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Evaluating forest policy implementation effectiveness with a cross-scale remote sensing analysis in a priority conservation area of Southwest China

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A B S T R A C T

China's Natural Forest Protection Program (NFPP) and Sloping Land Conversion Program (SLCP), introduced in 1998 and 1999, respectively, are integral parts of the world's largest reforestation effort. State-reported forest cover data indicate effective policy implementation through net forest cover expansion but overlook the scale-dependence of and spatial variation in forest cover change patterns and also lack reliable data on small-scale and illegal logging. As a result, there is considerable uncertainty over the spatial distribution of forest cover change and ultimately the policies' effectiveness at increasing forest cover. This research uses Landsat Thematic Mapper imagery-derived multitemporal Tasseled Cap variables and a decision tree classifier to map short- and long-term forest cover change across three administrative levels in the priority conservation area of Diqing Tibetan Autonomous Prefecture in Yunnan Province. Results indicate a 73% reduction in the rate of forest cover loss and a more than doubled rate of forest cover gain from 1990–1999 to 1999–2009 across the prefecture, both of which support a positive assessment of policy implementation. However, prefectural results are countered by spatially disparate forest cover gain and loss trends at the county- and township-level in the decade following the policies' introductions. Further, more than half of Diqing's townships, mainly those in the prefecture's south where tourism has been rapidly developing, saw continued net forest cover loss attributable to small-scale timber harvesting for tourism-driven construction. This research thus exposes cross-scale spatially disparate forest cover change indicative of highly differentiated policy implementation effectiveness, and shows the pattern by which regional development has redirected, rather than reduced, forest cover loss, contrary to the goals of the NFPP and SLCP.

Introduction

Introducing the NFPP and SLCP

Deforestation has been the dominant historical land cover change in China as forests have been cleared en masse for agricultural land use or harvested for fuelwood and timber (He, Ge, Dai, & Rao, 2008; Menzies, 1992). During the modern era of the People's Republic of China (PRC), the Great Leap Forward (1966–1976) followed by the opening of commercial timber markets in the early 1980's brought an increased annual rate of commercial harvesting in some regions to five times that of natural forest regrowth by the mid-1980's (Winkler, 2003). However, in the late 1990's, a dramatic shift in Chinese forest policy design came in response to a series of eight floods that swept through the Yangtze River in the summer of 1998 and took between two and four thousand lives and caused approximately 170 billion RMB (12 billion USD) in damages (Yeh, 2009). With deforestation identified as the primary factor responsible for the flooding, policy design shifted away from the commercial viability of forests and towards sustainable management (Liu & Tian, 2010; Zhang et al., 2000).

Introduced in August 1998, only days after the floodwaters had receded, the Natural Forest Protection Program (NFPP) (天然林保护工程), alternately translated as the Natural Forest Conservation Program (NFCP), sought to "protect natural forests, facilitate

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forestation, and build planted forests" (CAS, 2007). The NFPP closed timber markets in the upper Yangtze by September 1998 (Hillman, 2003), required the four largest logging companies to promptly halt logging in primary forests (Wang, Innes, Lei, Dai, & Wu, 2007), and initially banned all logging in the upper Yangtze though this complete ban was soon relaxed to allow for subsistence use. Similar restrictions soon spread to 17 provinces and autonomous regions in the Yangtze River headwaters containing 69% of China's total natural forest cover (Mullan, Kontoleon, Swanson, & Zhang, 2009; Yin, Xu, Li, & Liu, 2005).

The NFPP initially sought to increase national forest cover to 19% by 2010 (Zhang et al., 2000) and has since been renewed through 2020 with the goal of increasing national forest cover to 25% (SFA, 2011). In addition to the logging ban, the NFPP has funding for afforestation and reforestation through aerial seeding and manual planting. Afforestation has been aggressively pursued with widespread tree planting on hillsides and barren lands complemented by a complete restriction on resource use across 31 million ha of land that had been afforested or had the potential to support forests. In 1999, the NFPP was joined by the Sloping Land Conversion Program (SLCP) or "Grain for Green" program (退耕还林工程), a program designed to limit soil erosion across 25 provinces by decreasing agricultural cultivation on steeply sloped lands (Démurger, Fournier, & Shen, 2005). The goal of the SLCP is to convert over 14 million ha of agricultural lands to forests, which include 4.4 million ha of steep (greater than 25°) agricultural lands, and to afforest over 17 million ha of "wasteland," lands that are degraded or out of active land use for other reasons (Liu, Li, Ouyang, Tam, & Chen, 2008; Yeh, 2009).

Policy implementation evaluations

In only the first two years following the NFPP's introduction, national timber harvest levels dropped from 29 million m^3 to 14 million m^3 (Zhang et al., 2000; Zhao & Shao, 2002) and, by 2009, China had established itself as the global leader in afforestation with nearly 6 million ha of afforested land (Wang et al., 2007; Yu et al., 2011). The State Forest Administration's (SFA) National Forest Resource Inventory (NFRI) data – based on county-level ground surveys every five years – has been the primary dataset used to quantify forest cover change. NFRI data show a 3.2% net national forest cover gain between 1995 and 2000 and a 3.6% net gain between 2005 and 2010 under expanded policy implementation (FAO, 2000, 2012). By 2010, Chinese national forest cover had already reached 22%, surpassing the NFPP's initial goal of 19% national forest cover (FAO, 2012; Xu, 2011), and was quickly approaching the goal of 25% forest cover by 2020.

While these trends suggest effective policy implementation, the value of NFRI data is limited by a host of reasons: the lack of spatially-explicit and historical inventories (Miao & West, 2004; Yin, Yin, & Li, 2009; Zhang & Song, 2006), shifts in the formal definition of "forest" (Ho, 2005; Miao & West, 2004), misleading reforestation assessments (Liu & Tian, 2010), and unaccounted for impacts of small-scale, selective or illicit logging (Melick, Yang, & Xu, 2007b; Xu & Wilkes, 2004). Further, NFRI data disagree with UNEP/SEPA (United Nations Environment Program/Strategic Environmental Policy Assessment) data on the amount of national forest cover in 2000 by as much as 7.5% of China's total land area (Sayer & Sun, 2003) as well as Liu et al. (2005) who measured a 0.52% decrease in national forest cover during the 1990's while NFRI data reported a contemporary increase of 1.94% (FAO, 2000).

Moreover, results from multiple case studies (e.g., Ives, 2006; Liu & Tian, 2010; Trac, Harrell, Hinckley, & Henck, 2007; Xu, Katsigris, & White, 2002) counter NFRI-backed claims of policy effectiveness and expose great variability in implementation (Yeh, 2009). Xu, Tao, and Amacher (2004) found that NFRI-reported gains in forest cover could not be verified during site visits across 28 provinces. Using 250-m resolution MODIS imagery, Li et al. (2013) measured regional variability of recent forest cover change in central China, and found "no significant change in forest cover" in over half of the studied townships. Collectively, these case studies illustrate cross-scale variability unseen in NFRI data but exposed through spatial disaggregation and inter-regional forest cover change comparisons.

Study overview

To measure the scale-dependent, spatiotemporal variability of forest cover change during NFPP and SLCP implementation, this research employs classified forest cover change maps based on Landsat satellite imagery in the priority conservation area of Diqing Tibetan Autonomous Prefecture, southwest China, in two ways that address the limitations of previous evaluations conducted at a single spatiotemporal scale. First, by measuring changes in the annual rate of forest cover change in Diqing across three administrative levels (i.e., prefecture, county, and township), this research exposes spatially differentiated forest cover change patterns resulting from various processes catalyzed by the policies' introductions. Second, by adopting two temporal scales (i.e., short- and long-term), this research examines the varying contributions of selective logging, industrial logging, and forest regeneration to forest cover change during policy implementation.

Study area

Because of its hydrologic importance at the Yangtze headwaters, history of widespread deforestation, and status as a biodiversity hotspot (Xu & Wilkes, 2004), Diqing Prefecture presents an ideal case study to evaluate the success of the NFPP and SLCP at promoting forest cover expansion. Diqing (Fig. 1) is located in northwest Yunnan Province just southeast of the Qinghai-Tibetan Plateau, straddles the north-south running Hengduan Mountains between 1500 and 6700 masl with an average elevation of 3400 masl, and sees 300–950 mm of annual precipitation, most of which falls between June and September (Sherman, Mullen, Li, Fang, & Wang, 2007). Diqing is approximately 2.3 million ha in size – slightly larger than the US state of New Jersey – and includes three counties, Deqin, Weixi, and Shangri-La, which collectively comprise thirty townships. Ethnic Tibetans account for 33% of Diqing's 350,000 residents across 1300 villages, towns, and cities (National Bureau of Statistics, 2005). Grasslands and pine forests are found at elevations up to 3000 masl; mixed alpine coniferous (fir, pine, and spruce) and oak trees constitute the majority of mid-elevation forests between 3000 and 4000 masl on south- and north-facing slopes, respectively; alpine heath and meadows occupy 3800 to 4800 masl; and alpine ecosystems extend to 6500 masl (Weyerhaeuser, Wilkes, & Kahrl, 2005; Willson, 2006; Winkler, 1998).

NFRI data report 65% forest cover in 2000, an amount well above the average of Yunnan Province (33%) or China (13%) (DYED, 2006) and which rose to 67% by 2005 and 75% by 2011 (Kunming Daily, 2011). There is no comprehensive report on the extent of historical forest cover change but available data suggest that over 20% of the prefecture's conifer forests were commercially harvested in the two decades prior to the NFPP's introduction (Xu & Ribot, 2004). The loss of forest cover to industrial logging was most pronounced in southern Weixi and Shangri-La counties, supported by existing roadway infrastructure and less topographic relief and better market access than the rest of Diqing (Hillman, 2003; Willson, 2006). Over 30% of Diqing's forests have been collectively managed since the mid-1960's and remained broadly off-limits to industrial logging (Qiang, H. Personal communication, July 20,