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Farmland fragmentation due to anthropogenic activity in rapidly developing region

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ABSTRACT

Measuring farmland fragmentation and its interactions with anthropogenic activities can advance our understanding of complexity in agricultural systems. Majority of previous studies focused on farmland ownership fragmentation rather than physical landscape fragmentation. This paper characterized the farmland landscape fragmentation dynamics in Tiaoxi watershed (China) from 1985 to 2013 using a set of variables (area-weighted mean patch area, patch density, area-weighted mean shape index, mean Euclidean nearest neighbor distance, splitting index, and effective mesh size). Four categories of anthropogenic drivers (demographic, economic, social and cultural, and scientific and technological) and their relative importance were quantified by multiple regression and variance partitioning. Results showed a linear increasing trend of farmland fragmentation in Tiaoxi watershed during the study period. Drivers for farmland fragmentation differed with variables. In general, non-agricultural population and migration population were the key demographic drivers, while road mileage and investment in real estate were the principal social drivers. Two groups of economic drivers were identified: one group included fruit and seafood production, another included per capita income and proportion of tertiary industry. Besides, education expenses increases and technological improvement could significantly reduce farmland fragmentation. Considering the relative importance for different categories of drivers, economy was the most influential driver; its joint influences with social and cultural drivers and those with scientific and technological drivers were relatively stronger. Our study advanced the understanding of principle anthropogenic drivers influencing farmland fragmentation dynamics.

1. Introduction

Farmland supplies primary products and performs a variety of ecosystem services (Schipanski et al., 2014). It provides habitat for wildlife, regulates local climate, maintains biodiversity, absorbs pollutants, controls soil erosion, and offers recreational opportunities for urban dwellers (Zasada, 2011). Ironically, though farmland is widely acknowledged as a significant contributor to regional sustainability, it is completely susceptible to the dramatic land use transformation driven by anthropogenic activities. Such general perception is on the basis of numerous cases and anecdotal observations regarding anthropogenic impacts on farmland. It is reported that farmland has been experiencing various degradation processes, including depletion, contamination, declined productivity, and fragmentation (Bakker et al., 2011; Nabulo et al., 2012; Müller et al., 2013; Su et al., 2012).

Fragmentation refers to the process that entities supposed to be cohesive for optimally functioning are segregated in space (Carsjens and van Lier, 2002). Farmland fragmentation issues are two-folded—the issue of landscape physical fragmentation and the issue of land use ownership fragmentation (Brabec and Smith, 2002; Farley et al., 2012). Landscape physical fragmentation refers to it that the number of farmland patches increases and their patch size decreases. Land use ownership fragmentation denotes the situation that plots managed by one household are spatially separated (McPherson, 1982). Ownership fragmentation can lower the production efficiency and increase management costs (Tan et al., 2006), presenting great potential for future landscape physical fragmentation (Farley et al., 2012). Majority of previous studies focused on the ownership fragmentation rather than the farmland landscape fragmentation (Demetriou et al., 2013; Sikor et al., 2009;

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Tan et al., 2006). Landscape physical fragmentation is tightly linked with a number of ecological processes (Llausàs and Nogué, 2012; Uuemaa et al., 2013). Measuring farmland landscape fragmentation and its interactions with anthropogenic activities can advance our understanding of complexity in agricultural systems. We therefore argue that it is a worthwhile goal to characterize the dynamics of farmland landscape fragmentation and the corresponding anthropogenic drivers. However, rather few efforts have been made in this regard.

Landscape ecology offers theory basis and a diversity of variables for description of landscape fragmentation (e.g., effective mesh size, landscape division index, splitting index, patch density, etc.). Long time series of farmland information can be obtained from remotely sensed imageries (Brown and Pervez, 2014; Lobell et al., 2007; Yan et al., 2013). The comprehensive employment of remote sensing, landscape ecology, and geographical information systems (GIS) has been widely applied in agricultural systems modeling and management (Maeda et al., 2010; Sayer et al., 2013). Objectives of this paper are to investigate farmland fragmentation dynamics and the corresponding anthropogenic drivers using a landscape ecological approach, combined with remote sensing and GIS. Farmland fragmentation here refers to the landscape physical fragmentation instead of land use ownership fragmentation.

2. Materials and method

2.1. Study area

The Tiaoxi watershed, which is a part of the Taihu Lake drainage area, is located in the middle part of Chinese eastern coast (Fig. 1). Extending from 119°14′E to 120°13′E and from 30°07′N to 31°11′N, this watershed lies within the subtropical climate zone, characterized by long summer and winter seasons, but short spring and autumn seasons. Paddy soils are fertile and occupy a large part of the total area. The climatic and soil conditions are beneficial for grain production. The high grain yields make Tiaoxi watershed a regional important agricultural production base.

Tiaoxi watershed belongs to the Yangtze River Delta Economic Development Zone, which is the most developed and populous region in China. It has been experiencing rapid socioeconomic development and agricultural commercialization since the 1980s. Profound built-up land expansion has been driven by the booming socioeconomic development (Su et al., 2011). Many farmers also converted their cropland into gardens and artificial ponds. These land use changes significantly altered the structure and pattern of farmland systems. Thus, the case of Tiaoxi watershed is a good reference for the characterization of anthropogenic drivers for farmland fragmentation.

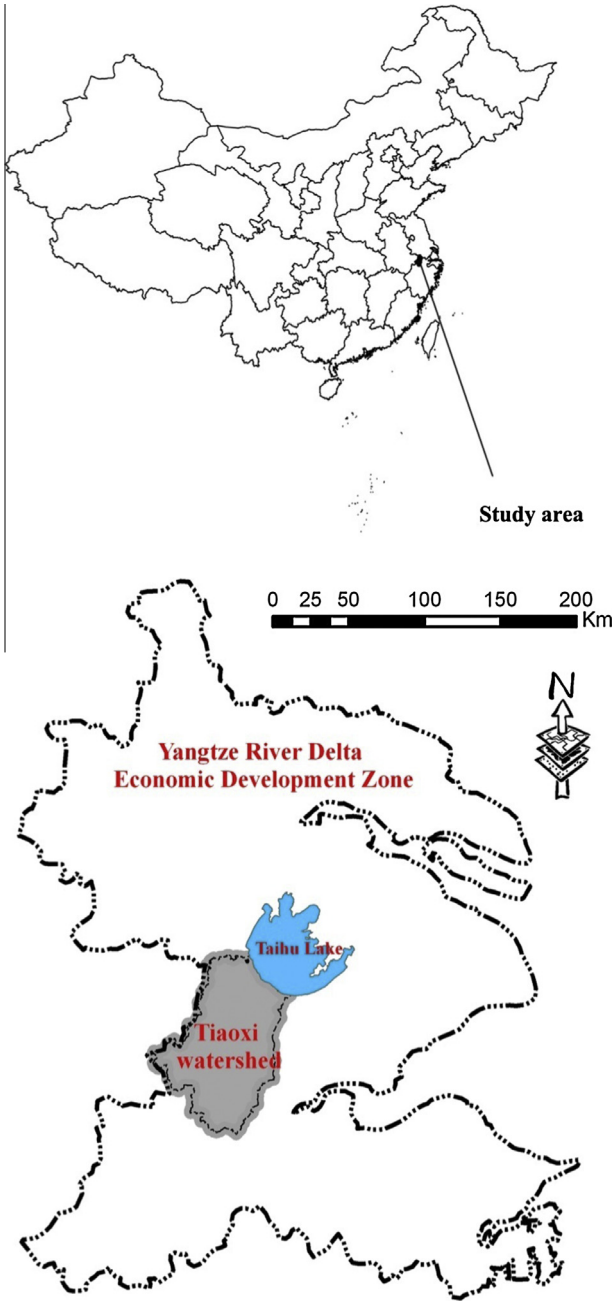

Fig. 1. Location of the Tiaoxi watershed within the Yangtze River Delta Economic Development Zone, China.

2.2. Image classification

Farmland in the study area included paddy and dryland. The farmland information from 1985 to 2009 was from Su et al. (2014a), which was based on China–Brazil Earth Resources Satellite images (2004, 2006 and 2007), Landsat Enhanced Thematic Mapper images (1999, 2000, 2001, 2002, and 2003), and Landsat Thematic Mapper images (1985, 1994, 2005 and 2009). Farmland information in 2013 was visually interpreted based on Landsat Operational Land Imager (OLI). The final farmland maps were displayed in Fig. 2.

2.3. Metric selection

Farina (1998) pointed that landscape fragmentation was closely related to patch size, edge, shape, connectivity, and isolation. We first collected a set of 51 class level landscape metrics based on literature review, and used varimax rotated principal component analysis to reduce redundancy (Plexida et al., 2014; Su et al., 2014b). Finally, six variables were selected to describe farmland fragmentation, including area-weighted mean patch area (AREA_AM), patch density (PD), area-weighted mean shape index (SHAPE_AM), mean Euclidean nearest neighbor distance (ENND_MN), splitting index (SPLIT), and effective mesh size (MESH). These variables represent the areal and shape characteristics, connectivity, as well as division degree among farmland patches.

2.4. Selection of potential anthropogenic drivers

Scholars have developed a number of variables to indicate anthropogenic activity, such as urban land expansion, road density,