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Notes

Effects of urbanization and industrialization on agricultural land use in Shandong Peninsula of China

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ABSTRACT

China is the most populated country in the world with slightly more than half of the population is still living in rural areas. In the past couple of decades, rapid urbanization and industrialization have significantly changed the land use/land cover (LULC) pattern in rural areas, particularly those around the big cities in eastern China. Shandong Peninsula, a traditional agriculture area, also has witnessed rapid urbanization and industrialization. Analysis of land use/land cover change in this area, specially the change of agricultural lands, would help us better understand the interaction between government's policies and farmers' economic interests.

This paper developed a method to extract single-cropping land, double-cropping land and other land use/land cover categories for 1978, 1999 and 2006 from seasonal variations in Normalized Vegetation Index (NDVI) during a crop calendar year. Spatial analysis results indicated significant changes of arable lands and other land use/land cover categories due to the urbanization and industrialization. The most possible reason is due to the continuous adjustment of government's policies and shift of farmer's economic interests. Results from this study would help government make wise decisions in the near future to mitigate urban sprawl and industrial development while maintain enough agricultural production.

1. Introduction

China has been witnessing rapid urbanization since the adoption of economic reform and the open-door policy in 1978. In the past 20 years, the number of small cities in China has increased more than 6 times, from about 3000 to 19,216. There are another 50,000 towns currently under development (Lu and Campbell, 2009). From 1980 to 2006, urban population percent had increased from 20.6% to 43.9% (Chen et al., 2009). Gross domestic production (GDP) has also increased at an annual growth rate of 9.6% during this period, which is much higher than the world's average of 3.3% (Hubacek et al., 2009). China ranks as the world's second largest economy in terms of purchasing power parity in 2010.

Chinese people have enjoyed the benefits from the rapid urbanization and industrialization. Their annual income increased accordingly, which led to significant changes in their dietary structures and created higher demands for agricultural products (Popkin, 1999; Delgado, 2003). Moreover, there was also a significant increase in the demand for agricultural products in industry due to the rapid industrialization. This period has also witnessed the land reform in China, which was initiated in 1978. Collective farms were dismantled and agricultural lands were distributed to individual household. Accordingly, farmers gained more control and flexibility in selecting crop species for their lands to maximize their profits.

Obvious changes have taken placed in agricultural land use in China due to urbanization and industrialization (State Statistical Bureau, 1978–2008). However, most current studies mainly focus on land use/land cover change (Liu et al., 2005; Gan et al., 2007; Zhang et al., 2007; Doygun et al., 2008; Liu et al., 2009; Yin et al., 2010). Change in the agricultural land use and interaction between government's polices and farmer's economic interests were seldom discussed.

Shandong Peninsula is one of the major agricultural production areas and it has been undergoing rapid urbanization and industrialization for the past couple of decades. Urbanization percent had increased from 35.4% in 1990 to 50% in 2001 (Xu et al., 2009). This research analyzed the dynamic change in agricultural land use in response to the rapid urbanization and industrialization to better understand the interaction between government's polices and farmer's economic interests. Studying the land use/land cover change in this area would also help unravel the potential effects of urbanization and industrialization on agricultural productions.

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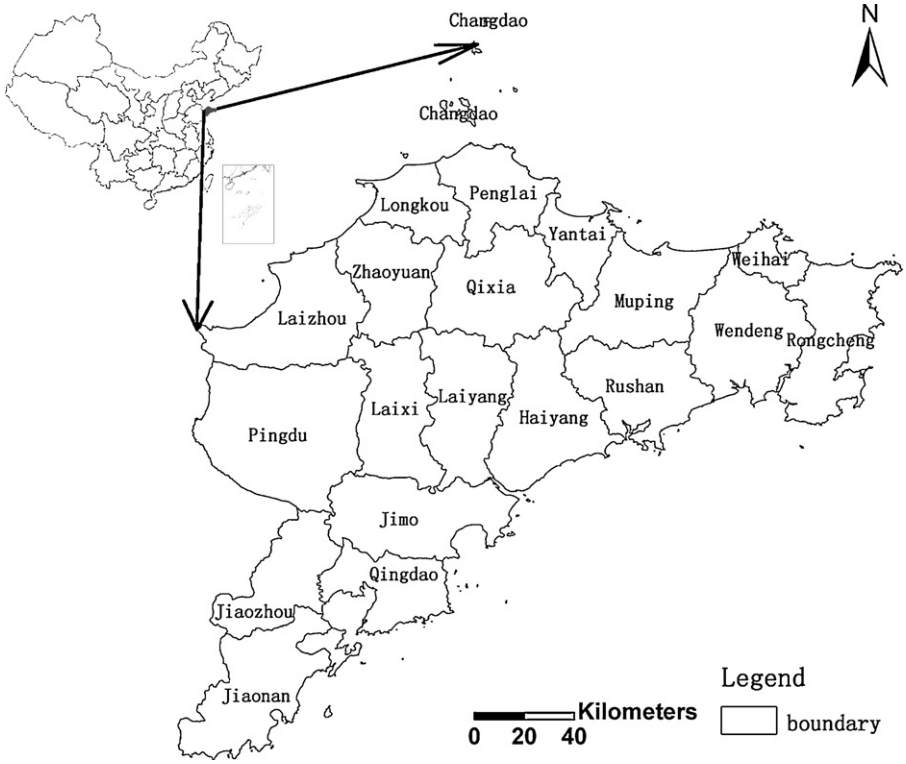

Fig. 1. Location of Shandong Peninsula in China.

2. Study area

Our study area is located in Shandong Province in eastern China (Fig. 1). This agriculture-dominated peninsula has 22 counties, with a total land area of 33,747 km^2. Elevations in our study area range from 0 to 1130 m above sea level and most agricultural lands are found in lowland areas with elevation less than 500 m. Climate in our study area is significantly controlled by the Asian monsoon system. Summer is warm and wet while winter is cold and dry. Annual precipitation ranges from 600 mm to 700 mm with a mean maximum air temperature of 25 °C and minimum air temperature of 0 °C. There are two cropping systems in our study area. The double-cropping system consists of winter wheat and summer corn while the single-cropping system is mainly peanut. Forest (mainly deciduous trees), water, and barren land are other major land use/land cover categories in our study area.

3. Data and methodology

3.1. Data and preparation

Landsat imageries were used to classify the land use/land cover in our study area. Preliminary classification tests based on single-day image yielded a very low overall classification results. It is not a surprise due to the similar and mixed reflectance signatures of different land use/land cover categories recorded on one single frame of remote sensing image. This research used multitemporal images to identify different land use/land cover categories in our study area.

The spectral signature of land use land cover is mainly dependent upon the vegetation type and its growing condition when the image was acquired. Generally, four growing stages of the double-cropping system can be identified in our study area. The first period from late October to next late June is the time when the winter wheat is growing. After winter wheat is harvested, the land is left fallow from late June to early July. The summer corn starts growing from early July and would be ready for harvest until late October. There would be another short fallow period from late October to early November right after the corn is harvested. By contrast, for the single-cropping system (mainly peanut), the growing period normally lasts from early May to late October and the land would be left fallow after peanut is harvested until next May. Forest in our study area starts to grow from late March and leaves start to fall in late November. Due to their special spectral signatures, barren lands and water bodies could be easily delineated from the Landsat images during the period from early July to late September when trees and crops are growing.

To better capture the variations in spectral signatures of different land use/land cover categories in our study area, multitemporal Landsat images were obtained. One image acquired during late October to early November was used to distinguish the croplands from other land use/land cover categories. The second image acquired in early March to early May in the next year was used to identify the single-cropping lands (which are left fallow during this period) from double-cropping lands with growing crops at this time. Another image acquired in late May to late September was also used to better identify the two types of cropping system. Totally twenty-six images were acquired for the period of 1978–1981, 1999–2002, and 2006–2009 in this study (Table 1).

Chinese government stopped collecting tax from agricultural products in 1999 and farmers started to receive a certain amount of subsidy from central government. Statistical results indicated a decline in area of double-cropping lands in 1999 (State Statistical Bureau, 1978–2008). It would be of significance to examine whether there was significant impact of policies change on the land use/land cover pattern before and after 1999.

Other geospatial data including municipal boundaries, geomorphic units and digital elevation data at the scale of 1:100,000 were

Table 1
List of images that were used in this study.

Images	Path and row	Acquisition date (day/year)	Images	Path and row	Acquisition date (mm/dd/year)
MSS	p128r034	116/1981; 233/1981; 289/1979	TM	p119r034	Aug./17/2006; Oct./20/2006
	p129r034	133/1978; 218/1979; 286/1978		p119r035	Aug./22/2005; Oct./04/2006; May/16/2007
	p129r035	133/1978; 288/1981; 213/1983		p120r034	Oct./27/2006; May/07/2007; Sep./12/2007
	p130r034	93/1979; 219/1979; 273/1979		p120r035	Oct./27/2006; May/07/2005; Jul./15/2009
			CBERS	p367r058	May/05/2008

Note: Landsat images were downloaded from USGS while CBERS images were acquired from China Center for Resources Satellite Data and Application.

used to facilitate image automatic classification in this study. GDP data were also obtained from the Statistic Yearbooks to study possible correlation between land use/land cover change and the domestic production.

3.2. NDVI calculation

The NDVI is one of the most widely used vegetation indices in remote sensing. It is the ratio of the difference in reflectance between the near-infrared (NIR) band and the red band to the sum of the reflectance of these two.

$$\mathrm{NDVI} = \frac{(\mathrm{NIR} - \mathrm{RED})}{(\mathrm{NIR} + \mathrm{RED})} \quad (1)$$

NDVI values normally vary between −1 and 1. Positive values indicate green and vegetated surfaces. Higher values suggest dense vegetative cover or luxuriant vegetation while negative values indicate no vegetative cover. NDVI values for the three time periods were directly calculated from the Landsat images.

The barren lands and water bodies have the lowest NDVI values with slight variations throughout the crop calendar year. As a result, the barren lands can be easily extracted by examining the variations in NDVI values from early July to late September when crops and other vegetations are growing. The forest tends to have much higher NDVI values than other land use/land cover categories at the time when the arable lands were left fallow.

3.3. Image classification

Five land use/land cover categories were automatically classified from the remote sensing images, including forest and orchard, double-cropping land, single-cropping land, no-vegetable land, and water. The three-date NDVI images within each crop calendar year were stacked together and then classified by using supervised maximum likelihood classifier. Training sites were first delineated from the natural color composite of the original Landsat images and then transferred to the NDVI composite. The no-vegetable land was further divided into three categories by visual interpretation in ArcGIS: urban area, rural settlement and barren land. Finally, a map with seven land use/land cover categories was produced for each individual year.

We randomly selected 144 point for each individual category and read their land use/land cover types from the above-mentioned maps. Results were then compared to the ground truth data, which were collected by field surveys, and visual interpretation from CBERS image and other high spatial resolution images in GoogleEarth. The overall classification accuracy is over 85% (Table 2).

Table 2
Classification accuracy for individual land use/land cover category in our study area.

Type	Year	Double-cropping land (%)	Single-cropping land (%)	Orchard and Forest (%)	Water (%)	Bare and residential land (%)
User's accuracy	1978	93	85.4	87.5	99	95
	1999	96.4	85.8	99.2	97.2	88.8
	2006	91	93.1	90.3	100	96.5
Producer's accuracy	1978	91.8	87.2	87.5	99	94.5
	1999	93.1	88.1	92.9	96.5	98.6
	2006	96.3	97.8	91.5	99.3	92.1

Table 3
Area of individual land use/land cover category derived from image classification results for 1978, 1999, 2000 and 2006. Absolute gain/loss and change rate for each category are also listed.

Class	Area			1978–1999		1999–2006	
	1978	1999	2006	Gain/loss	Rate (%)	Gain/loss	Rate (%)
Double-cropping land	372486	580851	364531	+208365	2.6	−216320	−5.3
Single-crop land	1014555	789983	709113	−224572	−1.1	−80870	−1.5
Forest and orchard	941766	1202802	1325388	+261036	1.4	+122586	1.5
Water	53746	91384	81978	+37638	3.4	−9406	−1.5
Urban	37469	67173	176257	+29704	3.8	+109084	23.2
Rural resident	81273	104357	114322	+23084	1.4	+9965	1.4
Barren land	527968	199833	267468	−328135	−2.9	+67635	4.8
Total	3029263	3036383	3039057				

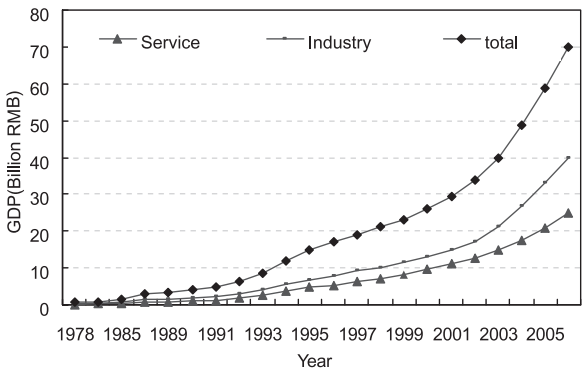

Fig. 2. Increasing trend of GDP from 1978 to 2006.
(Source: State Statistical Bureau)

3.4. Change detection and change rate

Dynamic changes in single or double-cropping arable lands and other land use/land cover categories were summarized in Table 3. Rate of change was then calculated using the following formula (Chen, 1998; Wang and Bao, 1999):

$$K = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100\% \quad (2)$$

where K is the rate of change for individual category (%), U_a and U_b are the areas with a specific land use/land cover category in the beginning and end of a specific period, respectively, and T is the total number of the years within that period.

4. Results

4.1. Rapid urbanization and industrialization

Shandong Peninsula has experienced rapid urbanization and industrialization since 1978 (Figs. 2, 3 and Table 3). Urban area significantly expanded from 37,469 ha in 1978 to 176,257 ha in 2006. The annual rate of change is 3.6% between 1978 and 1999 and markedly boosts up to 27% in the period from 1999 and 2006. This period also witnessed a rapid GDP increase, from ¥ 0.7 billion in 1978 to ¥ 6.9 billion in 2006.

4.2. Variations in agricultural structure

As shown in Table 3 and Fig. 3, area of barren land decreased from 1978 to 1999. The most possible reason is that during this period some farmers converted barren lands into agricultural lands to increase agricultural production. By contrast, barren land increased from 1999 to 2006 mainly because some arable lands were abandoned. Most of these new barren lands are found on the periphery of urban areas. Obviously most of them were confiscated by government to meet the increasing demands for more built-up land due to the urbanization and industrialization.

Area of single-cropping lands continued to decrease between 1978 and 2006 (Table 3 and Fig. 3). In contrast, the area with double-cropping lands increased between 1978 and 1999 and then dropped between 1999 and 2006. The forest and orchard gradually increased between 1978 and 2006.

Urbanization and industrialization in China was still at a relatively low level from 1978 to 1999. Maintaining and improving grain production was the prior task for the government. Chinese central government issued many polices to insure high enough grain production to meet the increasing demands. For example, the central government released the "Ten Polices to Further Promote Agricultural Economy Development" in 1985 and "Guidelines to

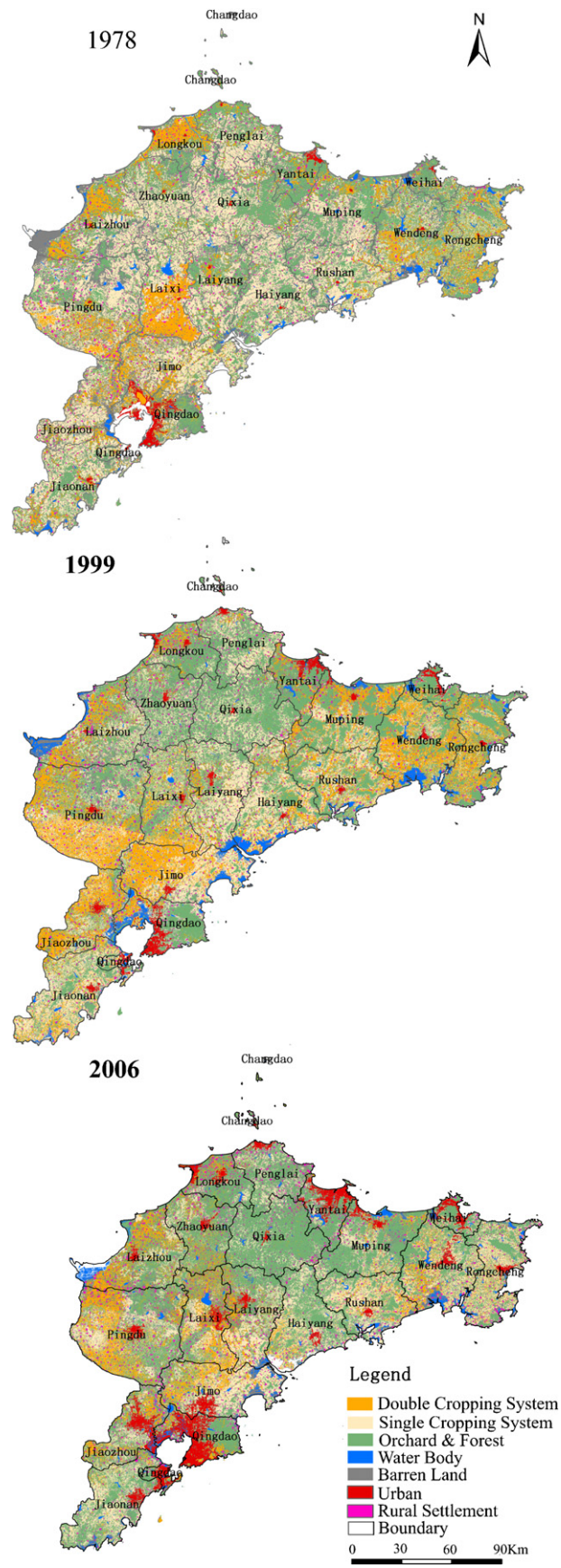

Fig. 3. Land use/land cover classification results for 1978, 1999 and 2006.

Strengthen Works in Rural Area" in 1986. These policies encouraged the local farmers to expand double-cropping lands to maximize their profit.

To further accelerate urbanization, Chinese government strongly subsidized industrialization at the cost of agricultural economic development in the 1990s. Agricultural products were always pricing unreasonably low. The booming industry development in eastern China since the 1990s also attracted lots of local farmers, particularly young adults, to migrate from rural area to eastern industrialized provinces to look for more job opportunities and higher pay. As a result, there was a sharp decrease in arable lands with both double and single-cropping lands from 1999 to 2006. During this period, local farmers actually learned that they can earn more from orchards than from crops due to the differences in prices between fruits and grains. As a result, more arable lands were replaced by orchards.

5. Discussion

Our study results suggest that land use/land cover change in our study area were strongly affected by the government's policies. By contrast, after 1999, control on the agricultural activities in China from central government gradually loosened and farmers' economic interests began to play a dominant important role in agricultural land use. Obviously it is necessary for the local and central governments to balance the development of agricultural economy and the rapid industrialization and urbanization.

Other parts of northern China have same cropping system as in our study area. As a result, the method proposed in this study can be directly used to study the land use/land cover change in other areas in North China. This method may also be applied to study the croplands in southern China, where a single, double, and even triple cropping systems may coexist. Obviously, the method proposed in this study should be modified and the multi-date remote sensing images are needed to capture the seasonal variations in NDVI within a crop calendar year in order to distinguish different cropping systems in southern China.

6. Conclusions

Multitermporal remote sensing images were used in this study to distinguish double-cropping cropland from the single cropping land, as well as other land use/land cover categories. Our study results indicated that land use/land cover change in Shandong Peninsula was strongly controlled by government's policies and farmer's economic interests under the background of rapid industrialization and urbanization in China during the past couple of decades. However, these two factors may play various roles on affecting the agricultural activities. As a result, it is necessary for the Chinese governments to consider a trade-off between agricultural development and urbanization/industrialization before any new policies on agriculture are released.

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