Conversion from rural settlements and arable land under rapid urbanization in Beijing during 1985–2010

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ABSTRACT

With significant economic development over the last several decades in China, urban land has increasingly sprawled and encroached upon arable land and rural settlements. In this context, this paper explores the dynamic spatiotemporal characteristics and trends of rural settlement loss and arable land depletion in the process of urban expansion, which could offer a theoretical basis and scientific support for further research of rural development and restructuring. The conclusions of the study are summarized as follows: (1) approximately 80% of urban growth has been at the expense of rural settlements (23.42%) and arable land (57.14%) in Beijing; and (2) an obvious rural non-agriculturization-intensive belt was observed in spatial units from 1985 to 2010, primarily distributed between the Fourth Ring Road and the Fifth Ring Road. Non-agriculturization is defined here as the conversion of land formerly used for agricultural purposes, including rural settlements and arable land, to more densely developed urban uses. (3) The spatial distribution of fastest, fast and medium non-agriculturization began to shift from the northern area to the southern area after 2005. (4) The curves of variation of rural non-agriculturization intensity under urbanization along the urban-rural gradient presented as inverted "U" shapes leading away from the socioeconomic center, while that along the motorways displayed exponential decay. Adhering to the policy of urbanization strategy will be essential for rural restructuring in China.

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1. Introduction

Urbanization, referring to a growth in the proportion of a population living in urban areas, is one of the major land use and land cover changes sweeping the globe. Over the last several decades of Open and Reform Policy beginning in 1978, urbanization in China is taking place at an unprecedented rate (Liu and Yang, 2015; Bai et al., 2014), created by the monumental flow of rural-urban migration (Zhang and Song, 2003). Statistics from the Ministry of Construction of China show that the urbanization level in China increased from 17.9% in 1978 to 52.6% in 2012 (Bai et al., 2014) while the urban population jumped from 170 million to 710 million during the same period (Chen, 2007; Li, 2014b).

Despite numerous benefits originating from urbanization, a rapidly urbanizing world, including China as a developing country on the fast track, is facing intensified resource scarcity and environmental degradation. Along with rapid urbanization and city sprawl, there definitely is a drastic loss of rural settlements and depletion of arable land (Döös, 2002; Tan et al., 2005a; Liu et al., 2003; Cai et al., 2002; Liu et al., 2013b), exhibiting evident rural non-agriculturization. According to the monitoring data of the Ministry of Land and Resources (TMLR, 1999), it was estimated that a total net arable-land area of approximately 4.5 million ha (0.31 million ha per year) was lost between 1987 and 2000. Among the factors affecting cropland loss, such as population growth, rapid economic development, urbanization, agricultural restructuring, land degradation, etc (Yang and Li, 2000; Tan et al., 2005a,b; Ding, 2003), urban land expansion has been perceived as the crucial factor threatening agricultural production and food security in China. Recently, many papers have examined the characteristics of urban land expansion and the consequent arable land loss at various scales (Skinner et al., 2001; Tania et al., 2001; Yeh and Li, 1999; Verburg, 2000; Tan et al., 2005b), but relatively less attention has been paid to the effect of urbanization on rural settlements. Research showed that China had 3.6 million villages in 2000. By 2010, the figure had sharply dropped to 2.7 million, a loss of

approximately 90 thousand villages (Feng, 2013). There are four mainly reasons behind this phenomenon and the latter three are the most important factors that affect the loss of villages — relocated residents from areas with fragile ecosystems or those more prone to natural disasters or lacking the basic living conditions; administrative change of villages or disappearance through villages renovation, central village cultivation, hollowed village revitalization and intensive land use in the process of new rural construction; farmers' preference to living in the cities to obtain better besides compensation and benefits under the attraction of urban economy; and the expropriation on contracted land or homestead for the main financial revenue of the local governments under the rapid urbanization, compelling farmer to leave their villages and settle in the towns or cities.

Rural development and urban development in China now are experiencing a crucial transition period of both society and economy (Long et al., 2010, 2007, 2012; Liu et al., 2008; Lu et al., 2013). Rural-urban development transformation is a comprehensive human process of elements transfer, strategy change and mechanism transformation between rural and urban areas (Liu and Yang, 2015). The quantity and spatial distribution of arable land and rural settlements, the two major land-use types closely related to human livelihood and production activities (Long and Li, 2012), could reflect rural industrial structure, employment structure, consumption structure and agricultural production patterns. New urban land converted from these two land use types over the last several decades has exerted a profound effect on rural depopulation, rural-urban migration, rural transformational development, rural sustainability and rural restructuring (Weekley, 1988; Liu et al., 2009, 2010; Long et al., 2011). Such transition is especially rapid and substantial in the capital city—Beijing (Gu and Shen, 2003; Song et al., 2015; Zhao and Chai, 2015; Jiang et al., 2016). Thus, it is essential to understand the dynamic spatiotemporal characteristics and trend of rural settlement loss and arable land depletion in the process of urban expansion, and the relationship between urbanization and rural development, which could offer a theoretical basis and scientific support for further research of rural development and restructuring.

Bearing this context in mind, this paper goes one step further by linking the processes of rural non-agriculturization and urbanization in Beijing to elucidate the trend of rural settlement loss and arable land depletion in the process of rapid urban expansion. The specific aims are (1) to analyze quantitatively the conversion from rural settlements and arable land to urban sprawl from 1985 to 2010 in Beijing; (2) to zone different degrees of rural non-agriculturalization by calculating the non-agriculturization intensity index (NAII) in each unit; and (3) to study the spatial mode of rural non-agriculturalization during rapid urbanization along urban-rural gradients and the motorways in the past several decades.

2. Materials and methods

2.1. Study area

Beijing (N39°28′-N41°25′, E115°25′-E117°30′) (Fig. 1) is located in the northeast of the North China Plain. Great topographic variation is observed in this region. The mountainous areas are mostly located in the north and west, with an average elevation of approximately 1000–1500 m, while the plains areas are in the center and southeast, with an elevation ranging from 20 to 60 m (Li et al., 2013). The so-called "Beijing Plain" is the main focus of urban expansion (Li et al., 2005). Beijing is now composed of fourteen districts (Xicheng, Dongcheng, Haidian, Chaoyang, Shijingshan, Fengtai, Mentougou, Fangshan, Daxing, Tongzhou, Shunyi,

Changping, Pinggu, and Huairou), and two counties (Yanqing and Miyun) after the latest administrative division adjustment in 2010.

2.2. Data

Based on the available data in the study area, monitoring of the rural settlement loss and arable land depletion under rapid urbanization in Beijing was done at five time nodes: 1985, 1995, 2000, 2005, and 2010. We collected the multi-temporal remote sensing images (Landsat-TM), used artificial visual interpretation to obtain the land use and land cover (LULC) map in each time node and then detected non-agriculturization of rural land in the process of urban expansion by overlaying multi-temporal LULC maps from 1985 to 2010 (Fig. 2). Due to the relative maturity of the remote sensing image interpretation technique, it will not be explained in detail here. In this study, we took the land use classification system used by the Chinese Academy of Sciences that includes six categories and 25 subclasses (Liu et al., 2003), where non-agriculturization of rural land under rapid urbanization means transformation from arable land and rural settlements to urban land. Then the category of arable land and two subclasses of urban land and rural settlements were extracted separately from other land use types for this study.

2.3. Methods

2.3.1. Non-agriculturization intensity index

To evaluate the spatial distribution of non-agriculturization intensity, we adapted and employed an indicator called non-agriculturization intensity index (NAII) for measuring and quantifying the magnitude and pace of conversion from both rural settlements and arable land to urban land in various units. NAII is defined as follows:

$$NAII = \frac{\Delta U_{in}}{TA_i} \times \frac{1}{n} \times 100\% \tag{1}$$

where ΔU_{in} is area of new urban land at the expense of rural settlements and arable land in the target unit i at the time interval n; TA_i is total land area of the target unit i; and n is the time interval of the calculating period (in years). In this equation, the target-calculating unit is set to the administrative district to link with administration statistics.

2.3.2. GIS-based buffer analysis

Two types of proximity variables (i.e., distance to socioeconomic centers and distance to motorways) were selected to study the mode of non-agriculturization of rural land under rapid urbanization in Beijing during 1985—2010. The socioeconomic center was usually represented as the city center, the central business district (CBD), the suburban center, etc. GIS-based buffer analysis was adopted in our research, which involved circular buffer zones surrounding the city centers or line buffer zones surrounding the motorways. To achieve our research objectives, two types of socioeconomic centers - the central center and the sub-centers - were selected. The former may explain the spatial pattern of transformation from arable land and rural settlements to urban land under concentric urban expansion, while the latter can better explain the rural non-agriculturization with urban expansion of satellite cities in the study area. Therefore, two different circular buffer systems were established by delineating separate buffer zones to compare spatiotemporal characteristics of conversion from rural settlements and arable land to urban land between Beijing central city and sub-central cities in the study area (Fig. 3). One system was a buffer zone system with a width of 3 km covering the entire central city taking the municipal government of Beijing