Land use changes to cash crop plantations: crop types, multilevel determinants and policy implications

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ABSTRACT

Cash crop plantation has recently become an expanding global phenomenon. Characterizing the dynamics of cash crop plantations and the corresponding determinants should provide critical references for land use policy. Using aerial photos and geographic information system, this paper investigated the trends of four types of cash crops (tea, fruit, mulberry and nursery) and their relations to other land use changes within Hangzhou region in subtropical China. Results showed that the total cash crop cultivated surface increased by 541.3 ha from 2004 to 2014. Most of the new tea and fruit plantations were established in places previously used as forest and woodland. Mulberry and nursery mainly expanded by replacing paddy, woodland and forest. By combining household survey, geospatial techniques and multilevel regression, multilevel determinants of cash cropping probability and cash crop expansion were quantified. At the parcel level, tea and fruit plantations inclined to occur on hilly land with gentle slope. Mulberry and nursery plantations were likely to be observed in flat areas with low elevation. Parcels covered by high quality soils and with convenient communications experienced greater cash cropping probability. At the household level, households constituted of female and old-aged labor or with low agricultural labor intensity demonstrated high probability of tea and mulberry plantations. Conversely, households constituted of middle-aged labor or with high agricultural labor intensity tended to grow more fruit and nursery. Besides, wealthier households were prone to establish fruit and nursery plantations but were reluctant to involve in tea and mulberry cropping. At the village level, population density was a significant determinant of cash cropping probability, but was an insignificant determinant of cash crop expansion. Greater occurrence of cash cropping was observed in villages with higher proportion of migrant labor and leasing land. Distance to county road and distance to provincial road were identified as negative determinants. Policy was evidenced to be of significant influence on cash cropping probability and cash crop expansion. We argue that a balance should be achieved between cash cropping promotion and natural resources protection in formulating the local land use policy.

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1. Introduction

Recently, tropical and subtropical cash crop plantation has become an expanding global phenomenon (Ahrends et al., 2015; Ziegler et al., 2009). While cash cropping supports rural livelihoods and accelerates the economic boom in the production areas (Manivong and Cramb, 2008; Yi et al., 2014; Zhang et al., 2014), it has also received criticism from ecologists and environmentalists. Many observations highlight that dramatic rates of natural resources (e.g., forest and farmland) clearing are occurring in South-

east Asian nations (e.g., Malaysia, Vietnam, Thailand, China and Indonesia) due to the monoculture plantation of cash crops, including rubber, commercial fruits, palm oil, nursery and tea (Hung, 2013; Miyamoto, 2006; Su et al., 2014; Wicke et al., 2011; Zhai et al., 2012). The conversion of native resources to cash crop plantations, in most cases, can alter local hydrology (Yi et al., 2014), accelerate soil erosion (Xiao et al., 2014), fragment traditional landscapes (Godone et al., 2014), threat biodiversity (Qiu, 2009; Wilcove and Koh, 2010), and increase carbon dioxide emissions (Carlson et al., 2012). These problems become more complicated because scale development of cash crop plantations and active involvement of households are essential parts of official land policy in many countries (Gatto et al., 2015; Zhang et al., 2014). In this context, two key questions should be addressed in order to help adjust land use policy and avoid undesirable outcomes: (1) what are the trends

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of cash crop plantations and relations to other land use changes across time and space? (2) what are the determinants of the cash crop plantations and their variations with crop types and scales?

Spatial patterns of land use themes over time are usually captured by remotely sensed data. Several studies have documented the dynamics of cash crop plantations in tropical areas using coarse spatial resolution satellite imageries, such as MODIS, LANDSAT, HJ-1A/1B CCD and ALOS PALSAR (Chen et al., 2015; Dong et al., 2013; Li and Fox, 2012; Su et al., 2014; Xiao et al., 2015). While the land under cash crop plantations can be observed frequently by these sensors, their coarse resolution makes it insufficient to describe the process of land use changes to cash crop plantations at fine scale (Su et al., 2014). For example, feature-oriented information for individual cash crop types (commercial fruits, nursery and tea in subtropical regions) cannot be interpreted precisely and directly considering the mixed pixel problem (Su et al., 2014; Xiao et al., 2015). Consequently, dynamics of different cash crop types have been seldomly monitored and compared in the subtropical places.

Cash cropping is involved in complicated social and natural environments; therefore, it is influenced by various geographical and socioeconomic factors. From the socioeconomic perspective, the choice of cash crop plantations is comprehensively affected by the household individual characteristics, local and macro economy, and land use policy (Gatto et al., 2015; Miyamoto, 2006; Zhang et al., 2015). From the geographical perspective, cash crop plantations occur at multiple scales, from parcel to administration and region (Su et al., 2014). Thus, the cash cropping decision is the result of interactive processes acting at different levels. It suggests that multilevel determinants should be quantified simultaneously when analyzing the driving mechanism of cash crop plantations. However, previous studies investigated the corresponding determinants either from the socioeconomic perspective based on household survey (Choudhury and Goswami, 2013; Gatto et al., 2015; Zhang et al., 2014, 2015), or from the geographical perspective using remote sensing and geographical information system (GIS) techniques (Castiblanco et al., 2013; Reis and Yomralioglu, 2006; Su et al., 2014; Xiao et al., 2015). The multilevel determinants of cash crop plantations therefore remain unclear.

Considering the above shortcomings, this paper attempts to investigate the multilevel determinants of cash crop plantations by combining geospatial techniques (remote sensing and GIS) with household survey. With a case of Hangzhou region in China, our specific objectives are to: (1) monitor the land use changes to cash crop plantations and compare the dynamics of different cash crop types; (2) quantify the determinants of cash crop plantations at the parcel, household and administrative levels; and (3) discuss the implications for land use policy. The general logistic framework involves three major parts: (1) Remote sensing and GIS were used to monitor the land use changes to cash crop plantations from 2004 to 2014 in Hangzhou region. (2) Household survey was carried to collect data of cash cropping in Hangzhou region. (3) Determinants of cash crop plantations were characterized at the parcel, household and administrative levels from two aspects: cash cropping probability and cash crop expansion. In particular, household survey data in 2014 were used to identify the determinants of cash cropping probability. Spatial data obtained by remote sensing were utilized to analyze the determinants of cash crop expansion.

2. Background

2.1. Cash crop plantations in China

Cash crop plantations have been expanding in China during the recent decades. Rubber is the fastest expanding monoculture in south China (Ziegler et al., 2009), while tea and commercial fruits rank the top in terms of planting areas in the subtropical regions. Before the 1978, cash crop plantations were primarily sustained by state-owned farms, and they occupy a small land area. The commercial scale monoculture of cash crops was initiated in the early 1980s, when the government introduced the land use policy of Household Responsibility System (Krusekopf, 2002). Small-holder cash cropping brought unprecedented wealth for some pioneers. The high returns inspired the local people and cash cropping was acknowledged as a profitable land use choice. It led to widespread land use changes to cash crop plantations in tropical and subtropical China (Su et al., 2014; Xiao et al., 2015; Zhang et al., 2014). Cash crop plantations experienced a booming expansion after the 2000s, driven by the growing consumer demand, increasing price of cash crops and upscaling transportation networks (Li et al., 2008). Statistics show that rubber plantations in 2010 occupied 14% and 22% of the total land area in Hainan and Xishuangbanna, respectively (Dong et al., 2013; Zhai et al., 2012). In the subtropical provinces, area of tea plantations increased from 597.9 thousand ha in 2000 to 1308.2 thousand ha in 2013 (China Tea Yearbook, 2014). With the cash crop market continues to heat up, the process of land use changes to cash crop plantation probably continues and even speeds up.

Cash crop plantations in China have attracted increasing attention, and scholars primarily focused on the tropical regions. Ziegler et al. (2009), Zhai et al. (2012), Dong et al. (2013) and Chen et al. (2015) monitored the rubber plantations in Hainan using remotely sensed data. Zhang et al. (2014) analyzed the household level determinants of commercial banana expansion in Xishuangbanna. Zhang et al. (2015) relied on field survey to discuss the expansion of small-holder rubber farming in relation to socio-biophysical factors. Yi et al. (2014) evaluated the biodiversity loss associated with rubber plantations in Xishuangbanna. Zheng et al. (2015) evidenced the point that rubber plantations would decrease biodiversity. Fewer efforts have been made to investigate the cash crop plantations in subtropical China. Su et al. (2014) documented the cash crop expansion in Tiaoxi watershed using Landsat images. Xiao et al. (2015) discussed the determinants of cash crop expansion at regional level. However, a high resolution themed map of cash crop plantations is still not available for the subtropical regions. Household survey of cash crop plantations has been seldomly reported. Consequently, the multilevel determinants of cash crop plantations remain poorly understood in subtropical China.

2.2. Study area

Located in China's southeastern coast (Fig. 1), the Hangzhou region covers 16,596 km^2 and has a population of 8.8 million in 2013 (Zhejiang Statistical Yearbook, 2014). Dominated by a subtropical monsoon climate, it is humid and warm with plentiful rainfall and sufficient sunshine. The average annual temperature is 17.5 °C, annual rainfall is 1274 mm, average relative humidity is 70%, and annual sunshine is 1641 h. The terrain is plain in the northeast and hilly mountain in the southwest. Benefiting from the geographic and climatic features, a variety of cash crops are grown within the region, including tea, fruit, mulberry, and nursery. Renowned as "Home of Silk", Hangzhou is famous for raising silkworm and mulberry. The Dragon Well tea originates from this region, and Hangzhou is of high international reputation to be "Tea Capital". Recognizing that cash cropping can increase fiscal revenues, the local government encourages scale development of cash crop plantations and active involvement of households. Cash crop plantations have expanded rapidly in Hangzhou region during the past decade. This region exemplifies the cash cropping in subtropical China and therefore can be typically selected to examine the multilevel determinants of cash crop plantations.