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Farmland transition and its influences on grain production in China

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ABSTRACT

Land use transitions and socio-economic transitions jointly drive urban-rural transformation development in China. Farmland resources are a core element contributing to food security, and the characteristics of farmland transition and its influences on grain production in the urban-rural transformation development process help reveal the underlying laws governing farmland transition. Farmland transition characteristics also help effectively regulate grain production transition in China. Given the "man-land relationship" defined by large populations with relatively little arable land in China, this paper constructs a theoretical model for farmland transition using the per capita farmland area (PCFA) metric, which consists of the temporal changes in PCFA and PCFA spatial transitions as elevations change. Based on the theoretical model for farmland transition, we designed a coupling coefficient between PCFA and per capita grain possession, uncovering the inner link between farmland transition and grain production transition in China. Based on transitions measured at a 1 km gridded resolution of PCFA across the country, this study found that China's PCFA transitioned from a gradual decline to a steady rise during 1990–2010. In addition, the spatial transition trends for farmland were significant. The elevations of 1000 m and 500 m marked two important lines in the spatial transition of farmland, representing inflection points for the PCFA change trend and PCFA growth rate, respectively. The study concludes that regional differences in grain production transition are significant in the farmland transition process. While traditional agricultural areas gradually transitioned from an "Intensive type" to a "Modern type," grain production in South China experienced a significant "Declining type" transition trend. Regulating the farmland transition process can provide a basis for decision making about appropriate grain production scales of farmers in China. Farmland transition and urban-rural transformation development are closely related; as such, properly coordinating the relationship between them can help stabilize the socio-economic transition in China.

1. Introduction

Studies of land use transitions reveal changes in land use morphologies during socio-economic transitions; these studies also analyze the evolution in patterns among different land use morphologies. Land use transitions include dominant transitions and recessive transitions (Long and Qu, 2017); both are influenced by socio-economic transitions. Meanwhile, optimizing the land resources management system can regulate land use transition processes and trends, further coordinating conflicts among different land use morphologies and maintaining the benign development of socio-economic and eco-environment systems (Rudel et al., 2010; Long and Qu, 2017). Studies on land use transitions provide theoretical and practical guidance for optimally regulating the "man-land relationship" conflict that emerges during social transitions. Thus, an in-depth investigation can provide practical insights about the land use transition process and its feedback effect on socio-economic transition (Grainger, 1995; Lambin and Meyfroidt, 2010; Long et al., 2012; Long and Qu, 2017).

The concept of land use transition was first proposed in forest transition studies. The concept was later extended to studies on other land use morphologies. Mather and Needle (1998) surveyed change trends in forest area in different countries, and proposed the theory of forest transition (Grainger, 2008; Mather, 2004; Barbier et al., 2010). Following their steps, many scholars began to conduct in-depth studies on the regional differences, causes, and factors influencing forest transitions. Based on these studies, a theoretical model was constructed for forest transition using a theoretical framework of "economic development path" and "forest scarcity path" (Mather et al., 1999; DeFries

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and Pandey, 2010; Rudel et al., 2005; Barbier et al., 2017). In addition, many study results have also been obtained, addressing the influence of forest transitions on the eco-environment and food security (Mather and Thomson, 1995; Morton et al., 2006), the ways of peasant households participate in forest transition (Mather, 1996), and the impacts of forest transition on socio-economic transition (Song, 2017).

There have been many theoretical and empirical studies on forest transition; however, farmland transition (FT) has not been significantly researched. The farmland transition refers to the turning curve of farmland morphologies in different temporal and spatial scales, which includes the trend changes of farmland morphologies in temporal scale, and the transition in spatial scale (Long and Qu, 2017; Song, 2017). The core difference between FT and forest transition lies in the higher degree of human engagement with farmland than with forests (Rounsevell et al., 2005; Su et al., 2016); that is, farmland is more closely related to human life and production than forests. Scholars worldwide have explored changes in farmland quantity (Bren d'Amour et al., 2016), the process of farmland de-agriculturalization (Qu et al., 2005; Chen et al., 2014; Deng et al., 2015), and the coupled relationship between farmland and rural residential land (Long and Li, 2012). In the context of rapid urbanization, studies have also explored the relationship between farmland quantity and economic development (Jiang et al,. 2012; He et al., 2013), the abandonment of marginal farmland (Shao et al., 2014; Wang et al., 2016; Zhang et al., 2016), and the relationship between farmland quantity and food security (Yang and Li, 2000; Long and Zou, 2010; Liu et al., 2015; Li et al., 2017). Some scholars have also noted changes in farmland areas and uses as forests have transitioned; however, there are few theoretical and empirical studies targeting FT (Mather, 1995). Existing studies mainly focus on changes in total farmland quantity, resources and environmental effects of farmland changes; however, these studies have rarely explored per capita farmland area (PCFA) changes and their influences on grain production (Jiang et al., 2017). These changes are particularly important given the fundamental reality that China has a large population with relatively little arable land.

More studies are needed to investigate FT and its influences on grain production. Agricultural labor is an important driver for forest transition, and constitutes the "economic development path" of forest transition (Mather et al., 1999; Barbier et al., 2017). At the same time, changes in urban-rural residential characteristics have led to diverse demands for forest products, which also constitute an important factor of forest transition along the "forest scarcity path." Mather (1996) investigated the influence of forest transitions on agricultural production, and summarized the inner relationship between forest transition and agricultural production transition, which indicated that forest transitions profoundly influence the adjustments of agricultural industry structure and peasant households' response strategies (Deng et al., 2006; Long and Zou, 2012; van Vliet et al., 2017). Thus, compared with forest transition, FT has a more direct influence on agricultural production, and closer attention needs to be paid to the influence of human activities (Liu et al., 2016; Song, 2017). Population quantity is an important index characterizing human activities. Changes in PCFA provide core data for studies on FT: They reflect trends in the changes in farmland area; measure the flow in population trends during social transition; and further reveal the evolutionary process of the regional "man-land relationship." By analyzing the influencing mechanism and mode of the changes in PCFA on grain production during urbanization, a theoretical foundation can be provided for understanding agricultural production transitions (Satterthwaite et al., 2010; Yan et al., 2016; Seto and Ramankutty, 2016; Robinson and Carson, 2015).

Based on the study of the coupling relationship between FT and grain production transition (GPT), we can summarize the urban-rural transformation tendency in rural areas (farming areas), which is a useful tool for regulating the agricultural production system. The spatio-temporal process of FT can be used to reveal the trend of man-land interrelationship transformation of agricultural production system in the process of urbanization, which can provide theoretical and practical operation guidance for optimizing the FT. By investigating the issue of FT and its influences on grain production, a theoretical foundation can be provided for rationally optimizing China's GPT.

Given the significance of FT, this paper applies forest transition theory to develop a theoretical model for analyzing FT from the perspective of PCFA in temporal and spatial scales. Based on the analysis of the spatio-temporal process of PCFA and per capita grain possession (PCGP), we establish the PCFA and PCGP coupling model, so as to reveal the influence of FT on grain production and the change tendency of GPT. By analyzing the evolution of the coupling relationship between FT and GPT, we further discuss the policy suggestions of regulating the spatio-temporal process of FT, optimizing the mode of GPT, and coordinating the relationship between FT and socio-economic transition in the context of urban-rural transformation development.

2. Theory and methods

2.1. Theoretical models for farmland transition

2.1.1. Theoretical model for the temporal transition of farmland

Changes in rural China's PCFA during urbanization could be hypothesized to reflect a "U-shaped" reversion trend. To remove the error associated with PCFA in traditional administrative statistical unit-based calculations, this paper constructs a theoretical model for per capita farmland transition (PCFT), based on micro spatial population and farmland distributions. The quantity of PCFA is influenced by both farmland resources and the rural population quantity and distribution. In an agricultural society, as the population begins to transition, a relatively high birth rate continues to increase the population in rural areas (Hussain, 2002); however, there has not yet been a rural-to-urban migration. Meanwhile, the rural population distribution relates closely to farmland resource endowments. In other words, an area with more abundant farmland resources frequently has a larger population (Ge et al., 2018), a higher land reclamation rate, and fewer reversed farmland resources. As the rural population increases, rural settlements demand more land for construction. As an increasingly higher proportion of rural farmland is occupied by construction (Long et al., 2012; Liu et al., 2014), there is a constant decrease in farmland area. Thus, in this stage, the increase of population quantity per unit area leads to a decrease of farmland area and a constant decline of PCFA (the portion before T in Fig. 1 belongs to this stage).

During urbanization, the rural-to-urban population migration reverses declines in PCFA. Under the urban-rural dual system pattern, urbanization induces a rural-to-urban population migration, transforming the urban-rural spatial population pattern. In the process of population transition, the birth rate first declines, followed by a decline in net population growth (Kirk, 1996; Hussain, 2002). In addition, as surplus agricultural labor migrates, the population gradually

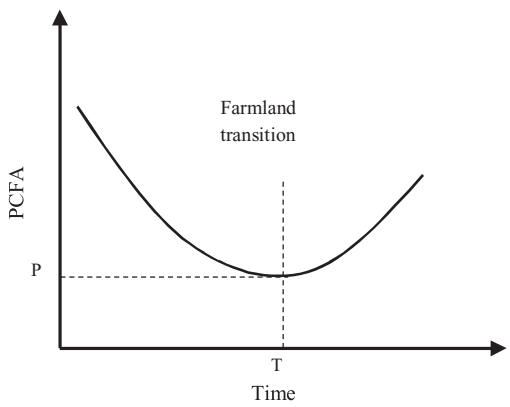

Fig. 1. Theoretical model for the temporal transition of farmland.