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Analysis

Rubber Boom, Land Use Change and the Implications for Carbon Balances in Xishuangbanna, Southwest China

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ABSTRACT

Rubber farming expansion in Xishuangbanna, in the Upper Mekong region of Southwest China, has resulted in profound land use change and led to the severe degradation of the local environment. This study explores the dynamics of land use change as a result of the rubber boom, examines the factors influencing the heterogeneity in farmers' land allocations for rubber farming, and assesses the implications of this change for the local environment in terms of carbon balances. The analyses use a comprehensive household survey data set of 612 smallholder rubber farmers in Xishuangbanna. The historical data illustrate the trajectory of rubber expansion and land use change over the past three decades. The model of smallholder land allocation for rubber farming suggests its determinants include ethnicity, experience in rubber farming, household wealth, elevation, and several explanatory variables at the village level. A net loss in carbon stocks at the aggregate level was found due to the expansion of rubber plantations. The rubber farming expansion of smallholders outside the natural reserves in Xishuangbanna has led to a carbon loss of approximately 21 Mg/ha/year over the past three decades. The findings complement discussions on the future of the rubber-based land use system and its sustainability in Xishuangbanna and other rubber-growing areas in the Mekong region.

1. Introduction

Over the last three decades, Xishuangbanna Dai Autonomous Prefecture (XSBN), in the upper Mekong region, Southwest China, has experienced widespread and dramatic land-use changes such as deforestation, agricultural expansion and the conversion of secondary vegetation into monocultures, in particular, rubber plantations (Ahrends et al., 2015; Xu et al., 2005; Zhang et al., 2015). Since the 1980s, motivated by the combination of the domestic protection of rubber prices, the introduction of the Household Responsibility System, and the introduction of new technologies, smallholder rubber farming has been expanding rapidly in Xishuangbanna (Xu et al., 2005). By 2004, the total area devoted to rubber plantations in XSBN was 2.59 million mu,[1] with an annual dry rubber production of approximate 0.17 million tons, while by 2014, the total area covered by rubber plantations was 4.55 million mu, with dry rubber production of 0.29 million tons. Currently, > 50% of rubber plantations in XSBN are operated by smallholders (Min et al., 2017a). Min et al. (2017b) showed that the share of rubber plantations in the total household land area was approximately 80%, but there were heterogeneous farmers in XSBN. Similarly, the increasing expansion of natural rubber farming can also be seen in other countries in the Mekong region, such as Laos, Myanmar, and Vietnam (Fox and Castella, 2013; Liu et al., 2013; Manivong and Cramb, 2008; Min et al., 2018). The establishment of rubber plantations also caused rapid and extensive changes in land-use patterns (Gerber et al., 2009). Unfortunately, due to the constraint of data availability, it remains unclear which types of land have been replaced by rubber plantations and how much.

The significant land use change with rubber expansion in XSBN had both positive and negative consequences (Hauser et al., 2015; Jiang et al., 2017). On the one hand, the rapid intensification of rubber farming has improved rural incomes (Fu et al., 2009; Min et al., 2017b). On the other hand, the shifting of traditional land-use patterns and forests towards specialized rubber plantations also implies a higher liability in terms of climatic and economic risks and has led to the large-scale destruction of ecologically important forest resources, thereby

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[1] 15 mu = 1 ha.

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challenging the sustainability of land use in XSBN (Fu et al., 2009; Kassa et al., 2017; Qiu, 2009; Xu, 2006). Smallholder rubber farmers are also subject to potential economic risks due to potentially high sunk costs when investing in rubber (Min et al., 2017c). Particularly, the recent decline in rubber prices left smallholders vulnerable to a drop in income and the potential to again fall into poverty. Above all, the rapid expansion of rubber farming has triggered a series of negative effects on local ecosystems such as biodiversity, soil and water conservation (Hu et al., 2008; Liu et al., 2006; Xu, 2006; Yi et al., 2014), while the loss of agro-biodiversity may also have adverse implications for food and nutritional security (Fu et al., 2010).

Moreover, the impact of these significant changes in land use on landscape carbon sequestration has been demonstrated by researchers (Blagodatsky et al., 2016; de Blécourt et al., 2013; Li et al., 2008; Yi et al., 2014; Zhang et al., 2007). Although the cultivation of rubber trees on non-forested land could provide a carbon sink by sequestering carbon in biomass and indirectly in soils (Gnanavelrajah et al., 2008; Nizami et al., 2014; Wauters et al., 2008), the carbon sequestration ability of rubber trees is much lower than that of natural forest (de Blécourt et al., 2013; Jiang et al., 2017; Yang et al., 2016). Thus, although the conversion from traditional agriculture to rubber plantations may result in some improvements in carbon sequestration, the shift from forests to rubber plantation leads to a massive loss in carbon sequestration (de Blécourt et al., 2013). Yang et al.'s (2016) study of the Naban River Watershed National Nature Reserve in XSBN found that although a biosphere zoning strategy (i.e., experimental, buffer, core zones) and reforestation activities could enhance the carbon stocks, to date, rubber plantations had not compensated for carbon losses in the natural reserve due to deforestation. However, it is less clear what the effect of rubber expansion on the carbon balance outside the nature reserves in XSBN has been, considering the transition from the combination of forestland and traditional agriculture, including from swidden farming to rubber plantations, that has actually been taking place over recent decades.

The overall goal of this study is to gain a better understanding of the land use change under rubber expansion in XSBN and its implications for carbon balances. The focuses of analysis are on drawing the trajectory of land use change and the rubber expansion of smallholders and the trend of carbon balances over the past three decades in XSBN. Specifically, the analysis will trace how much land, in which years and of what types was converted into rubber. In addition, this study also tries to identify the factors determining the heterogeneity in land use allocation for rubber farming among smallholder rubber farmers in XSBN.

To achieve the above goal, first, this study uses representative household data from 612 smallholder rubber farmers collected through a comprehensive household and village survey conducted in 2013 in XSBN. The dataset includes detailed information on smallholders' land use situation, including historical land use, and therefore provides a unique opportunity to document the temporal patterns of land use transformation experienced by smallholder rubber farmers in XSBN. Second, a simple land use allocation model is established to assess the impacts of farmers' socioeconomic characteristics and geographical conditions on their decision regarding land use for rubber farming. Third, following the study of Yang et al. (2016), which evaluated carbon stocks using the *rapid carbon stock appraisal* method based on tree, plot, land use and landscape assessments, this study simulates the carbon balances of land use systems given the expansion of rubber farming in XSBN over the past three decades. Finally, we discuss the carbon balances stemming from the land use patterns of smallholder rubber farmers in the future under the context of current policy and land constraints.

This study can complement discussions on the future of a rubber-based land use system and its sustainability in XSBN and other similar rubber-growing areas in the Mekong region. Moreover, the findings add to those from studies on rubber plantations in XSBN (e.g., Fu et al., 2009; Xu et al., 2005; Xu, 2006; Zhang et al., 2015) by using a broader empirical base and drawing conclusions on carbon balances (e.g., Blagodatsky et al., 2016; Li et al., 2008; Nizami et al., 2014; Wauters et al., 2008; Yang et al., 2016; Yi et al., 2014; Zhang et al., 2007).

The paper is organized as follows. The next section briefly introduces the data collection and statistically describes the trend in the land use change and the rubber expansion of smallholders in XSBN. Section 3 presents a simple model of smallholders' land allocation for rubber farming and estimation methods for carbon stocks considering the rubber-based land use change. Section 4 reports results, analyzes the determinants of smallholders' land use allocation for rubber farming and simulates the trend of carbon balances with the expansion of rubber plantations. Based on the findings of the analyses, the last section concludes and submits policy implications.

2. Data and Descriptive Statistics

2.1. Data Collection

In this study, we employ household survey data collected from a comprehensive socioeconomic survey of smallholder rubber farmers in XSBN carried out in March 2013. A modular household questionnaire was designed to collect detailed information on rubber farming and other socioeconomic conditions of smallholder rubber farmers. To understand the dynamics of rubber expansion among smallholders, information on planting time, area, density, and the crops in each plot before rubber was planted was collected from every household in the sample. Additionally, we collected plot level information including elevation, which is an important factor for rubber productivity.

A stratified random sampling approach (i.e., stratified by rubber planting area per capita and considering the distribution of rubber planting regions) was applied during the household survey to obtain a representative sample of smallholder rubber farmers in XSBN (Min et al., 2017b). First, 8 townships were stratified and randomly chosen from the rubber planting area in one city (Jinghong) and two counties (Menghai and Mengla) in XSBN: 2 townships were chosen from Menghai due to the relatively low intensity of rubber distribution there, while 3 townships were selected from both Jinghong and Mengla. Second, a total of 42 villages were drawn from the sample townships. Finally, we successfully administered 612 household questionnaires in 42 villages of 8 townships in XSBN. Our sample widely represents the various types of rubber planting regions in XSBN and broadly covered the geographical scope and elevation range of XSBN.

2.2. Sample Characteristics

Table 1 presents the socioeconomic characteristics of the 612 sample households and household heads. The household heads are relatively middle-aged, with an average age of 48. However, the household heads are in general low-educated, having received only approximately four years of education on average. A total of 5% of the population were of the Han majority, 58% represented the Dai minority, 11% the Hani minority and 26% other minorities. Each household has at least five family members. The households on average had been planting rubber for approximately 17 years. Household wealth is proxied by the total value of all non-land productive and consumptive assets (Teklewold et al., 2013). Accordingly, the average wealth is approximately 69.54 thousand yuan/person with a standard deviation of 81.07, reflecting the relatively large inequality of wealth among smallholder rubber farmers. The average farm size was approximately 13 mu, and nearly 85% are planted with rubber. All households are located in mountainous regions, with an average elevation of 756 m above sea level (MASL).

Regarding the characteristics at the village level, the average distance of sample villages to the nearest rubber processing factory is approximately 12.5 km. Approximately 26% of households were located in villages with special agricultural products, while