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Exploring the socioeconomic and ecological consequences of cash crop cultivation for policy implications

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ABSTRACT

Cash crops have kept expanding at an accelerating rate across the globe during the last decades. It therefore requires elaborate efforts to examine the socioeconomic and ecological consequences of cash crop cultivation. With a case of the Hangzhou region in subtropical China, this paper investigated the dynamic patterns of four cash crop types (tea, fruit, mulberry and nursery) at town level by using aerial photos; and then quantified the subsequent socioeconomic and ecological consequences using spatial regression. In particular, the socioeconomic impacts were examined based on a set of socioeconomic indicators and the ecological consequences were described by ecosystem service values (ESV) and landscape pattern changes. Results indicated that the economic benefits of cash crop cultivation were evident, including raising household income, boosting rural economy, increasing fiscal revenues, and attracting foreign investment. Cash crop cultivation generally yielded positive social impacts (welfare promotion, infrastructure improvement and job creation), but the impacts also varied with crop types. Cash crop cultivation not only increased landscape fragmentation, isolation and irregularity, but also decreased the dominance, connectivity and aggregation of forest and farmland. Specifically, forest was more subjected to tea and fruit expansion, while farmland was more vulnerable to mulberry and nursery expansion. A significant negative relationship was identified between ESV changes and cash crop expansion. It implied that cash crop cultivation would impair the capacity of ecosystems to deliver services. Our study demonstrated an applicable framework to identify the essential indicators for land use policy makers to monitor the socioeconomic and ecological consequences of cash crop cultivation.

1. Introduction

Global demand for cash crops has kept increasing during the recent past (Delpeuch and Leblois, 2014). Cash crop cultivation, including the rubber, commercial fruit, palm oil, tea and nursery, has become an expanding global phenomenon, especially in tropical and subtropical countries (Carlson et al., 2012; Castiblanco et al., 2013; Gatto et al., 2015; Godone et al., 2014; Qiu, 2009; Xiao et al., 2015; Ziegler et al., 2009). However, the contribution of cash crop cultivation to social welfare, economic development and ecological conservation has sparked a controversial debate (Castiblanco et al., 2015; German et al., 2011). For one thing, cash crop cultivation is regarded as a source of export and a critical contributor to economic growth for the producer regions, and has accelerated local economies integration into global economies (Dal Belo Leite et al., 2015; GLOBAL, 2011; Rist et al., 2010; Su et al., 2016, 2017a,b; World Bank, 2010; Obidzinski et al., 2012; Zhang et al., 2014). For another, cash crop cultivation is criticized for increasing negative social and environmental externalities, since it promotes competition in natural resources with traditional staple food crops, puts pressures on food inflation, raises conflicts over land rights (Barkmann et al., 2010; Ewing and Msangi, 2009; McCarthy, 2010; Tilman et al., 2009). It is notable that cash crop expansion usually occurs with deforestation, and this land use conversion can lead to various ecological problems (e.g., soil erosion, biodiversity loss, hydrological turbulence, raw materials reduction, and decreasing carbon stock) (Cha, 2005; Carlson et al., 2012; Fitzherbert et al., 2008; Petsri et al., 2013; Yi et al., 2014a). Specifically, previous studies pointed pointed that bird diversity and abundance decreased along with increasing revenues from oil palm plantations; soil organic carbon stocks had decreased by conversing forest to rubber. In addition, while the enlarging cash crop cultivation strengthens the local finance stability, its impact on socioeconomic welfare of households in the long run remains controversial (Castiblanco et al., 2015; German et al., 2011). Amid this controversy, it requires elaborate efforts to examine the

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socioeconomic and ecological consequences of cash crop cultivation.

It is not an easy endeavor to establish a thorough examination of the consequences of cash crop cultivation. First, accurate information of the spatiotemporal patterns of cash crop cultivation is unavailable for most places. Second, fine level (e.g., village and town) socioeconomic database are scarce in most developing countries. Household survey always relies on subjective indicators, which incorporates bias in sample choice and impedes the assessment of impacts at broad level (e.g., city and state) (Castiblanco et al., 2015). Third, it is rather difficult to quantify the dynamic changes of ecosystem functions and structures, since long-term observation data are always absent and intensive field trips would generate very high costs (Mairota et al., 2013; Sowińska-Świerkosz and Soszyński, 2014; Su et al., 2014a).

Multitemporal remotely sensed images provide essential data source to monitor land use and cover changes in space and time. Recent literature has demonstrated that remote sensing was a practical and promising tool to obtain the spatiotemporal information of cash crops (Castiblanco et al., 2013; Dong et al., 2013; Godone et al., 2014; Li and Fox, 2012; Xiao et al., 2015). Ecological functions and processes, evidenced by a number of experiments, are significantly influenced by landscape patterns (Girvetz et al., 2008; Uuemaa et al., 2013). Scholars generally agree that ecological consequence of anthropogenic activity can be indirectly quantified by analyzing landscape pattern changes (Fernandes et al., 2011; Sowińska-Świerkosz and Soszyński, 2014; Su et al., 2012; Weng, 2007). Landscape ecological approach, compared to field survey, permits a more rapid assessment of eco-environmental quality at regional scale (Fernandes et al., 2011). Besides, it provides quantitative and comparative figures to document the dynamic changes of eco-environmental quality (Su et al., 2014a). However, brief description of landscape pattern changes may not offer a full-view of the ecological consequences of anthropogenic activity, since the economic values of ecosystems are not revealed (Su et al., 2012; Wainger et al., 2010). Ecosystem services refer to the benefits provided by ecosystems to support and maintain the life and living of human beings (Millennium Ecosystem Assessment, 2003). Evaluation of the ecosystem service values (ESV) has shown promising potential to combine the economic outcomes with ecological processes (Wainger et al., 2010). Su et al. (2012) argued that monetary evaluation of ecosystem service values (ESV) and characterization of landscape patterns should be both applied to quantify the ecological consequences of anthropogenic activity. However, rather few studies have been done to investigate regional ESV and landscape pattern changes in relation to cash crop cultivations. In addition, the socioeconomic and ecological consequences of cash crop cultivation have been rarely examined simultaneously in the literature.

Considering the above limitations, this paper attempted to quantify the socioeconomic and ecological consequences of cash crop cultivation. Data at town level were collected for the Hangzhou region, a typical cash crop production place in subtropical China. Our specific objectives are to: (1) investigate the dynamic patterns of cash crop cultivation at town level within Hangzhou region; (2) examine the socioeconomic impacts of cash crop cultivation; and (3) analyze the ecological consequence of cash crop cultivation.

2. Materials and method

2.1. Study area

The Hangzhou region is situated in eastern coastal part of Zhejiang Province (Fig. 1), one of the most developed and populous administrations in China. Covering about 17,000 km^2, it is hilly in the southwest and plain in the northeast. The subtropical monsoon climate controls the Hangzhou r egion, with plenty of sunshine (annual 1641 h) and rainfall (1274 mm). In addition, the red soils are loamy and thick and river networks are dense and connected. Thereby it provides a perfect farming environment to grow cash crops. A diversity of cash crops with high yield and quality grow in Hangzhou region and the most famous ones include fruit, tea, nursery, and mulberry (Su et al., 2016). Local specialty cash crops of Hangzhou enjoy a high reputation and show obvious price advantage in markets. In pursuit of high income, the farmers have showed higher and higher enthusiasm towards cash crop cultivation. The cultivated area of cash crops has expanded to a large extent during the past decade (Su et al., 2016). It is argued that Hangzhou region should be a typical case of cash crop expansion and should be ideal for examining the socioeconomic and ecological consequences of cash crop cultivation.

2.2. Digital land use data

The 2.5 m resolution color-infrared aerial photos, provided by the Su et al. (2016) were employed to interpret land use information. These photos were imported to ArcGIS 10.2 with WGS84 geographic coordinates and then visually interpreted at 1: 50,000 photogrammetric scale. The interpreters were selected from the local experts and all were familiar with the land use patterns in Hangzhou. In particular, considering the actual land use characteristics in Hangzhou, we interpreted four cash crop types (tea, orchard (fruit), mulberry and nursery). In order to facilitate the metric analysis and ESV calculation, six other land use types (farmland, forest, artificial ponds, natural water bodies, built-ups and fallow land) were also interpreted. In order to evaluate the accuracy, we used field survey data and the number of reference points amounted to 235 points for 2004 and 298 points for 2014. The land use distributions were presented in Fig. 2. The interpreted cash crop information was joined with the digital administrative map (1: 50,000) at town level (Fig. 1). Then, the area of the four cash crop types was summed for each town (146 in total). It should be mentioned that administration in China is divided into four levels, including province, city, town (district) and village (community). In most cases, comprehensive socioeconomic statistical data are available at town level rather than village level. Analysis was therefore conducted at town level in this study.

2.3. Selection of landscape metrics

Metric analysis permits the numerical and comparative description of landscape patterns. A large amount of metrics has been developed to depict the landscape characteristics from different aspects, including size, edge, connectivity, shape and diversity (Girvetz et al., 2008; Uuemaa et al., 2013). However, landscape metrics usually present high redundancy in most cases (Sowińska-Świerkosz and Soszyński, 2014). It is therefore suggested to choose a set of metrics rather than to employ all the metrics. The selection of landscape metrics was based on four criteria: (1) comparability with previous studies (Kromroy et al., 2007; Leitão and Ahern, 2002; Pôças et al., 2011; Solon, 2009; Su et al., 2011; Weng, 2007); (2) ability to reflect ecological conditions (Ribeiro and Lovett, 2009); (3) low redundancy among landscape metrics by performing a multicollinearity test, calculating metrics at eco-regional scale (Leitão and Ahern, 2002); and (4) ability to indicate characteristics of landscape patterns of the study area.

Metrics selection in this study followed the three-step procedure demonstrated in Su et al. (2014a). First, literature review was based on to select a set of metrics (30 landscape level and 38 class level), which represented the landscape pattern characteristics from various aspects (e.g., density, edge, area, isolation, shape, diversity and contagion). Second, after normalization and standardization, these indices were subjected to Pearson's correlation analysis. When one pair of metrics were found to be highly correlated ($|r| \geq 0.9$), one of them was abandoned. Third, the remaining indices were further subjected to principal component analysis with varimax rotation. When one metric in the extracted component presented high loadings (> 0.75), it was kept. Finally, five landscape level metrics (patch density (PD), landscape shape index (LSI), connectance index (CONNECT), split index (SPLIT)