is that all of the land use data are in $1km^2$ units and yields are only available at the county level. In another paper we examine the correlation between measures of potential agricultural productivity and yields at the county level.

conversions, and the constraints related to land use that may be overcome by technology, management and investment. Such assumptions are well documented in the literature as being standard ways to estimate potential productivity .

The Food and Agriculture Organization of the United Nations (FAO), in collaboration with the International Institute for Applied Systems Analysis (IIASA), has developed one commonly-used method of calculating potential productivity, the Agro-ecological Zones (AEZ) methodology. The AEZ methodology can serve as an evaluative framework for biophysical limitations and production potential of major food and fiber crops under various levels of inputs and management scenarios at global and regional scales (Albersen et al., 2002, Fischer and Sun, 2001, Fischer et al., 2000, Heilig et al., 2000, Keyzer, 1998). In its simplest form, the AEZ framework contains three elements: selected agricultural production systems with defined input/output relationships, termed land utilization types (LUTs); geo-referenced land resources data (including climate, soil and terrain data); and procedures for calculating potential yields, matching crop/LUT environmental requirements (by land units and grid cells) with the corresponding environmental characteristics available in the land resources database.

The LUC group of IIASA has applied the AEZ methodology in China to assess the cultivated land potential throughout China. In IIASA's procedure the land-resources inventory of China comprises 375,000 grid cells measuring 5 by 5 kilometers. As part of the agro-climatic characterization, Fisher et al. employed a water-balance model in each grid cell, based on monthly historical data from 1958 to 1988 to simulate when and for how long water is available to sustain crop growth (Fischer and Sun, 2001, Fischer et al., 2000). The model also uses soil moisture, together with other climatic characteristics (such as radiation levels and temperature profiles) in a simple crop growth model to calculate potential biomass production and yield. In the next step, LUC group combines the potential yield of each cell in a semi-quantitative manner with several reduction factors directly or indirectly related to agro/climatic factors (e.g., pests and diseases) and/or soil and terrain conditions (Fischer and Sun, 2001, Fischer et al., 2000). The reduction factors vary according to crop type, the specific environment of each grid cell, and assumptions about the level of inputs and management. The final result consists of attainable crop yields under various production circumstances. To ensure that the results relate to sustainable production, LUC imposes fallow periods, and excludes terrain slopes and soils too susceptible to topsoil erosion (Fischer and Sun, 2001, Fischer et al., 2000). In this study we follow the results on cultivated land production from IIASA as baseline values to estimate the changes of potential agricultural productivity of cultivated land due to LUT conversions.

Data

One of the strengths of our study is the quality of data that we use to estimate cultivated land use change and potential agricultural productivity. Satellite remote sensing digital images for our purposes are the most suitable data for detecting and monitoring LUC at global and regional scales. There are a number of choices. Satellite sensors, such as Advanced Very High Resolution Radiometer (AVHRR), Landsat Thematic Mapper (TM), and French SPOT system, have been used successfully for measuring deforestation, biomass burning and other land cover changes, including the expansion and contraction of deserts (Skole and Tucker, 1993). Remote sensing techniques also have been used widely to monitor the conversion of agricultural land to infrastructure (Milesi et al., 2003, Ogud et al., 2003, Palmera and Lankhorst, 1998, Woodcock et al., 2001).

In our study we use a LUT dataset developed by the Chinese Academy of Sciences. Based on Landsat TM scenes with a spatial resolution of 30 by 30 meters, our study's data are from satellite remote sensing data from the US Landsat TM/ETM images (Vogelmann et al., 2001). The database includes time-series data for three time periods: a.) the late 1980s, including Landsat-TM scenes for 1986-1989 (henceforth, referred to as 1986 data for simplification purposes); b.) the middle 1990s, including Landsat-TM scenes for 1995/1996 (henceforth, 1995); and c.) the late 1990s, including Landsat-TM scenes for 1999/2000 (henceforth, 2000). For each time period, we used more than 500 TM scenes to cover the entire country. Specifically, we use 514 scenes in the late 1980s, 520 scenes in the middle 1990s and 512 scenes in the late 1990s. The Landsat-TM images also are geo-referenced and ortho-rectified. To do so, the data team used ground control points that were collected during fieldwork as well as high-resolution digital elevation models. Visual interpretation and digitization of TM images at the scale of 1:100,000 were made to generate thematic maps of land cover (Deng et al., 2002, Deng et al., 2003). A hierarchical classification system of 25 land-cover classes was applied to the data . In this study, the 25 classes of land cover were grouped further into six aggregated classes of land cover – cultivated land, forestry area, grassland, water area, built-up area and unused land (Table 1).

The interpretation of TM images and land-cover classifications were validated against extensive field surveys (Liu et al., 2003). The interpretation team from CAS conducted ground truth checks for more than 75,000 kilometers of transects across China. During the ground truthing more than 8,000 photos were taken using cameras equipped with global position system (GPS). The average interpretation accuracy for land cover classification is 92.9% for the late 1980s and 97.6% for the late 1990s. By comparing land cover patterns between the late 1980s and the late 1990s, we determined the change in land cover for the entire country in 1986-2000. Additional details about the methodology, which we used to generate the databases of land cover from Landsat TM, have been documented by Liu (Liu et al., 2002) and Deng (Deng et al., 2003).

In order to obtain even more accurate estimates of land use, we also designed a matrix that will help us account for the areas in which there are ground objects that are linear in shape. To do so, we use information from aerial patches based on the CAS LUC dataset. The precision of measurement was up to the centimeter level. The width of linear objects including small canyons, ditches and roads were measured via the ZOOM IN functions in the ArcGIS 8.02 environment (the smallest of the magnifying function is 10 times). For irregular linear thin objects, we divided them into more regular ones and measured them one by one and then aggregated them into areas of the entire thin objects. When handling the data in this way, we guarantee the accuracy of the discounting of linear thin objects as well as the measurement for the aerial patches. In addition, for small objects, we measured their true areas rather than generalized areas (the traditional way which is less accurate) in order to guarantee the accuracy of aerial patches and ensure that they are relatively free from aggregation errors.

Results

Using the Landsat imagery and associated methods with our data in this section we estimate changes to China's cultivated land between 1985 and 2000. In the first part of the section we examine changes in quantities. In the second part we estimate changes in the average potential agricultural productivity of the land. From these two components we can come up with an estimate of the net impact of land conversions on food security during the late 1980s and 1990s.

Changes in cultivated land

Using the methods and data described above, our study shows that China's the conversion of cultivated land to other uses was surprisingly low during the study period, 1986 to 2000. According to our results, the conversion of cultivated land to non-agricultural uses totaled 3.06 million hectares between 1986 and 2000. When compared to total cultivated area in 1986, the converted land accounted for 2.21 percent of total cultivated land. Conversion of this amount of land implies that the annual conversion of cultivated land to other uses was only 0.15 percent of total cultivated land during the study period, a rate that is much lower than that experienced in many other countries during the times in which their economies were taking off.

Using the output of the GIS mapping and spatial analysis, we are able to create a map showing the geographical distribution of cultivated land conversions into other land use categories (Figure 1). Among land converted out of agriculture, a considerable amount of land was in the east coast of China. Given that there are few forests or grasslands in these areas, it is likely that a large part of this area was converted to built-up areas (see areas in red). We also can see that smaller shares of cultivated land in the Loess Plateau and the Sichuan Basin were also converted into built-up areas in the areas around Chengdu, Chongqing, Xian and other provincial capitals. In addition to the areas that turned into industrial, infrastructure and residential area, cultivated area was also converted to forestry area (areas in blue).

Most of the area converted from cultivated area into forests was in the south and southwest. Finally, the figure shows that the cultivated land also changed into grasslands (mostly in the northeast) and other types of land use.

Aggregating across China, our data can be used to estimate the main uses of converted cultivated land (Figure 2, white bars). Of all of the land that was land converted out of cultivated area, the most—about 38 percent—was converted to built-up areas. In absolute terms, this means that during the period between 1985 and 2000 about 1.2 million hectares were converted from cultivated area into built-up area. Hence, while China's total conversions out of cultivated area during the study period were already relatively small, the amount that shifted into built-up area (0.08 percent of cultivated area annually) is even smaller. In addition, 17 percent of the cultivated area was converted to forestry, 30 percent into grasslands and 16 percent to other areas.

Although considerable cultivated land was converted to other uses between 1986 and 2000, during the same time period even more land was converted from other uses into cultivated area. Overall between 1986 and 2000, 5.7 million hectares of new cultivated land was created. As a share of cultivated land in 1986, the conversion of other land to cultivated land resulted in a gross expansion of 4.1 percent. Hence, when taking the net gain (5.7 million hectares) from the net loss (3.1 million hectares), we find that between 1986 and 2000, far from losing significant quantities of land, the cultivated land area of China actually increased by 2.7 million hectares (Figure 2). When compared to the base of cultivated area in 1986, China's farmers were cultivating 1.9% more land in 2000 than they were in 1986.

Mapping analysis also shows the distribution of the newly converted area (Figure 3). Most of the area converted from grasslands, as expected, is mainly located in the northwestern part China and the eastern parts of Inner Mongolia. In northeast China, the map shows that there were large tracts of forests that were converted to cultivated land during the study period. Some areas in Sichuan also were converted from forests to cultivated area during the study period. Finally, in northeast China, especially in Heilongjiang, large tracts of unused wetland and unused barren land were converted to cultivated area. Interestingly, although not counted as conversion of cultivated area, our analysis also shows that there is considerable conversions of one type of cultivated land (e.g., upland) to other types of cultivated area (e.g., paddy). Among the different types of land, most of the newly converted cultivated land, 55 percent, came from grasslands; 28 percent came from forested areas and around 20 percent came from wet lands, the reclamation of unused land and other uses (Figure 2, gray bars).

Comparing the maps in Figures 1 and 3, of course, shows that the location of land converted into cultivated area differs fundamentally from that converted from cultivated land into other uses, including built-up area. In Table 2 we summarize the data by ranking the provinces by the net percentage of total cultivated area (using 1986 as a base) that was converted into or out of cultivated land during 1986-2000. The results of such an analysis show that cultivated land of more than half of the provinces falls. In general, cultivated land falls most sharply for the large municipalities and those provinces in southern and eastern China. Most of the provinces that experienced net rises are in northeast China and in some parts of north China. In examining the provinces that experienced the most conversions as a percentage of their location's total cultivated area, it should be noted that only in the case of Beijing, Shanghai and Zhejiang did the conversions exceed 5 percent. Interestingly, while the share of land in these localities is high, since the regions are among the smallest provinces and province-based municipalities in the country, the reduction of land in these three areas represents a loss of less than 0.2 percent of all of China's cultivated area in 1985. One-third of the provinces experienced a net increase in cultivated land.

Changes in potential agricultural productivity and production due to land conversions

Using the results of the AEZ analyses in conjunction with our data that tells us the net changes of cultivated land, we can come up with an estimate of the net change in potential agricultural productivity due to the conversion of land into and out of cultivated area. When considering the effect of all conversions, we find that unlike the story being told by some policy officials, the effect of conversion of cultivated land is negligible. The average potential agricultural productivity decreased by 76 million Kcal.[2] In percentage terms, this means that the average productivity during the 15-year study period fell by 2.2 percent. Aggregating over all of the cultivated area, the total production potential fell by 1506.0 million Kcal, or by only 0.3 percent.

While there is only a small change overall, our analysis requires us to further break down the net change by land type so that we can assess how much the conversion of cultivated land to different uses (e.g., to built-up areas) has affected total production potential (Table 3 and Figure 4). In total the conversions of cultivated land to other uses led to a net loss of 8756 million Kcal or 1.8 percent of total potential productivity in 1986. Of this total amount, a decrease of 5153.3 million Kcal or about 59 percent of the total decreased production potential (or 5135/8756) is due to the conversion of cultivated land to built-up areas. The high

[2] The average productivity in 1986 and 2000 is 3515.76 million Kcal (=486932.33 / 138.50) and 3439.33 million Kcal (=485426.35/141.14), respectively.

percentage due to the conversion of built-up area is due in a large part to the fact that the land being converted into built-up area is higher quality than the other types of land. In a potential productivity sense, a large part for this higher quality is due to the fact that the converted land is in the south and east (so it can be cultivated during two or more seasons). Land in the south and east also is on less steep land in areas with more precipitation. In addition, of the total reduction in cultivated area due to conversion, 16 percent (or 1410 million Kcal) is due to conversion to forestry. As will be seen this figure will likely have been higher had the Landsat data been available through 2004 since the nation's Grain for Green program (or China's conservation set-aside program) did not begin until 1999.

At the same time that the conversion of cultivated land to other uses was reducing the production potential, the conversion of land from other uses to cultivated land has also led to increases in China's production potential. In total newly converted land accounted for 7250 million Kcal more in production potential. As a percentage of production potential in 1986, newly converted land raised production potential by 1.5 percent. Of the total, conversions from grasslands (48 percent or 3469 million Kcal) and forests (36 percent or 2587 million Kcal) account for most of the increased production potential. Hence, although the quality of land that was converted into cultivated area was lower than the land converted into cultivated area (especially for that converted into built-up area), the increased land that could be cultivated in 2000 versus 1986 significantly offset the fall in production potential due to conversion to built-up area.

When ranking China's provinces by the changing rates of production potential, we can see that there exists an obvious spatial distribution patterns (Table 3). The developed provinces located in the North China provinces, e.g., Beijing and Tianjin, account for a large share of the falling production potential. The eastern and southeastern provinces also account for a large fraction of the fall. In contrast, the large shares of land reclaimed as cultivated land in Northeast China, Inner Mongolia and some of inland provinces help boost production capability.

When taken together, our analysis demonstrates that between 1986 to 2000 China's food security has only slightly diminished by cultivated land conversion. During the study period the quantity of cultivated land rose by 1.9 percent. The average potential productivity of land fell, but by only 2.2 percent. Hence, the quantity of land almost offset the fall in total production potential and we can conclude land conversion decreased the total potential output of China's land resources by only 0.3 percent.

Cultivated Land Changes Since 2000

While our paper so far has established on the basis of Landsat data that land conversions did not negatively affect food security between 1985 and 2000, we have no data after 2000. Therefore, it could be that the recent concern is purely being voiced about trends in more recent years. According to data since 1997 (which are more consistent than a longer time series due to the fact that the Ministry of Land and Resources of China (MLRC) collected all of the post-1997 data themselves using a single, consistent set of definitions), it is true that cultivated land loss has accelerated. During the period 1997 to 2000, 0.5 million hectares of cultivated area were lost annually. During the period 2001 to 2003, 1.56 million hectares were lost annually. Perhaps it is on the basis of these figures that concerns over the effect of conversion of cultivated land on food security have appeared.

Decomposing the MLRC data, however, makes the focus of the issue clearer. According to national statistics after 2000, the main reason for reductions in cultivated land is the nation's "Grain for Green" program that was launched in 1999. Between 2000 and 2003, over 80% of the total decrease in cultivated land was due to the land set-aside program. In fact, between 1997 and 2003, there was little change in rate of conversion of cultivated land into urban expansion and industry construction. Moreover, since China's leaders have continued to invest in land, the creation of newly cultivated area also continued to significantly offset the falls the conversions of cultivated to non-agricultural uses (ARDTF, 2004a, ARDTF, 2004b, Ho, 2001).

Hence, since the analysis shows that aside from Grain for Green there is no impact of land conversion on food security, the last question is whether or not there any effect of Grain for Green on food security. While a complete analysis is beyond the scope of this paper, in another paper we study this precise question and show that the overall effect of Grain for Green on grain prices and imports between 2000 and 2003 is minimal. Between 1999 and 2003, forestry officials oversaw the conversion of more than 7 million hectares of cultivated land into forest land as part of the upper Yangtze River Basin and Yellow River Basin Protection plan (a plan that is designed to reduce floods and increase watershed retention that will have an overall productivity enhancing effect on China's agricultural sector) (ARDTF, 2004a, ARDTF, 2004b). Despite the large scale of the conversion program, our analysis demonstrates that the effect on national grain supply and demand balances have been almost imperceptible. Since officials made effort to target steeply sloped land in mountainous regions, the quality of the land that is being converted to forests is very poor. The average yields on the converted land are less than 30 percent of the national average (ARDTF, 2004a, ARDTF, 2004b). When farmers retire their land, it is also documented that their production efforts on the rest of their land rises and there is an increase in yields that offsets the output lost due to the reduction in area. Hence, although wheat, maize and rice prices rose, on average, by 40 percent between late 2003 and mid 2004, less than 5 percent of that rise is due to the conversion of land. In other words, the price rises in the past year was due mostly to other factors, not the conversion of cultivated area. In return, the creation of a huge forested area has already reduced soil erosion and improved the hydrological capacity of China's mountainous areas. In this way it is actually plausible that Grain for Green will have positive impacts on agricultural production in downstream regions along and have positive future effects on food security.

Moreover, as long as the geographic distribution of land conversions have not changed between the 1990s and post 2000 periods, there also is not any reason for concern about excess waste for irrational conversions of cultivated area. Landsat-based analysis show that most of the change is occurring in the coastal areas and around cities—exactly in the places where the conversion should be occurring. In other words, there is no evidence of excessive waste which would be indicated if there were massive conversions of land out of cultivated area in inland areas (which there are not).

Conclusions

Our study finds that after the 25 years of rapid economy growth, unlike the perception of many, there has not been a large shift of land, especially in a net sense, out of cultivated area. In fact, in terms of retention of cultivated land, China's agriculture is actually doing well. Indeed, net cultivated land actually increased during the study period, 1986 to 2000. Decompositions of cultivated land changes show that nearly half of lost cultivated land was due to cultivated land converted to grassland (30%) and forest (17%). Of the remaining, most, indeed nearly 40%, were due to the shift to built-up area. However, there also was a considerable amount of newly cultivated land, some shifting from grassland and other from forestry area.

Although newly cultivated area rose, average potential agricultural productivity actually fell. The most important reason is due to the fact that the quality of land converted to built-up area from cultivated area is higher quality than that converted to cultivated area from other uses. Despite this, however, when examined in aggregate for the entire period, the effect on production potential is negligible. Our study also finds that, despite the changes in cultivated land production potential and the further decline of cultivated land in recent years (2000-2003) and in the future, China's national food security will remain high in the coming decades.

When considering the main message to policymakers, one of the most important lessons is that at least through 2000, and also mostly likely through 2004, there is not any real problem on food security. It is true that land use needs strict management to facilitate rational land use in the short and long-run, but our work suggests that the current ban on land conversion is not warranted as long as China still has capacity to improve agricultural production through further conversion from other land uses and through increasing yields on existing cultivated land. Since the process of development is one of shifting the population from rural and agriculture to urban and industry, a complete ban on conversion, especially at the growth rates of China, may pose a serious threat to rapid development.

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Table 1. The classification system of land use categories used in this study.

Land use types	Explanations
Cultivated land	Original data include both paddy and non-irrigated uplands, which is aggregated into total cultivated land for this study.
Forestry area	Natural or planted forests with canopy covers greater than 30%; land covered by trees less than 2 meters high, with a canopy cover greater than 40%; land covered by trees with canopy cover between 10 to 30%; and land used for tea-gardens, orchards and nurseries.
Grassland	Lands covered by herbaceous plants with coverage greater than 5% and land mixed rangeland with the coverage of shrub canopies less than 10%.
Water area	Land covered by natural water bodies or land with facilities for irrigation and water reservation, including rivers, canals, lakes, permanent glaciers, beaches and shorelines, and bottomland.
Built-up area	Land used for urban and rural settlements, industry and transportation.
Unused land (remaining area)	The rest of all other lands.

Table 2. Changes of cultivated land by province, 1986 to 2000. (million ha, %)

Province	Cultivated land in 1986	Cultivated land in 2000	Net change of cultivated land	Percentage changes
Beijing	0.41	0.34	-0.07	-16.17
Tianjin	0.50	0.48	-0.01	-2.96
Hebei	7.21	7.09	-0.13	-1.74
Shanxi	4.95	4.95	0.00	0.07
Inner Mongolia	8.51	9.50	0.98	11.52
Liaoning	5.12	5.29	0.17	3.39
Jilin	5.89	6.25	0.36	6.17
Heilongjiang	12.88	14.55	1.67	12.97
Shanghai	0.36	0.33	-0.03	-8.29
Jiangsu	5.26	5.08	-0.18	-3.41
Zhejiang	2.30	2.16	-0.14	-6.17
Anhui	6.17	6.10	-0.07	-1.20
Fujian	1.64	1.63	-0.01	-0.67
Jiangxi	3.35	3.34	-0.01	-0.44
Shandong	8.41	8.31	-0.10	-1.22
Henan	8.44	8.44	0.00	0.05
Hubei	5.24	5.19	-0.05	-0.91
Hunan	4.58	4.55	-0.03	-0.57
Guangdong	3.42	3.30	-0.13	-3.76
Guangxi	3.82	3.83	0.01	0.21
Hainan	0.69	0.69	-0.01	-1.06
Chongqing	2.86	2.85	-0.02	-0.55
Sichuan	8.82	8.78	-0.04	-0.45
Guizhou	3.92	3.95	0.03	0.73
Yunnan	5.11	5.08	-0.04	-0.70
Tibet	0.47	0.47	0.00	-0.19
Shaanxi	5.64	5.65	0.01	0.24
Gansu	5.42	5.48	0.06	1.19
Qinghai	0.63	0.65	0.02	3.19
Ningxia	1.27	1.44	0.17	13.41
Xinjiang	4.51	4.72	0.21	4.70
Taiwan	0.70	0.69	0.00	-0.42
Total	138.50	141.14	2.65	1.91

Table 3. Change of total production potential associated with changes in cultivated land by provinces, 1986-2000. (million kcal, %)

Province	Total production potential in 1986	Increase	Decrease	Net change	Percentage change
Beijing	1022.27	5.96	209.12	-203.16	-19.87
Tianjin	1557.28	3.39	50.94	-47.55	-3.05
Hebei	17983.06	99.00	487.51	-388.50	-2.16
Shanxi	8563.83	71.93	59.48	12.45	0.15
Inner Mongolia	8877.45	1227.59	406.73	820.85	9.25
Liaoning	8499.64	370.82	128.13	242.68	2.86
Jilin	7802.58	495.34	110.76	384.58	4.93
Heilongjiang	13234.62	1557.02	131.04	1425.98	10.77
Shanghai	2442.04	0.05	256.74	-256.69	-10.51
Jiangsu	28542.73	59.82	1248.99	-1189.17	-4.17
Zhejiang	17110.27	84.43	764.48	-680.06	-3.97
Anhui	33986.41	117.85	526.31	-408.47	-1.20
Fujian	11934.44	136.45	204.85	-68.39	-0.57
Jiangxi	26073.93	133.85	256.50	-122.64	-0.47
Shandong	24355.84	46.99	359.44	-312.45	-1.28
Henan	27559.89	370.48	335.98	34.50	0.13
Hubei	36728.54	177.64	577.44	-399.80	-1.09
Hunan	34663.19	83.36	290.26	-206.90	-0.60
Guangdong	22648.08	68.03	892.26	-824.24	-3.64
Guangxi	27874.79	335.04	213.00	122.04	0.44
Hainan	4028.87	48.50	89.28	-40.78	-1.01
Chongqing	13964.64	21.65	98.83	-77.18	-0.55
Sichuan	43663.41	103.71	347.43	-243.71	-0.56
Guizhou	15528.43	152.58	24.86	127.72	0.82
Yunnan	16643.49	223.34	273.11	-49.77	-0.30
Tibet	465.78	0.00	0.88	-0.88	-0.19
Shaanxi	10043.98	103.38	94.87	8.51	0.08
Gansu	7858.38	136.97	43.44	93.54	1.19
Qinghai	678.80	24.41	5.90	18.51	2.73
Ningxia	2121.33	300.50	26.79	273.71	12.90
Xinjiang	7095.82	686.87	220.91	465.96	6.57
Taiwan	3378.53	3.20	19.84	-16.65	-0.49
Total	486932.33	7250.11	8756.09	-1505.98	-0.31

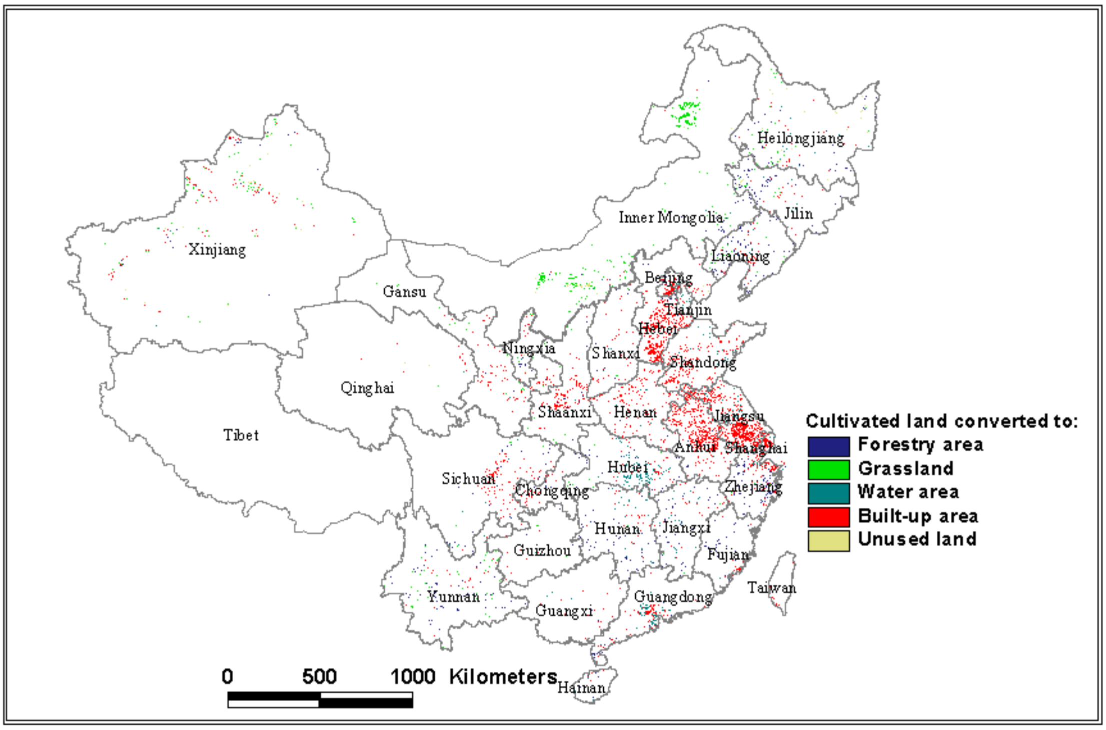


Figure 1. Distribution of land converted from cultivated land to other uses, 1986 to 2000.

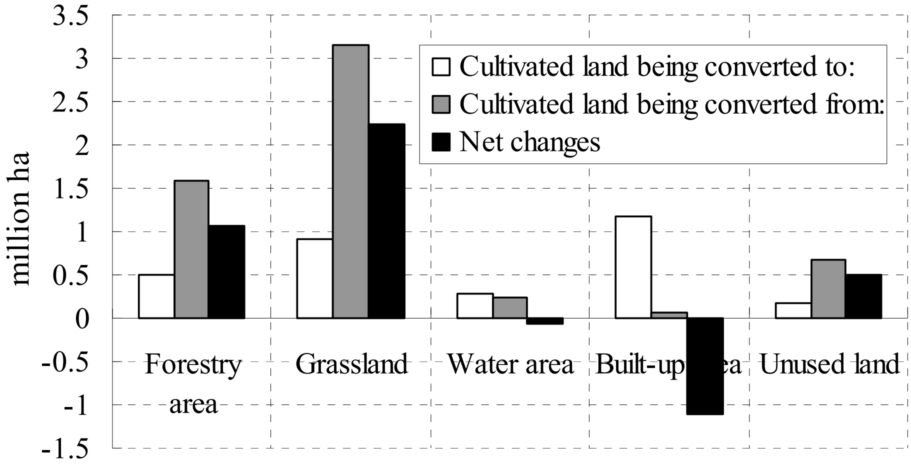
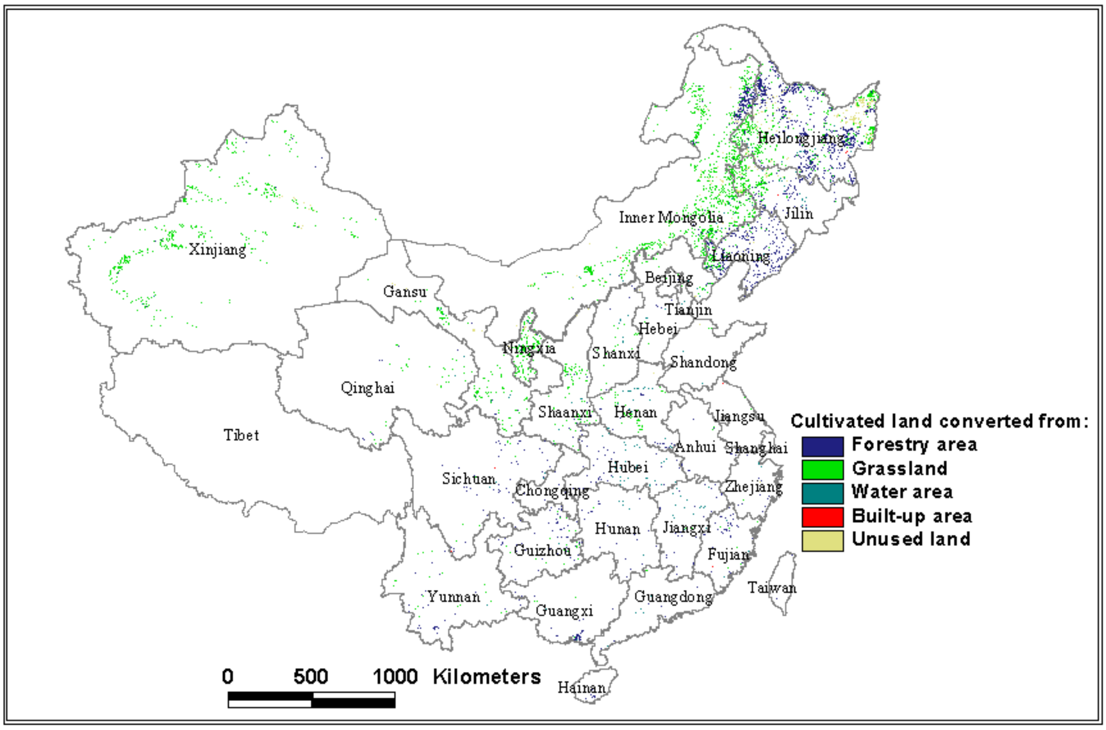


Figure 2. Conversion of Cultivated Land in China, 1986-2000.


Heilongjiang
Inner Mongolia
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Liaoning
Beijing
Gansu
Tianjin
Hebei
Ningxia
Shanxi
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Qinghai
Shaanxi
Henan
Jiangsu
Tibet
Anhui
Shanghai
Hubei
Sichuan
Chongqing
Zhejiang
Hunan
Jiangxi
Guizhou
Fujian
Taiwan
Yunnan
Guangdong
Guangxi
Hainan
Cultivated land converted from:
Forestry area
Grassland
Water area
Built-up area
Unused land
0 500 1000 Kilometers

Figure 3.

This job requires the 90ms font used in this document.