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Tree plantations displacing native forests: The nature and drivers of apparent forest recovery on former croplands in Southwestern China from 2000 to 2015

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ABSTRACT

China is credited with undertaking some of the world's most ambitious policies to protect and restore forests, which could serve as a role model for other countries. However, the actual environmental consequences of these policies are poorly known. Here, we combine remote-sensing analysis with household interviews to assess the nature and drivers of land-cover change in southwestern China between 2000–2015, after China's major forest protection and reforestation policies came into effect. We found that while the region's gross tree cover grew by 32%, this increase was entirely due to the conversion of croplands to tree plantations, particularly monocultures. Native forests, in turn, suffered a net loss of 6.6%. Thus, instead of truly recovering forested landscapes and generating concomitant environmental benefits, the region's apparent forest recovery has effectively displaced native forests, including those that could have naturally regenerated on land freed up from agriculture. The pursuit of profit from agricultural or forestry production along with governmental encouragement and mobilization for certain land uses – including tree planting – were the dominant drivers of the observed land-cover change. An additional driver was the desire of many households to conform with the land-use decisions of their neighbors. We also found that households' lack of labor or financial resources, rather than any policy safeguards, was the primary constraint on further conversion of native forests. We conclude that to achieve genuine forest recovery along with the resulting environmental benefits, China's policies must more strongly protect existing native forests and facilitate native forest restoration. Natural regeneration, which thus far has been grossly neglected in China's forest policies, should be recognized as a legitimate means of forest restoration. In addition, social factors operating at the household level, notably the pursuit of profit and conformation to social norms, should be harnessed to promote better land-cover, biodiversity, and environmental outcomes. More generally, for China and other countries to succeed in recovering forests, policies must clearly distinguish between native forests and tree plantations.

1. Introduction

The recovery of forest landscapes ("forest recovery" hereafter) carries considerable promise for halting and reversing the negative biodiversity impacts of forest loss, mitigating greenhouse-gas emissions, and generating other ecosystem services (Chazdon et al., 2017). For this

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reason, forest recovery is attracting increasing amounts of political attention and financial investment globally (Aronson and Alexander, 2013; Suding et al., 2015). At a landscape scale, forest recovery happens when forest restoration – realized via natural regeneration, artificial reforestation, and/or the spectrum of approaches in between (Suding, 2011) – exceeds forest loss. The gain or loss of forest cover necessarily involves changes in land use and land cover, with concomitant environmental and socioeconomic implications (Foley et al., 2005). Given increasing international attention directed toward forest recovery, understanding the land-cover dynamics involved in forest recovery and their underlying drivers is of great policy relevance (Rudel et al., 2016; Uriarte and Chazdon, 2016; Wilson et al., 2017).

The question of what constitutes a forest is at the core of understanding forest recovery (Chazdon et al., 2016; Sexton et al., 2016). The definition of forest used by the United Nations Food and Agricultural Organization (FAO)–"land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ; it does not include land that is predominantly under agricultural or urban land use" (FAO, 2012)–is widely used in policy discourses worldwide and in the vast majority of national forest statistics. It is also used or implied in a number of prominent international agreements related to forest protection and recovery such as the Bonn Challenge (Bonn Challenge, 2011; see also www.infoflr.org) and the New York Declaration on Forests (United Nations, 2014). However, because this definition includes tree plantations and thus disregards their marked differences from native forests (typically consisting of diverse stands of native species) in terms of environmental, and particularly biodiversity, attributes (for reviews on this topic, see Brockerhoff et al., 2008; Liao et al., 2010; Paquette and Messier, 2010), this definition risks misrepresenting the environmental implications of alleged forest recovery (Putz and Romero, 2014; Wilson et al., 2017; Hua et al., in press). To avoid confusion, in this article we use "tree cover" to represent what FAO defines as forest (i.e. the combination of native forests and tree plantations that meet the defined areal, tree-height, and canopy-cover requirements), and we limit the use of "forest" to the native-forest subset of land cover within the FAO definition, thereby separating it from "tree plantations", which consist of monocultures or simple polycultures of planted trees (Lindenmayer et al., 2012a). Thus, in this article, an increase in tree cover does not necessarily correspond to forest recovery unless it involves an increase in the extent of native forests.

China is said to have undergone a remarkable increase in tree cover over the past three decades: According to the state forest inventory, China's tree cover – reported in the inventory as "forest cover" – has increased from 12% of the country's terrestrial area in 1981 to 21.4% in 2013 (SFA, 1999–2014; see Hua et al., in press for a visualized time series of the inventory data). Such an increase is without precedent in such a short period of time in any large nation. At least for the period after year 2000, as remotely sensed land-cover data became more accessible, reports of increases in China's tree cover have generally been corroborated by remote-sensing studies (Ren et al., 2015; Ahrends et al., 2017; Li et al., 2017). These increases are considered to be particularly attributable to a system of state programs begun in the late 1990s to promote forest protection and reforestation for ecological benefits (Robbins and Harrell, 2014; Yin and Yin, 2010), and they have been widely credited with generating enormous environmental benefits (Liu et al., 2008; Deng et al., 2014; Ouyang et al., 2016). However, multiple local studies suggest that China's recent increase in tree cover has been dominated by tree plantations, usually monocultures (Hua et al., 2016), while native forests continue to be lost (Greenpeace East Asia, 2013–2015; Li et al., 2007; Zhai et al., 2014). Such reports highlight the fact that without differentiating between tree plantations and native forests, it is impossible to know what the increase in tree cover means for China's *forest* recovery, and indeed, for the ecological benefits that are the primary goal of the country's forest policies.

Currently, assessments of China's tree-cover dynamics that distinguish between native forests and tree plantations since the late 1990s are non-existent at the national scale and scarce at the regional scale (e.g. Hu et al., 2014; Li et al., 2007; Zhai et al., 2014). Moreover, little is known about the factors driving land-cover change related to trees, particularly why, according to some sources, native forests continue to be lost despite major government policies intended to protect them, such as the Natural Forest Protection Program (NFPP; Ren et al., 2015). While there are suggestions that NFPP and other forest policies contain loopholes that inadvertently and perversely favor tree plantation expansion over the retention of native forest (Greenpeace East Asia, 2013–2015; Zhai et al., 2014), evidence of this has been anecdotal. Thus, understanding the nature and underlying drivers of land-cover dynamics related to China's tree-cover increase, and, in particular, differentiating between tree plantations and native forests, are key to understanding the environmental implications of China's increase in tree cover and to designing effective policies to maximize its ecological benefits.

In this study, we aim to understand the nature and drivers of land-cover dynamics involved in the increase in tree cover in southwestern China between 2000–2015, a region that, according to China's state forest inventory and numerous remote-sensing studies, has undergone significant tree-cover increase during this period (Li et al., 2017; Xu et al., 2006). We combine remote-sensing analysis and household interviews to ask two key questions. First, what is the nature of land-cover dynamics involved in the region's increase in tree cover, i.e., what vegetation type(s) provided the land for the increase in tree cover, and what proportion of the increase is due to tree plantations versus native forests? Second, what social and economic factors drove the land-use choice pertaining to tree cover in the region? Our goal is to provide recommendations to ensure that China's forest policies maximize the ecological benefits that can be obtained through forest recovery, including biodiversity conservation. This need is particularly salient considering China's heavy expenditures on forest protection and reforestation (Liu et al., 2008; Robbins and Harrell, 2014). Additionally, China's experience could also be informative to other developing countries, as they grapple with the challenges of recovering their forest landscapes (Hosonuma et al., 2012; Wilson et al., 2017).

2. Study region

We focused on a region of ~15,800 km^2 in south-central Sichuan Province in the transition zone from the western Sichuan Basin to the Hengduan mountain range (Fig. 1). The study region spans an east-to-west elevational gradient of 300–5000 m with an accompanying gentle-to-steep topographical gradient. The area below treeline was historically forested but suffered deforestation throughout the region's long human settlement history, which continued well into the late 1990s (Elvin, 2004; Liu and Tian, 2010). According to China's state forest inventory and numerous remote-sensing studies, it has more recently witnessed substantial tree-cover increase since the late 1990s (SFA, 1999–2014; Liu et al., 2014; Li et al., 2017).

Importantly, the region has been part of China's two largest forest programs: the NFPP, aimed at protecting and regenerating native forests (Ren et al., 2015), and the Grain-for-Green Program (GFGP), aimed at curbing soil erosion via compensated retirement of sloped croplands followed by reforestation (Delang and Yuan, 2015). The NFPP was introduced in 1998 and has been responsible for ~$19 billion in expenditures nationwide through 2010 (Ren et al., 2015). The GFGP was introduced in 1999 and has expended ~$47 billion nationwide through 2013 (Hua et al., 2016); it has been the single largest reforestation scheme in the study region over the past two decades. Both programs are ongoing and are expected to last until at least 2020 (NDRC, 2014; SFA, 2011). Official statistics for the region claim that the two programs have substantially curbed tree-cover loss and contributed to tree-cover regrowth from 2000 to 2015 (SFA, 1999–2014; Ren et al., 2015). On the other hand, considerable loss of native forests in the region has also