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# Spatial and temporal patterns of China's cropland during 1990–2000: An analysis based on Landsat TM data

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**Abstract**

There are large discrepancies among estimates of the cropland area in China due to the lack of reliable data. In this study, we used Landsat TM/ETM data at a spatial resolution of 30 m to reconstruct spatial and temporal patterns of cropland across China for the time period of 1990–2000. Our estimate has indicated that total cropland area in China in 2000 was 141.1 million hectares (ha), including 35.6 million ha paddy land and 105.5 million ha dry farming land. The distribution of cropland is uneven across the regions of China. The North-East region of China shows more cropland area per capita than the South-East and North regions of China. During 1990–2000, cropland increased by 2.79 million ha, including 0.25 million ha of paddy land and 2.53 million ha of dry farming land. The North-East and North-West regions of China gained cropland area, while the North and South-East regions showed a loss of cropland area. Urbanization accounted for more than half of the transformation from cropland to other land uses, and the increase in cropland was primarily due to reclamation of grassland and deforestation. Most of the lost cropland had good quality with high productivity, but most gained cropland was poor quality land with less suitability for crop production. The globalization as well as changing environment in China is affecting land-use change. Coordinating the conflict between environmental conservation and land demands for food will continue to be a primary challenge for China in the future.


*Keywords:* Cropland; China; Land use; Remote sensing

## 1. Introduction

China is the world's third largest country, the most rapidly developing nation and home to 1.3 billion people. Since the early 1980s, the unprecedented combination of economic and population growth has led to a dramatic land transformation across the nation (Chen, 1999; Houghton & Hackler, 2003; Liu et al., 2005; Tian et al., 2003). Accurate information on cropland area in China is of critical importance for assessing China's food security (Fischer et al., 1998) and greenhouse gas emission such as $N_2O$, $CO_2$ and $CH_4$ (Houghton & Hackler, 2003; Li et al., 2003; Tian et al., 2003; Verburg & Denier van der Gon, 2001; Wang, 2001). It was reported that cropland area is decreasing due to urban expansion and increasing population, which has caused many concerns regarding China's food security in the near future (Brown, 1995). Data quality and reliability, however, is one of the *greatest* problems in generating a clear picture of China's food system (Brown, 1995; Fischer et al., 1998; Huang & Rozelle, 1995), the carbon cycle (Houghton & Hackler, 2003; Tian et al., 2003), nutrient cycles (Galloway et al., 2002; Verburg & Veldkamp, 2001; Zhang et al., 2005) and ecosystem sustainability (Smil, 2000).

There are large discrepancies among estimates on the state and change of land use in China based on several data sources (Tian et al., 2003). The first data source is the official statistical data by State Statistical Bureau (SSB, hereafter) (Li, 1999),

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which is generated based on agricultural census data at the county level. It was reported this data source could possibly underestimate the actual cultivated area (Crook, 1993; Frolking et al., 2002; SSB, 1994) by 27.0% (Liu, 2000). The second data source is the national land resources inventory data sponsored by the Ministry of Land and Resources (MLR, hereafter). This program was completed in 1996 after a 14-year survey and mapping based on aerial photos and census data with different scales (Fischer et al., 1998; Li, 1999; Liu, 2000; Ma, 2000; SLA, 1996). Since it covers a long time period, this data source is not suitable for retrieving land-use change information over a short period of time with fine spatial resolution at national scale. The third data source is 1 : 1,000,000 scale maps of China's land use by Wu (1990), which was generated from extensive field surveys, interpretation of aerial photos, and Landsat images during the late 1970s and the early 1980s. This is the first national land-use survey and mapping program which used standard method and routines (Wu, 1990; Wu & Guo, 1994). The fourth data source is land resources maps at the scale of 1 : 1,000,000, which are based on 1972–1984 Landsat MSS images and field land survey. In this data set, the land was classified as different types according to land-use/land-cover classes and its suitability for cultivation, forestry and grazing, respectively (CISNR, 1993; Ge et al., 2000). The fifth data source is an IGBP DIScover data set which was produced from 1-km resolution National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) data (Loveland & Belward, 1997; Loveland et al., 2000). Although the IGBP DIScover data set has been used widely in global scale ecological and geographical studies (Ramankutty & Foley, 1998), it is inadequate for estimating cropland area and its change in China due to the coarse resolution (Xiao et al., 2003). Frolking et al. (1999) reported that cropland area estimate in China based on the AVHRR data set is about 50% higher than that using agricultural census data. According to the same classification system with assistance from other geographical databases, Chinese scientists developed a new version of a 1 km land-cover map, which was validated against field survey and more accurate than the IGBP DISCover map (Liu et al., 2003b). The most recently available data with 1 km resolution is land-cover production from MODIS (Moderate Resolution Imaging Spectroradiometer) data (http://geography.bu.edu/landcover/userguidelc/lc.html).

As described above, all of the data and maps above do not provide information on the detailed spatial patterns of cropland across China. Moreover, the spatial-temporal dynamics of cropland in the recent decade remain unknown, which is important to the assessment of how land transformation affects biogeochemical and hydrological cycles at regional and global scales. To characterize spatial and temporal patterns of land use/land cover in China, we used Landsat Thematic Mapper (TM) to develop the National Land-Use/Land-Cover data sets (NLCD, hereafter) for the three time periods: the end of the 1980s, 1995/96, and the end of the 1990s, with a mapping scale of 1 : 100,000 (Liu et al., 2002, 2005). Based on this data set, we analyzed the spatial and temporal patterns of China's cropland during 1990–2000. We also compared our analysis with other studies to identify the uncertainties in the estimation of cropland area and its spatial distribution. The results drawn from our study are important for scientists as well as policy makers for assessing a number of cutting-edge issues associated with global change and sustainability.

## 2. Data sources and method

In the late 1990s the Chinese Academy of Sciences organized eight research institutions and about 100 scientists to conduct its second nationwide land cover and land use classification project. In 1997, using 520 Landsat TM images primarily from 1995/1996, we developed the national land use databases at a spatial scale of 1 : 100,000 by visual interpretation and digitalization with technical support from Intergraph MGE (Modular GIS Environment) software (Liu et al., 2002; Zhuang et al., 1999). Before the interpretation began, remote sensing images were geo-referenced by using 1 : 50,000 relief maps. For each TM/ETM scene, there are at least 20 evenly distributed sites served as Ground Control Points (GCPs). The Root Mean Squared Error (RMS error) of geometric rectification was less than 1.5 pixels (or 45 m). Interpreters used MGE software to identify the land-use types on the computer screen, based on his/her understanding on the object's spectral reflectance, structure and other information. Then they drew the boundaries of the objects and added the attributes (labels) of the polygons to produce the digital map. Finally we edited and compiled the vector digital maps, which are the core of the national spatial database.

A hierarchical classification system of 25 land-cover classes was applied to the Landsat TM/ETM (Enhanced Thematic Mapper) data (Table 1). The 25 classes of land cover were further grouped into 6 aggregated classes of land cover: croplands, woodlands, grasslands, water bodies, unused land and built-up areas including urban areas. Croplands include paddy and dry farming land. Woodlands include forest, shrub and others (e.g., orchards). Grasslands include three density-dependent types: dense, moderate and sparse grass. Water bodies include stream and rivers, lakes, reservoir and ponds, permanent ice and snow, beach and shore, and bottomland. Unused land includes sandy land, Gobi, Salina, wetland, bare soil, bare rock and others such as alpine desert and tundra. Built-up land includes urban area, rural settlements and others such as roads and airports. The definition of each land-cover class is given in Table 1. The cropland in our national database is defined as all agricultural lands. It includes permanently cultivated land, new cultivated land, fallow, and grassland-farming rotated land. It also includes intercropping land such as crop-fruiter, crop-mulberry, and crop-forest land in which a crop is a dominant species. At the second classification level, the cropland is further divided into paddy land and dry farming land according to hydrological condition and crop types. The paddy land has enough water supply and irrigation facilities for planting paddy rice, lotus, etc. including the rotation between paddy rice and dry farming crops.

To support image interpretation and the validation of land cover classification, we have used a variety of data including soil type, DEM, roads and rivers and climate. In 1999, we