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Delineation of a permanent basic farmland protection area around a city centre: Case study of Changzhou City, China

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ABSTRACT

The delineation of permanent basic farmland will safeguard the production baseline of China's agricultural development by securing easily appropriated, high-quality farmland surrounding urban areas, thereby strictly controlling the use of farmland (especially high-quality farmland surrounding urban areas) facing accelerated urban expansion. This study researched the delineation of permanent basic farmland in a typical region undergoing rapid urbanization. By constructing a systematic classification model, farmland was classified into matrix, edge, and island farmlands in order to analyze farmland contiguity and fragmentation. Based on the indicator requirements of various plans related to farmland, an evaluation indicator system was constructed in order to develop an evaluation model for comprehensive farmland productivity. From the perspective of farmland spatial contiguity and highly efficient productivity, a delineation model for permanent basic farmland was proposed to delimit the permanent protection and utilization boundaries for high-quality farmland around urban areas. The results show the following: (1) matrix and edge farmlands can intuitively display farmland contiguity characteristics; (2) comprehensive farmland productivity was closely related to farmland spatial patterns, supporting infrastructure, and policy management and protection; and (3) there was a high degree of spatial overlap between contiguous and highly productive farmland. The model took both comprehensive farmland productivity and spatial clustering into consideration in order to delineate permanent basic farmland, which is a beneficial factor in protecting farmland quality and safeguarding sustainable farmland utilization. It can also be used as a control line to limit urban sprawl, guide urban cluster development, and improve economical and intensive urban land use.

1. Introduction

Farmland serves to protect human food security. It is also the foundation for industrial development and social stability and is a key factor in regional food and ecological security (Lambin et al., 2013; Cheng et al., 2015a; Ministry of Agriculture et al., 2015). With socio-economic developments in recent years, there has been a sharp decrease in the scale of farmland in certain areas and increasing pressure on the global food supply due to a gradually expanding population (Foley et al., 2005, 2011). The food security issue is especially prominent in China, which contains 7% of the world's farmland and feeds 22% of the global population (Ding, 2004). As the world's most populous country, there is no doubt that a reduction in farmland threatens China's food security (Liu et al., 2005).

China and several other developing countries are facing the issue of increased food demand and limited production growth (Fader et al., 2013; Cristina Rulli and D'Odorico, 2014). To this end, the Chinese government has invested significant financial and human resources in order to develop modern agriculture and promote its sustainable development (Ministry of Agriculture et al., 2015). Currently, however, China's basic conditions can be characterized by a large population, a scarcity of land, and a shortage

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of water. The steep growth in the demand for crops and major agricultural products as well as the gradual exacerbation of tight constraints on regional resources have made the task of safeguarding food security even more daunting (Ministry of Agriculture et al., 2015).

Due to the influence of factors such as disasters and withdrawing land from cultivation for ecological purposes, the net decrease in farmland within China between 2001 and 2010 was nearly 100 million mu, about 5.47% of the total farmland area in 2010 (Hu et al., 2014; Ministry of Agriculture et al., 2015). However, the primary driving factor behind the decrease in farmland is construction due to urban expansion. Paddy fields, irrigated land, and other high-quality farmland are distributed primarily in the Eastern and Southern provinces of China, which are also developing areas with high economic concentrations and urbanization (Ding, 2004). There is significant overlap between the spatial distribution of high-quality farmland and urbanization. High-quality farmland has gradually diminished as a result of the expansion of urban areas. At the same time, the gradual fragmentation of contiguous farmland and the destruction of farmland ecosystems have had serious effects on the quality, structure, and spatial patterns of farmland (MLR, 2013a). Furthermore, over 60% of farmland reserves are distributed in regions with fragile ecological environments, where farmland development and utilization are challenging (Hu and Qiu, 2008). After many years of construction and development, China's farmland reserves have dwindled to approximately 80 million mu. Farmland reserves in areas such as Shanghai, Beijing, Tianjin, and Zhejiang have been nearly depleted, and farmland protection is an extremely difficult undertaking (MLR, 2013b). Therefore, the Chinese Ministry of Land and Resources[1] (MLR) and the Ministry of Agriculture[2] jointly issued the "Circular on Further Improvements in the Delineation of Permanent Basic Farmland," which emphasized the importance and urgency of delineating permanent basic farmland in the new era (Ministry of Agriculture and MLR, 2014). This delineation can be used to implement the basic requirements of the national policy and strategy for food security, which serve as "meticulous and rational land use and effective farmland protection." It is also an important measure to develop new urbanization strategies in China, a crucial task in fulfilling the responsibility of protecting farmland resources.

Currently, many related studies have been conducted to address farmland loss and its driving forces, impacts, etc. Yang and Li (2000) discovered the trend that farmland was significantly declining on a national level and that there was a drastic reduction in fertile land at the provincial level in China. The main driving force of such change was attributed to the spatial sprawl of construction land. Chen et al. (2012) used Yucheng as a case study to explore the reasons for the dynamic changes in farmland by using logistic regression models. The results indicated that location, population growth, and farmer income played key roles in farmland loss. Rahman and Rahman (2009) discussed the effects of farmland pattern fragmentation on rice production in Bangladesh with survey data from the farm level. The research revealed that rice outputs would be reduced by 0.05% if farmland fragmentation increased by 1%. Terres et al. (2015) assessed the driving forces behind farmland abandonment in the 27 EU Member States. The results showed that these forces include low farm stability and viability and poor regional backgrounds. Cohn et al. (2016) modelled the variability of agricultural output coupling with the responses of grain yields, crop frequency, and farmland areas to climate change. They believe that agricultural outputs that are affected by climate mainly depend on crop frequency and/or farmland area changes. Lambin et al. (2013) performed a "bottom-up" analysis to estimate the potentially available farmland throughout the world. This study indicated that the competing demands and tradeoffs would be the greatest barriers to agricultural production expansion. Mazzocchi et al. (2013) analyzed the potential risk of the conversion from farmland to construction land by using the Sensitivity Index of Agricultural Land (SIAL). They found that the exogenous factors were the prime force behind this conversion. Thompson and Prokopy (2009) carried out a spatial analysis regarding land conversions from farmland to construction land in Indiana and Illinois. The analysis provided a reference for utilizing spatial data for farmland protection in the United States.

The primary research question of our paper aims to solve the contradiction of urban sprawl and farmland protection around city centers in China. We proposed a series of hypotheses as follow: (1) matrix and edge farmlands can intuitively display farmland contiguity characteristics; (2) farmland spatial patterns, supporting infrastructure, and policy management and protection contributed more to comprehensive farmland productivity; and (3) the contiguous farmlands may own the property of high productivity. Based on the law of distance decay in geography and edge effects in landscape ecology, we used mathematical morphology (MM) image processing and geographic information system (GIS) spatial analysis techniques to develop a Farmland Morphological Spatial Pattern Analysis (FMSPA) model (Fig. 1) depending on the features of regional farmland systems (Riitters et al., 2007; Vogt et al., 2007; Riitters et al., 2009; Cheng et al., 2015a,b). The purpose was to analyze the characteristics of farmland spatial patterns within the geographic research area. In addition, an evaluation model (Fig. 1) of comprehensive farmland productivity was constructed taking into consideration the natural and socio-economic influences on farmland productivity. On this basis, we developed a delineation model (Fig. 1) of permanent basic farmland that surrounds cities and is oriented toward a new type of urbanization. The model will allow us to accurately identify farmland protection boundaries and discover the spatial separation between farmland and construction land, thereby achieving the permanent protection of farmland resources.

The organization of the paper is as follows. Section 2 analyses the related research context of the evolution of China's farmland protection. Section 3 introduces the study area that we chose, presents the methodology including an FMSPA model that can be used to classify the farmland ecosystem into three types and provides an evaluation model of comprehensive farmland productivity. The delineation results of permanent basic farmland in the case study area can be found in Section 4. Several discussions on the research significance, research emphasis and the model generality are presented in Section 5. Finally, Section 6 is devoted to concluding remarks.

2. Related research context

2.1. Evolution of farmland protection in China's overall land-use planning

2.1.1. First round of national overall land-use planning (1985–2000)

The first round of land-use planning at the national level used monographs as a foundation and resulted in the "National Overall Land Use Plan." The base year for planning was 1985, the target year was 2000, and the plan was projected through 2020 and 2050.

[1] MLR, the Ministry of Land and Resources of the People's Republic of China, is the department of the State Council that assumes responsibility for the protection and rational utilization of land resources, mineral resources, marine resources and other natural resources.

[2] The Ministry of Agriculture of the People's Republic of China is the department of the State Council that is in charge of agricultural and rural economic development.