



# Reorienting paradoxical land use policies towards coherence: A self-adaptive ensemble learning geo-simulation of tea expansion under different scenarios in subtropical China



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## ABSTRACT

The expansion of cash crops has raised contradicting interests between two bureaucratic bodies (the economy-oriented one that advocates cash crop production and the conservation-oriented one that focuses on natural resources protection) in many places around the world. Recent past has saw growing efforts on the theoretical linkages between cash crop production and conservation, but the solutions to the cash cropping –related land use conflicts remain as violent controversy. Using a geo-simulation approach, this paper models the tea expansion under different policy scenarios and evaluates the effectiveness of these policies in Anji County (China), as a contribution to the scientific basis for formulating sustainable cash cropping practices and alternative land use policies. In particular, a new self-adaptive cellular automaton model based on ensemble learning (EL-CA) is developed and three policy scenarios (economy-over-conservation (EOC), conversion-over-economy (COE), and economy-balance-conservation (EBC)) are set to predict the tea expansion patterns in 2025. Results show that the EL-CA model significantly outperforms the traditional CA models based on empirical statistics. We find that the tea expansion under the EOC scenario is much more intensive than that under the COE and EBC scenarios. The most outstanding ecological consequence of tea expansion is the occupation of forests. Employing an equivalent coefficient approach, we further quantify the trade-offs between economic incomes (from tea expansion) and ecological loss (due to ecosystem service value (ESV) declines) under the three policy scenarios. In the EOC scenario, the loss in ESV far exceeds the benefit of tea expansion. Net change of ESV is higher than that of economic return under the COE. The economic benefit is approximately equal to the ecological loss in the EBC scenario. The EBC should be a socially preferred scenario, since it leads to sustainable tea expansion and minimal ecological impacts. Though the EBC scenario is a desirable choice, how to enforce these policies is an important consideration. Given the complexity in the Chinese policy context, we finally propose several possible measures to promote the coherence of paradoxical policies involving the allocation of land for cash crop cultivation.

## 1. Introduction

### 1.1. Global cash crop production –related land use conflicts

Across the globe, market oriented cash crop production systems have gained increasing dominance over ecologically oriented traditional farming systems (Amjath-Babu and Kaechele, 2015; Ehrlich and Pingle, 2008). Such a transition is particularly profound in the deprived regions of developing countries that are featured by accelerating economic development, rapid population growth, and limited land

resources. The expansion of cash crops has been identified as an essential contributor to deforestation and farmland conversion (Gatto et al., 2015; Haberl et al., 2014; Lambin et al., 2001; Su et al., 2016), posing great threat to environmental sustainability (Carlson et al., 2012; Su et al., 2014, 2017; Xiao et al., 2015). It therefore raises contradicting interests between two bureaucratic bodies: the economy-oriented one that advocates cash crop production and the conservation-oriented one that focuses on natural resources protection (Fig. 1). Conservationists consider natural land as ecosystem that needs preservation and restrict the over-profitable use, whereas local

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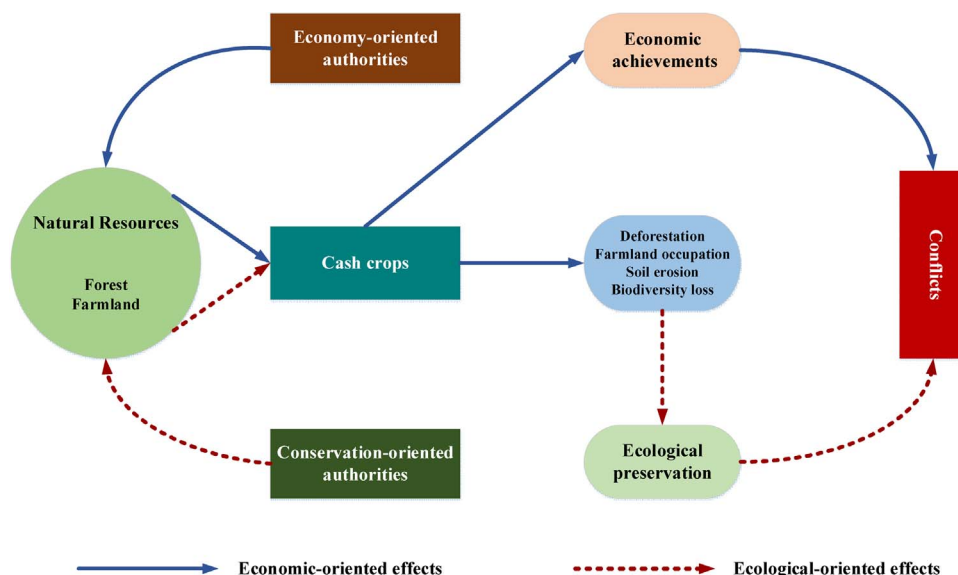


Fig. 1. Conceptual framework for the cash crop production – related land use conflicts.

bureaucrats prefer to over-exploit natural land resources and avoid the conservation task so as to sustain long-term economic achievements (Hubo and Krott, 2013). It makes the situation more complex that smallholders are overwhelmingly responsible for cash crop cultivation in most developing countries (e.g., Laos, China, Indonesia, Malaysia, and Columbia), where forest and farmland are becoming increasingly commoditized. The local farmers expect higher land profitability through cash cropping and ignore the conservation values in terms of ecosystem services. Cash crop production and conservation represent two strongly opposite positions under land scarcity. The diverging interests cannot be satisfied and create land use conflicts as a consequence (Sahide and Giessen, 2015).

Bureaucrats whose responsibility for socioeconomic development, in many countries, are disconnected from those responsible for ecological conservation (DeFries and Rosenzweig, 2010). In practice, land use policies either focus on economic development or target at ecological conservation. Towards different goals, they are mutually exclusive in scope of work, from a spatial perspective. Consequently, cash cropping promotion policies are rarely linked to the ecological conservation efforts (Brussaard et al., 2010). Many cases have demonstrated that cash cropping promotion schemes not only provoked conflicts with ecological protection efforts but also raised questionable effects on socioeconomic development. For example, policies failed to protect the remaining forests that promoted the maize in Madagascar (Scales, 2011), oil palm in Columbia, Indonesia, Malaysia, and Sarawak (Teuscher et al., 2015), biofuel feedstock plantations in Ghan and Laos (Kenney-Lazar, 2012; Neef et al., 2013; Vongvisouk et al., 2016), and rubber in China (Yi et al., 2014), Thailand, and Vietnam (Zhai et al., 2012). Additionally, the extensive cash crop production schemes led to large dispossession of land and even generated adverse outcomes (e.g., land rights, food inflation, poverty) for local communities (Cramb et al., 2009; Fox, 2009; Ngidang, 2002). Perceiving the negative effects on environment and livelihoods, some forest-dependent smallholders in Columbia, Malaysia and Indonesia present opposition over extensive cash crop production schemes (Abram et al., 2017). However, they choose to establish their own oil palms for livelihoods improvement (McCarthy and Cramb, 2009; Mertz et al., 2013). Other farmers in China, Cuba, and Italy to the contrary support the cash cropping policies since they obtain substantial income benefits (Godone et al., 2014; Sato, 2013; Su et al., 2016). The fragmented interests complicate the issue of land use conflicts associated with cash crop production.

Numerous studies have explored the complex issue of land use conflict across different local levels (Harahap et al., 2017; Hares, 2009; Ianoş et al., 2017; Kaya and Erol, 2016; Kovács et al., 2016; Nie, 2006;

Riggs et al., 2016; Sun et al., 2016; Yusran et al., 2017). Recent past has saw growing efforts on the theoretical linkages between cash crop production and conservation (Dhiaulhaq et al., 2014; de Vries et al., 2015; To et al., 2015; Soltani et al., 2016) and the solutions to the cash cropping – related land use conflicts remain as violent controversy. Earlier scholars held a polarized view, either favoring strict conservation in which land use policies should regulate high nature value areas as prohibitive zoning (Gibson et al., 2011; Phalan et al., 2011), or advocating cash cropping intensification through shifting cultivation in which delineating land as untouched is not necessary (Berry et al., 2010; Lambin and Meyfroidt, 2011; Rerkasem et al., 2009; Rudel et al., 2005; Xu et al., 2009). Following authors expressed reconciling views that the conflicting goals of cash cropping production and ecological conservation can be balanced to reach an optimized land use choice (Butsic and Kuemmerle, 2015; Fischer et al., 2014; Grau et al., 2013; Law and Wilson, 2015). Moreover, the optimization can help local people make more rational land use decisions by offering subsidy as new economic opportunities for conservation. Prior publications provide essential references to guide land use policies, but whether they can be transferred as direct instructions to appropriate policy makers remains to be a problem. In this regard, the paradoxical land use policies must be coherent and coordinated to make the balanced choices between cash cropping intensification and ecological conservation. Nevertheless, the existing literature has a rather vague description on the coherence of paradoxical land use policies. Rather few studies have quantitatively compared the impacts of different policy scenarios on land use conflicts.

### 1.2. Paradoxical land use policies related to cash cropping in China

China provides an interesting case for exploring the topic under investigation. Since the open-door economic reform in 1978, China has transformed to a market-oriented economy from a centrally planned economy. Land became a commodity and the “household responsibility system” replaced the original self-supportive agricultural production mode (Su et al., 2016). Cash crops such as the commercial fruits, tea, commercial flowers, energy crops, and rubber have presented an accelerating rapid trend in sowing acreage and production amount (Su et al., 2016). The scientific community has raised concerns on the fast growing cash crop production in China (Wu and Li, 2012) and several observations also report the ecological consequences of cash crop expansion (Su et al., 2014; Yi et al., 2014). Currently, there are no official specialized guidelines on cash crop production in China, but several land use policies from national to local level have close relation with

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