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Projecting cropping patterns around Poyang lake and prioritizing areas for policy intervention to promote rice: A cellular automata model

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A B S T R A C T

Rural households' cropping choices are increasingly influenced by non-farm activities across the developing world, raising serious concerns about food security locally and globally. In China, rapid urbanization has led to agricultural decline in some regions. To stimulate agriculture, the Chinese government has recently increased its effort in farmland consolidation by providing special support to large farms in an attempt to address land-use inefficiency associated with small farming operations in rural areas. Focusing on the Poyang Lake Region (PLR), we develop an empirical Cellular Automata (CA) model to explore future agricultural land use and examine the impact of farmland consolidation, with the intention of providing insight for policy to effectively promote food production. The PLR is an important rice producing area for Jiangxi Province and China. In the PLR, rice can be grown once a year on a plot, called one-season rice, or twice a year on the same plot, called two-season rice. Our CA model simulates the transition between one-season and two-season rice. We use the modeling results to identify five types of areas (zones) where rice cultivation is (i) relatively stable for one-season rice, (ii) more likely to be one-season rice, (iii) of equal probability for either type, (iv) more likely to be two-season rice, and (v) relatively stable for two-season rice. In addition we explore the characteristics of these zones in terms of biophysical and geographical features to offer a detailed analysis and discussion of how the government may prioritize areas for interventions to sustain rice production amid urbanization. Our analysis also shows some positive effect of farmland consolidation on increasing rice production in the study area.

1. Introduction

As rural households in the developing world increasingly participate in urban economies, their agricultural activities and crop choices are influenced by non-farm activities, which can have significant consequences on agricultural production and food security locally and globally (Seto et al., 2012; Liu et al., 2013; Müller and Munroe, 2014; Seto and Reenberg, 2014). In China, rapid urbanization has led to decline of agriculture in some regions, especially in areas with relatively high industrial development (Liu et al., 2005; Deng et al., 2006; Lichtenberg and Ding, 2008; Seto et al., 2011; Tian et al., 2015b). Farming operations are typically small in rural China, which causes land-use inefficiency and is associated with the de-intensification of agriculture (Jin and Deininger, 2009; Tan et al., 2010; Wang and Chen, 2014; Tian et al., 2015b). An average rural household has about 8 mu (1 mu = 0.067 ha) for farmland. To stimulate agricultural production, China has recently increased its effort in farmland consolidation by providing a variety of special supports to large farms, ranging from cash subsidies to assistance in building new facilities. There is, however, little understanding of how urbanization and farmland consolidation may interact to influence future agricultural land use and food production. Ensuring national food security has been an important goal for Chinese governments at all levels and a top policy priority (Gu and Zhang, 2009; Gale, 2013; Xinhua News, 2016); by increasing our understanding of such interactions we can provide important insights for policy to promote food production amid the negative influences of urban development.

This paper uses an empirically grounded Cellular Automata (CA) model to explore future agricultural land use under the influence of urbanization and examines the impact of the Chinese farmland consolidation policy with respect to increasing food production. CA models simulate cells in a lattice that follow local state transition rules to

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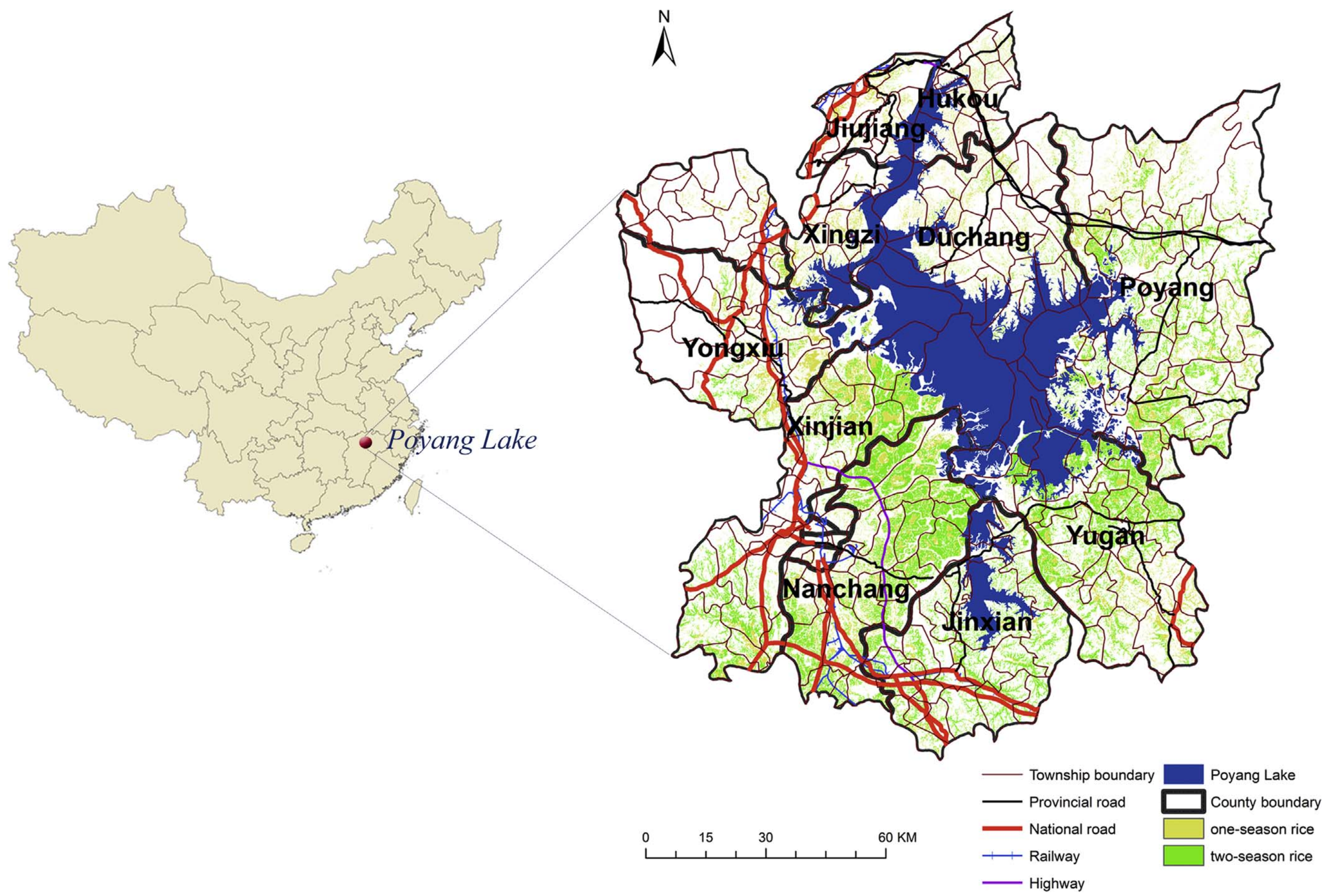

Fig. 1. The Poyang Lake Region. The left map shows its location in China. Rice cropping patterns shown on the right map were interpreted from Landsat images in 2013.

investigate the micro-level mechanisms of system-level outcomes (Batty, 2005). As CA models are spatially explicit, and the state transitions rules can incorporate socioeconomic and environmental factors along with neighborhood effects, they have been shown to be extremely suitable for simulating land-use systems in a variety of contexts (e.g. White and Engelen, 1993; Clarke et al., 1997; Jantz et al., 2004; Walsh et al., 2006; Ahmed and Bramley, 2015; Chaudhuri and Clarke, 2013; Ferreira et al., 2013; Lin et al., 2014; Long et al., 2014; Halmy et al., 2015; Stan et al., 2015; Ghilardi et al., 2016; Troupin and Carmel, 2016).

CA models can provide projections of future land-use patterns and as such they allow planners or policy makers to effectively manage land to achieve specific goals, such as the control of urban expansion, conservation, sustainable agriculture, risk management, or climate impact mitigation (e.g. Theobald and Hobbs 1998; Pijanowski et al., 2002; Wickramasuriya et al., 2009; Kamusoko et al., 2009; Young, 2013; Halmy et al., 2015). When used for prediction, CA models often extrapolate land transition trends based on spatial land use from two past periods (e.g. Muller and Middleton, 1994; Li and Reynolds, 1997; Kamusoko et al., 2009; Ferreira et al., 2013; Halmy et al., 2015).

CA models often combine GIS data that represent land-use drivers and are used to derive land transition suitability maps. GIS data are particularly useful in the context of rural land use as agricultural land use and crop choices are influenced by a range of socioeconomic and environmental factors (e.g. Walsh et al., 2006; Kamusoko et al., 2009; Ferreira et al., 2013; Yan et al., 2013; Long et al., 2014). To understand and quantify the relationships between land-use drivers and land transition, some sort of statistical analysis method is often applied, such as logistic regression (e.g. Li and Reynolds, 1997), weights of evidence (e.g. Ferreira et al., 2013), spatial regression (e.g. Ku, 2016), and decision learning trees (e.g. Basse et al., 2016) to name but a few. CA models have also demonstrated their ability to project spatial crop patterns over large areas.

Our study focuses on the Poyang Lake Region (PLR) in Jiangxi Province. The PLR is an important rice producing area for the province and China more generally. In the PLR, rice can be grown once a year on a plot, which is called single cropping or one-season rice, or double cropped on the same plot, which is also called two-season rice. While plots of farmland that had traditionally been used for two-season rice production have been converted to one-season rice in many villages due to rising non-farm income (Tian et al., 2015b), the switch from one-season rice to two-season rice has also been observed on remotely sensed images in other areas (Li et al., 2012). Further details about our study area is described in Section 2.

We use a CA model (described in Section 3) to explore future rice cropping patterns around Poyang Lake assuming that current transition trends continue. Because the projection is intended to provide insight for policy to promote rice-production in the area, our model does not examine other types of land use in the rural land system but focuses on and simulates the transition between one-season and two-season rice. Neither do we use the model to provide precise point predictions: we look at the future likelihoods of crop choices for each location and examine spatial distributional differences of rice cropping patterns over the region, because these differences allow the government to prioritize areas for intervention, and the government may intervene differently in different places to promote rice effectively.

Specifically, we use the modeling results to identify five different types of areas (zones) where rice cultivation is (i) relatively stable for one-season rice, (ii) more likely to be one-season rice, (iii) of equal probability for either type, (iv) more likely to be two-season rice, and