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Chinese cropland losses due to urban expansion in the past four decades☆

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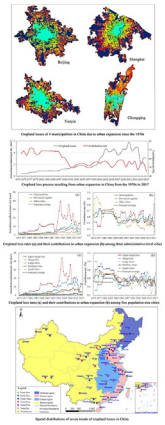
HIGHLIGHTS

- We retrieved the high-frequency and long-term cropland losses of 75 sample cities during the urban expansion process.
- Croplands were the primary contributor to urban expansion in China, and its losses underwent five different stages.
- Cropland losses were unbalanced in China, obvious losses always emerged in cities with high administrative-level and large population-size.
- Seven basic trends of cropland losses were quantitatively recognized.

GRAPHICAL ABSTRACT



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ABSTRACT

Since 1970s, China has experienced the large-scale losses of croplands during urban expansion process, which has drawn great attentions to Chinese government. Although in-depth studies about cropland losses have been executed widely, relatively little attention has been paid to describe long term and high frequency influences of urban expansion on it and reveal its differences systematically. Based on remote sensing and GIS technology, we quantified, analyzed, and mapped cropland losses in China due to urban expansion from the national, administrative-level, population-size, and city scales. Results indicated that (1) Since the 1970s, croplands were the primary contributor to urban expansion in China, and their losses due to urban expansion underwent five obvious stages. The consciousness of cropland protection is being strengthened continuously and has developed from the initial to the deep execution stages. (2) Cropland losses were unbalanced in China, with the loss magnitude, rate, and influences on urban expansion positively related to the administrative-level and large population-size. That is, obvious losses always emerged in cities with high administrative-level and large population-size. (3) Seven basic trends of cropland losses were quantitatively recognized, which was conducive to the formulation of different policies or strategies for cropland protection for different cities.

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1. Introduction

Although urban lands cover only 2% of the earth's surface, they host more than half of the world's population. The global urbanization rate is expected to rise from 50% in 2009 to 69% in 2050, and more than 1.86 billion people will live in urban lands (United Nations, 2015) with the most increase in developing countries (Bloom, 2011). As the most irreversible and significant form of land use, urban expansion is always characterized by the direct manifestation of urbanization (Liu et al., 2016). With the unprecedented global urbanization, urban lands expand dramatically (Haas and Ban, 2014), which not only creates positive externalities such as manifesting urbanization level and improving human living environment (Yang et al., 2018), but also generates negative externalities such as problems in regional climate (Deosthali, 2000), hydrology (Su et al., 2016), and ecological-environment (Yu and Zhou, 2018). The loss of croplands is one of the major negative effects of urban expansion (Deng et al., 2015) and has caused many concerns regarding global food security (Brown, 1996).

As the largest developing country, China is known for its long agricultural civilization and its cropland has traditionally been cherished (Bloom, 2011; Cheng et al., 2015). Thus, significant attention has been given by the government of China to the cropland protection, especially after the prediction that China could not feed its growing population (Brown, 1996). Although numerous policies and strategies have been implemented to protect croplands, losses of such land were still inevitable. In 1980s–2010, totally 6.17×10^4 km^2 traditional croplands lost (Zhang et al., 2012). Since the 1970s, China has experienced rapid urbanization (NBSC, 1997–2017), and urban expansion has become one of the important factors of cropland losses. 45.47% of croplands losses encroached due to urban expansion in 2000–2005, and this proportion continuously increased and reached to 63.52% and 76.88% in 2005–2008 and 2008–2010, respectively (Zhao et al., 2014). Given the small per capita arable land area, conflicts between cropland protection and urban expansion are incessant in China, which have serious effects on food safety (He et al., 2017). Therefore, scientifically recognizing Chinese cropland losses due to urban expansion is of practical significance and has become a formidable challenge in the 21st century.

Cropland protection is one of the primary factors influencing the sustainable development of China, and has caught the special attention (Tan et al., 2005) in recent years. Numerous empirical studies have been implemented by covering micro to macro scales (Chen et al., 2007; Wu, 2012; Meng et al., 2013; Song, 2014; Zhao et al., 2014; Cheng et al., 2015; Deng et al., 2015; Liu et al., 2015; Xie et al., 2018), and their contents refer to various aspects, such as, the monitoring of cropland losses (Liu et al., 2005a; Yu et al., 2018), exploring the loss mechanism (Liu et al., 2003; Lu et al., 2017), modeling the relationship between cropland losses and urban expansion (Jiang et al., 2012; He et al., 2017), etc. However, less attention has been given to the monitoring of long-term and high-frequency cropland losses resulting from urban expansion, especially its systematical differences on a national scale. In particular, as one of evaluation indices of cropland losses, the contribution rate of croplands is rarely adopted when quantifying cropland losses. Additionally, the basic trends of cropland losses due to urban expansion have not been fully described.

Traditional studies about cropland losses mainly depend on statistical data (Zhao et al., 2014), which need significant manpower and high cost and are easily affected by subjective factors. Since the 1970s, remote sensing has become a potentially powerful technology to monitor land-use change with a synoptic view, real-time data acquisition, repetitive coverage, high temporal resolution, and low cost (El-Raey et al., 1995). Geographic information system (GIS) can provide a convenient approach to processing information generated by remote sensing technology (Wu et al., 2006). Numerous studies have documented the extensive exploration about the monitoring methods of cropland losses, mainly including the automatic classification method and the visual-interpretation method. Although the former is always executed with relative high-efficiency (Zhang et al., 2016), it experiences difficulty in carrying out monitoring over a long-term and high-frequency and has poor universality in cropland loss reconstruction on the national-scale, whereas the latter can overcome these problems and has become a relatively mature method with high accuracies exceeding 90% (Liu et al., 2005b).

Based on remote sensing and GIS technology, we quantified, analyzed, and mapped the magnitude, rate, and contribution to urban expansion of the cropland losses in China from 1970s to 2017. The objectives of this study were to (1) retrieve the high-frequency and long-term cropland losses due to urban expansion in China; (2) quantify the basic characteristic of Chinese cropland losses on the national scale; (3) reveal the differences of cropland losses in China from the aspects of administrative levels and population sizes; and (4) exhibit the basic trends of cropland losses due to urban expansion. This study could establish a foundation for scientifically recognizing the cropland losses resulting from urban expansion in China and formulating a reasonable urban plan and cropland protection strategies for guideline.

2. Study area

75 cities were chosen as sample cities in this study by fully considering their locations, population sizes, administrative levels, and available multi-source remotely sensed imagery. Although these cities only account for 10.92% of Chinese cities and cover less than 3% of China, they hold over one third of population and load more than half of social-economic activities (MHURDC, 2015). According to the Chinese administrative division standard and the latest city scale classification criterion, these 75 cities were classified into three administrative levels, including municipalities, provincial capitals,[1] and other cities, and divided into five-level population sizes based on the urban population in 2015, consisting of super-mega, mega, large, medium, and small cities with permanent population lager than 10×10^6, between 5×10^6–10×10^6, between 1×10^6–5×10^6, between 0.5×10^6–1×10^6, and less than 0.5×10^6, respectively (Fig. 1).

3. Materials and methods

3.1. Data sources and data processing

In this study, more than 1500 scenes of multi-source remote sensing data were employed, consisting of 151, 849, 362, 67, and 129 scenes of Landsat MSS, TM/ETM+, OLI, CBERS CCD, and HJ–1 CCD imagery. Because the mapping of cropland losses due to urban expansion focused more on the interpretation of cropland information, the acquisition date of the selected remote sensing data was generally obtained in the vegetation growth period ranging from May to October. Furthermore, the cloud amount of these data should be controlled less than 10% (Zhang et al., 2014a, 2014b).

Visual-interpretation method was adopted to detect cropland losses resulting from urban expansion. First, pre-processing of remote sensing data was executed, which was conductive to distinguishing cropland loss information and mainly consisted of band composition, imagery enhancement, geometry correction, etc. (Liu et al., 2003). Second, visual-interpretation was employed to monitor cropland losses in terms of the professional experience

[1] Including two special administrative regions, Macao and Hongkong.