



# Effects of national forest-management regimes on unprotected forests of the Himalaya

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**Abstract:** Globally, deforestation continues, and although protected areas effectively protect forests, the majority of forests are not in protected areas. Thus, how effective are different management regimes to avoid deforestation in non-protected forests? We sought to assess the effectiveness of different national forest-management regimes to safeguard forests outside protected areas. We compared 2000–2014 deforestation rates across the temperate forests of 5 countries in the Himalaya (Bhutan, Nepal, China, India, and Myanmar) of which 13% are protected. We reviewed the literature to characterize forest management regimes in each country and conducted a quasi-experimental analysis to measure differences in deforestation of unprotected forests among countries and states in India. Countries varied in both overarching forest-management goals and specific tenure arrangements and policies for unprotected forests, from policies emphasizing economic development to those focused on forest conservation. Deforestation rates differed up to 1.4% between countries, even after accounting for local determinants of deforestation, such as human population density, market access, and topography. The highest deforestation rates were associated with forest policies aimed at maximizing profits and unstable tenure regimes. Deforestation in national forest-management regimes that emphasized conservation and community management were relatively low. In India results were consistent with the national-level results. We interpreted our results in the context of the broader literature on decentralized, community-based natural resource management, and our findings emphasize that the type and quality of community-based forestry programs and the degree to which they are oriented toward sustainable use rather than economic development are important for forest protection. Our cross-national results are consistent with results from site- and regional-scale studies that show forest-management regimes that ensure stable land tenure and integrate local-livelihood benefits with forest conservation result in the best forest outcomes.

**Keywords:** community-based forestry, environmental policy, logging ban, Mahalanobis matching, sustainable development

Efectos de los Regímenes de Manejo de los Bosques Nacionales sobre los Bosques Desprotegidos del Himalaya

**Resumen:** La deforestación continúa a nivel mundial y aunque las áreas protegidas protegen eficientemente a los bosques, la mayoría de éstos no están en áreas protegidas. Por lo tanto, ¿qué tan efectivos son los diferentes regímenes de manejo para evitar la deforestación en los bosques sin protección? Comparamos las tasas de deforestación de 2000 a 2014 en los bosques templados de cinco países del Himalaya (Bután, Nepal, China, India y Myanmar), de los cuales el 13% está protegido. Revisamos la literatura para caracterizar los regímenes de manejo forestal en cada país y realizamos un análisis casi experimental para medir las diferencias en la deforestación de los bosques desprotegidos entre los países y los estados de la India. Los países variaron desde los objetivos dominantes del manejo forestal y los arreglos específicos por antigüedad y las políticas para los bosques desprotegidos, desde políticas que enfatizan el desarrollo económico hasta aquellas enfocadas en la conservación forestal. Las tasas de deforestación difirieron hasta un 1.4% entre los países, incluso después de representar los determinantes locales de la deforestación, como la densidad poblacional humana, el acceso al mercado y la topografía. Las tasas más altas de deforestación estuvieron

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*asociadas con políticas forestales dirigidas a la maximización de las ganancias y regímenes inestables de antigüedad. La deforestación dentro de los regímenes de manejo forestal que enfatizaron la conservación y el manejo comunitario fue relativamente baja. En la India, los resultados fueron consistentes con los resultados a nivel nacional. Interpretamos nuestros resultados dentro del contexto de la literatura generalizada sobre el manejo de recursos descentralizado y basado en la comunidad. Nuestros hallazgos enfatizan que ese tipo y calidad de programas forestales basados en la comunidad y el grado en el que están orientados hacia el uso sustentable en lugar del desarrollo económico es importante para la protección forestal. Nuestros resultados trans-nacionales son consistentes con los resultados de estudios a escala regional y de sitio que muestran que los regímenes de manejo forestal que aseguran una antigüedad estable de suelo e integran los beneficios del sustento local con la conservación forestal resultan en mejores resultados forestales.*

**Palabras Clave:** desarrollo sustentable, emparejamiento Mahalanobis, política ambiental, prohibición de la tala, silvicultura basada en la comunidad

## Introduction

Despite efforts to protect Earth's forests, deforestation has accelerated (Kim et al. 2015; Morales-Hidalgo et al. 2015) and is especially persistent in developing countries because forests are still the main source of timber, fuelwood, and cultivable land for local needs and because of external demands for timber from other countries that are successfully protecting their own forests (Meyfroidt et al. 2010). In general, protected areas limit deforestation in developing economies (Joppa & Pfaff 2010; Ren et al. 2015; Bowker et al. 2017). However, protected areas encompass only a small proportion of Earth's forests (Bertzky et al. 2012). In forests outside protected areas, deforestation rates differ widely among countries (Hansen et al. 2013), and the causes of these differences are not well understood.

National forest-management regimes and associated policies can have a large impact on deforestation because they are ultimate, not just proximate, drivers of forest-related activities (Lambin & Geist 2006). The overarching goals of forest management can vary widely, from rapid economic development via timber extraction, to sustainable use, to supporting local livelihoods (Lambin & Meyfroidt 2010). Forest-management regimes implemented to achieve these overarching goals differ in terms of land-tenure arrangements (i.e., government, private, or community forest management), and extent to which conservation is included (e.g., protected areas and logging bans). Although social, cultural, political, and economic conditions shape national forest-management regimes and can limit their effectiveness, there has been disproportionate attention to these conditions as drivers of deforestation relative to national forest management itself as a driver of deforestation (Geist & Lambin 2002; Bare et al. 2015). Most researchers examining aspects of national forest management (e.g., degree of decentralization) use qualitative case studies or focus on village-level impacts of management (Lund & Treue 2008; Miller et al. 2015; Wright et al. 2016). These authors have explicitly called for more robust, cross-national studies and use of remote-sensing data to examine the relationships

between national management regimes and conservation outcomes.

A major challenge when assessing the effects of forest-management regimes is how to isolate the effects of a forest-management regime from other factors that can also influence deforestation. For example, countries with high population densities are probably more vulnerable to deforestation. One approach to control for factors not related to forest policy in national comparisons is cross-border analysis (i.e., comparison of deforestation along the border area of 2 countries) (Grogan et al. 2015). However, cross-border comparisons require a common border in an environmentally homogeneous region, and deforestation differences in border areas may be associated with border-specific factors including migration, leakage (i.e., demand in one area, where exploitation is restricted, is satisfied with exploitation of another area, where exploitation is not restricted), and trade (EIA 2015).

An alternative approach to examining the effect of conservation policies is to isolate policy and management-regime effects via quasi-experimental counter-factual matching analysis (Andam et al. 2008). Bias is controlled by matching treatments with controls. So-called treatment parcels (e.g., forested parcels under management regime A) are randomly selected and matched to so-called control parcels (e.g., forest parcels under regime B that are statistically similar in terms of their deforestation pressure to those under regime A). With the matched samples, it is possible to predict what outcomes would have been observed in forests under regime A had they been subject to regime B. Matching has been used to assess effectiveness of protected areas (Nolte et al. 2013; Ferraro et al. 2015; Robalino et al. 2015), community forests (Brandt et al. 2015; Rasolofoson et al. 2015), concessionary management (Bruggeman et al. 2015; Brandt et al. 2016), and certification policies (Miteva et al. 2015). However, to our knowledge, matching has not been used to compare forest-management regimes.

Our overarching goal was to empirically associate differences in deforestation rates with national forest-management regimes in unprotected forests. There is little precedent for systematically characterizing national

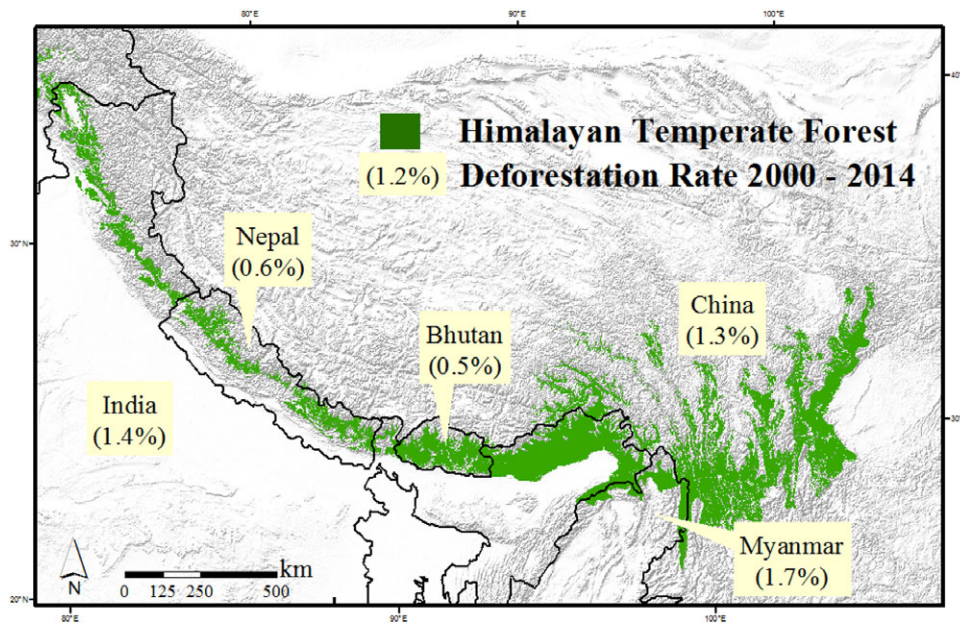


Figure 1. The Himalayan temperate forest zone and deforestation rates (in parentheses) from 2000 to 2014 in forests that are not officially protected.

forest-management regimes. We focused on degree of decentralization and permitted community management. Although some scholars question the benefits of decentralization (see Wright et al. 2016), the majority of site- and regional-scale research suggests decentralized control accompanied by secure land-tenure rights can lead to successful forest conservation (Agrawal & Ostrom 2001; Agrawal & Chhatre 2006; Coleman 2009). We also considered the degree to which a country's national policy emphasizes use of forests for economic development versus sustainable use and conservation. Although there is some evidence that economic growth can reduce deforestation over the long term (Ehrhardt-Martinez et al. 2002), we expected that policies that emphasize conservation and sustainable use over economic development would lead to lower deforestation rates.

We studied the Himalayan temperate forest biome (Fig. 1), which spans China, Myanmar, India, Bhutan, and Nepal. These countries have distinct approaches to forest management and provide an ideal natural experiment for comparing outcomes of diverse national forest-management regimes. We sought to characterize national forest-management regimes in each country; measure differences in deforestation rates among countries and states within India with a matching approach; and compare matching-based estimates with those derived from a cross-border approach.

## Methods

### Study Area

The Himalayan temperate forest zone extends in an arc of 3,000 km from southern Afghanistan to southwest China (Olson et al. 2001). The biome spans 2 of Earth's biodiver-

sity hotspots (Myers et al. 2000) and has one of the highest percentages of endemic and threatened species in the world (Grenyer et al. 2006). Many of these threatened species rely on forests, but logging has recently increased and regeneration of logged areas back to high-diversity forests is hampered by harsh climate, steep topography, and livestock grazing (Ives 2004; Brandt et al. 2012). Five countries contain >98% of the remaining forests: Bhutan, Nepal, India, China, and Myanmar. The Himalayan region has been populated by diverse ethnic groups for thousands of years, and local people depend on forests for their livelihoods.

### Characteristics of National Forest-Management Regime

To characterize forest-management regimes, we reviewed 37 peer-reviewed articles and 15 documents in the gray literature that contained information about relevant forest-related policies for each country. (Supporting Information contains a full list.) For India we also reviewed state policies for the states that contain temperate forest (Himachal Pradesh, Uttarakhand, Sikkim, and Arunachal Pradesh; MOEF 2005; Gupta 2007; HPFD 2013; Chettri et al. 2015). We did not analyze subnational policies for Nepal, Bhutan, or Myanmar because forest policies are relatively uniform in these countries, and in China policies were similar for Yunnan and Sichuan and not discoverable for the Tibet Autonomous Region. We used publicly available databases to determine the proportion of forest under 4 tenure categories: government protected area, government unprotected area, community, and private based on the Rights and Resources Initiative (RRI 2014) forest tenure database and the World Database of Protected Areas (UNEP-WCMC 2016).



## Comparison of Forest Conservation Outcomes

Deforestation was our measure of forest conservation outcomes, and we derived it from a publicly available data set of global forest change (Hansen et al. 2013), which is based on 30-m Landsat imagery. We defined forest as pixels that in 2000 had greater >50% cover of trees >5 m in height and deforestation as a stand-replacing disturbance or a change from a forested to unforested state from 2000 to 2014.

The countries in our sample differ in several socioeconomic and environmental characteristics that influence deforestation. We controlled for these factors as much as possible to isolate the effects of the national forest-management regime on deforestation. Thus, we took a 2-step approach. First, we calculated the average deforestation rate from 2000 to 2014 for each country's temperate forest zone. Second, we used matching to perform pair-wise comparisons of the deforestation rate in each country. Specifically, we applied Mahalanobis matching with replacement and bias adjustment to match cells in 1 country with cells in another country. For example, to compare China with Bhutan, we identified forest cells in Bhutan that were similar to China forest cells in terms of the deforestation pressure the forests were under. Prior to matching, we aggregated forest cover and covariate data into 1-km cells to achieve a sample size that was computationally feasible and consistent with similar analyses (Ferraro et al. 2013; Nolte et al. 2013). The study area contained 564,726 cells, of which 372,791 (66%) contained forest in 2000. For each pairwise comparison, we randomly sampled 20% of the treatment parcels and matched them with control parcels. The validity of matching estimators is influenced by the extent to which the pool of potential controls contains units that are sufficiently comparable to treatment units. Therefore, we applied a caliper to drop treatment parcels for which no comparable control parcel could be found within 0.5 SD of each covariate. To compute the reverse estimate, we switched control and treatment group. We repeated this procedure for all 10 possible pairwise combinations of countries and for states within India.

We excluded forests within protected areas from the analyses. The 5 countries have distinct protected-area strategies as indicated by strong differences in International Union for Conservation of Nature (IUCN) categorization among countries (UNEP-WCMC 2016). To avoid confounding the effect of national forest-management regime with the effect of protected-area designation, we analyzed only those forests without an IUCN designation (i.e., unprotected area forests). We controlled for 7 covariates (i.e., factors that influence deforestation): distance to market, population density, slope, elevation, precipitation, temperature, and percent forest cover in 2000. These variables capture the vulnerability of a given parcel to deforestation across a variety of social and en-

vironmental contexts. Forests closer to major markets or embedded in relatively dense transportation networks are more accessible and thus are more vulnerable to deforestation (Nolte et al. 2013; Brandt et al. 2015; Bowker et al. 2017). We used a global data set of travel time to the nearest market (Nelson 2008) to estimate distance to market and transportation networks. A given parcel's population density is indicative of its accessibility and the intensity of forest use, both of which have been linked to higher deforestation (Andam et al. 2008; Ferraro et al. 2013). We used the global LandScan population database to estimate population density in 2000 (Bright & Coleman 2001). Elevation and slope are primary determinants of land use because they influence agricultural potential, forest composition, and accessibility. For example, forests in areas of relatively low elevation and slope are more vulnerable to deforestation because they are more accessible (Joppa & Pfaff 2009). We calculated slope and elevation from the 90-m-resolution digital elevation model recorded by the Shuttle Radar Topography Mission. Climatic factors drive agricultural suitability and forest composition in mountainous regions; thus, climate also directly influences deforestation pressure (Sarmiento 2000; Brandt & Townsend 2006). We derived mean precipitation and temperature measures from WorldClim, which represents average climate for 1950–2000 (Hijmans et al. 2005).

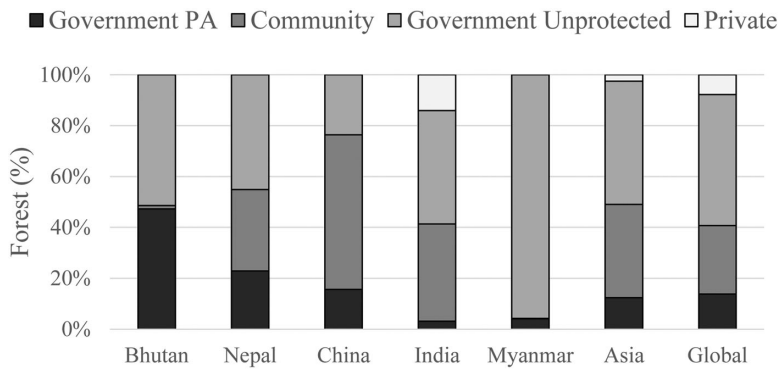
In addition to the quasi-experimental approach, we performed a cross-border analysis along 3 randomly selected borders: China–Myanmar, Bhutan–India (eastern border), and Nepal–India (eastern border). We calculated the mean deforestation rate within 20 km of both sides of the border. We performed the cross-border analysis to validate the ability of the matching approach to estimate differences in deforestation between countries.

## Results

### Characteristics of the Forest-Management Regimes

Bhutan's national policy goal is to maximize gross national happiness, and environmental sustainability is 1 of its 4 pillars (Brooks 2013). Bhutan has pursued forest conservation almost exclusively through centralized management (Bruggeman et al. 2016), and nearly all forests (~98%) are owned and managed by the government (Fig. 2). Of Bhutan's forests 46% are protected, 52% are reserve forests, and 2% are managed by communities (Dorji & Schmidt 2014). The nationalization of forests eliminated legal status for traditional forest management, although such practices remain (Dorji et al. 2006; Buffum 2012).

Nepal has progressive community-forestry and protected-area policies that give management responsibility to and provide benefits for local communities



**Figure 2.** Percentage of forest in 4 major classes of land-tenure arrangements in 5 countries, in Asia, and globally: government protected area (PA) (UN Statistics Division 2016), community forest (community), unprotected government area (government unprotected), and private ownership (private) (Rights and Resources Initiative 2014).

(Heinen & Shrestha 2006; Ojha et al. 2009). Of Nepal's forests, 68% are managed by the government, including 23% in protected areas (Fig. 2). The remaining 32% are under community management. Of the countries in this study, Nepal has the best record of successful community management (Shyamsundar & Ghate 2014). Nepal's community forestry gives control to communities and includes high levels of monitoring and enforcement (Nagendra 2007). Community forestry has had positive effects because it motivates communities without legal tenure to practice community forestry in nearby government forests (Bluffstone et al. 2015). Nepal has also experimented with different forms of community management, including leasehold forests, protection forests, and collaborative-management forests.

In India 38% of the forests are managed by communities, 45% are government managed (5% in protected areas), and 14% are in private ownership. India has a national community-forestry program called joint forest management (JFM). How much forest is governed and management quality under JFM (ENVIS 2016) (Table 1) varies considerably by state (Chate & Ghate 2013). Uttarakhand and Himachal Pradesh have additional forms of formally recognized community forest manage-

ment that play important roles in forest conservation. Uttarakhand has Van Panchayats (VP), community-managed forests dating back to colonial times, that are generally more effective than forests managed under JFM (Agrawal & Ostrom 2001; Ballabh et al. 2002) and state-managed forests (Somanathan et al. 2009; Baland et al. 2010). The number of Van Panchayats in Uttarakhand has increased from approximately 6000 in 2002 (nearly 30% of the forest area of the state) to 12,089 as of 2013 for the 15,761 villages in the state (Hussain et al. 2013). The effective enforcement of local rules there resembles Nepal's community-forestry system (Agrawal & Ostrom 2001). Himachal Pradesh also has strong, traditional, community forest management, with high levels of autonomy and secure tenure rights (Hobley 1992; Vasan 2001; Naidu 2011). Sikkim has little traditional forest management, although forests managed by the state allow for extraction by communities (Thakur et al. 2005) and traditional forest management is supported by the state government despite a lack of formal recognition (Chettri et al. 2015). Sikkim also has far more land in protected areas than the other 3 states (38%). Arunachal Pradesh has little forest under JFM (2%) and, although traditional forest management occurs in 62% of the state's forest,

**Table 1.** Proportion of forest under joint forest management (JFM) and in protected areas in each Indian state with Himalayan temperate forest and ranking of quality of community management based on a literature review.

State	Forests under JFM (%)	Forests in protected areas (%)	Total forests under some community ownership or management	Relative ranking of community-management success	Source
Uttarakhand	16	14	>30% in Van Panchayats (community forests) officially recognized by the government	1	ENVIS 2015
Himachal Pradesh	6	11	diverse traditional community management officially recognized by government	2	Forest Department 2013
Sikkim	16	38	little traditional community management	3	Chettri et al. 2015
Arunachal Pradesh	2	11	~60% under traditional community management but not recognized by government	4	Gupta 2007

there is no formal JFM recognized by the state government (Poffenberger et al. 2006). Arunachal Pradesh, like the rest of northeast India, was relatively isolated until India's independence. Since then, the government forest policy has prioritized timber production at the expense of traditional forest management (Mitra 1998).

China has the most forest under community management (61%); 39% is under government management (Fig. 2). Community forests are managed through China's collective forestry program, which has historically focused on timber extraction (Weyerhaeuser et al. 2005; Weyerhaeuser et al. 2006). However, frequent changes in forest policies have resulted in unstable and insecure tenure of forest resources (Baohua 2006; Zackey 2007). In many places, collective rights have been devolved to households rather than communities (Dachang 2001). In addition, the locus of control is inconsistent from forest to forest; government officials, rather than communities, often retain control over forest-management decisions (He 2016). In 1998 China implemented the National Forest Conservation Plan (NFCP), which banned commercial logging in southwestern China (Liu et al. 2008) but allowed harvesting by collectives, primarily for economic development (Vemuri 2008; Yang et al. 2015). New regulations in 2008 allowed for increased commercial use including commercial logging and tourism (Yang et al. 2015).

Myanmar has weak forest policies and unstable tenure regimes (Lin 2004; Woods 2015), partly due to decades of military rule and conflict (Ireland 2008). Myanmar has colonial-style centralized forest ownership and control by the national government (Bryant 1996). Forest-management prioritizes timber extraction for export, and both illegal logging and conversion for commercial agriculture are widespread (Woods 2015). Myanmar has one of the highest deforestation rates of in the world (FAO 2014). Kachin State, the northernmost state where Myanmar's temperate forest is located, has had large-scale timber extraction by Chinese companies since the late 1990s and has the second highest number of agribusiness concessions in the country after Tananatharyi State in the far south (Woods 2015).

### Differences in Deforestation

Rates of deforestation rates in unprotected areas of Himalayan temperate forests from 2000 to 2014 (Fig. 1) were lowest in Bhutan and Nepal (0.5% and 0.6%, respectively). China's and India's deforestation rates were much higher (1.3% and 1.4%, respectively). Myanmar had the highest deforestation rates (1.7%).

Matching (Fig. 3) indicated that Bhutan's national forest-management regime was associated with the most positive forest conservation outcomes. Forest parcels in Bhutan had lower deforestation rates than matched parcels in China, Myanmar, and India (−0.5%, −1.4%, and

−0.1%, respectively), and deforestation rates in Bhutan were not significantly different from Nepal (0.03%). Nepal had less deforestation than China (−0.7%) and Myanmar (−2.7%) and about the same deforestation as Bhutan (−0.02%) and India (−0.06%). India also had relatively low deforestation rates; less deforestation than China (−0.5%) and Myanmar (−1.4%); the same deforestation as Nepal (−0.01%) and more deforestation than Bhutan (0.3%). China had the second-worst deforestation rates. China had higher deforestation rates than Bhutan (0.2%), Nepal (0.1%), and India (0.5%) and deforestation rates similar to Myanmar (0.3%). Myanmar had the poorest outcomes for conservation as demonstrated by relatively high effect sizes, and it had higher deforestation rates than Bhutan (1.4%), Nepal (1.4%), India (1.0%), and China (0.5%). Raw estimates for all comparisons are in Supporting Information.

The intrastate matching analysis for India revealed significant differences in deforestation rates among states (Fig. 4). Sikkim and Uttarakhand had the lowest deforestation rates, Himachal Pradesh intermediate rates, and Arunachal Pradesh the highest deforestation rates. Specifically, Sikkim had lower deforestation rates than Arunachal (−1.0%) and deforestation rates similar to Uttarakhand (−0.004%) and Himachal (0.2%). Uttarakhand had lower deforestation rates than Himachal (−0.1%) and Arunachal (−0.7%) and higher rates than Sikkim (0.2%). Himachal had lower deforestation rates than Sikkim (−0.1%) and Arunachal (−1.8%) and higher deforestation rates than Uttarakhand (0.1%). Arunachal had higher deforestation rates than Uttarakhand (0.1%), Himachal (1.0%), and Sikkim (0.6%).

Cross-border estimates of deforestation were remarkably similar to the matching-based estimates (Fig. 5): little difference in deforestation rates between India (0.16%) and Nepal (0.12%) and higher deforestation rates in India (0.8%) than Bhutan (0.2%). The cross-border analysis indicated higher deforestation in Myanmar (1.3%) relative to China (0.3%), which was consistent with results of the matching analysis.

### Discussion

Globally, management of unprotected forests is critical to the long-term conservation of forests and biodiversity. We found substantial differences in deforestation rates in the countries we examined that were associated with national forest-management regimes. Countries that prioritize biodiversity conservation and community management and use of forests had lower deforestation rates. We found that Bhutan and Nepal place a greater emphasis on conservation and local use than China and Myanmar. Nepal prioritizes local participation in forest management and the distribution of benefits, primarily through community forestry (Bluffstone et al. 2015). Bhutan has more

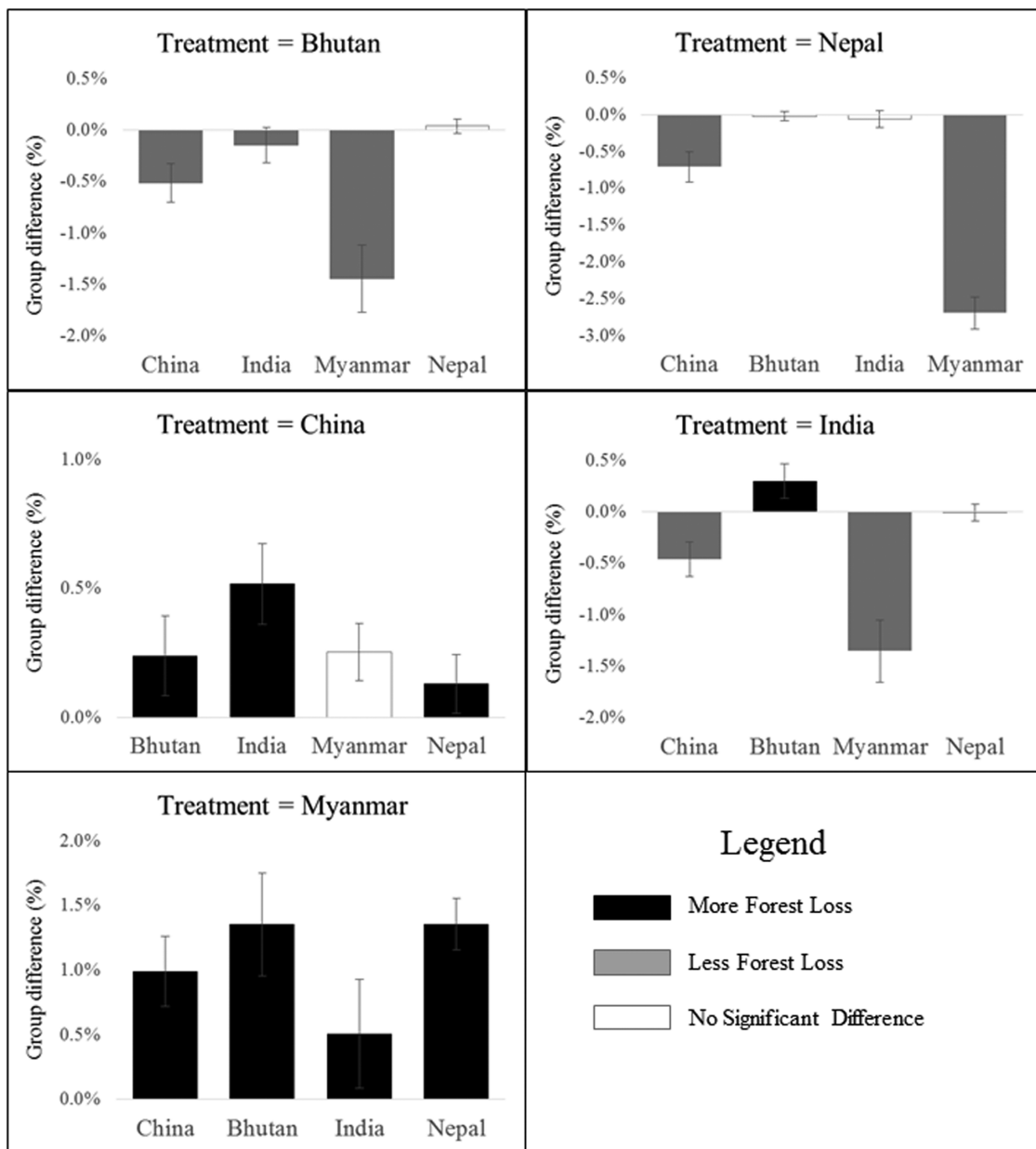


Figure 3. Matching-based estimates of differences in Himalayan temperate forest loss from 2000 to 2014 at the national scale (error bars, 95% confidence intervals for each matched pairwise comparison; estimates significant at  $p < 0.05$ ) (control countries along x-axis; black, treatment country has higher deforestation than control country; gray, treatment has lower deforestation than control). Raw estimates are in Supporting Information.

centralized management and has implemented innovative landscape-scale conservation policies that focus on conservation in protected areas and sustainable use in biological corridors (Brooks 2013). Both countries have high percentages of their land protected and have allowed human habitation inside some protected areas. In contrast, China, India, and Myanmar have not prioritized conservation or benefits to communities at the scale that Nepal and Bhutan have. Instead, China and Myanmar have forest-management regimes that are development and profit oriented; China has devolved rights to communities

but in an unstable and inconsistent manner (Woods 2015; Yang et al. 2015). Indian states display a similar pattern; 3 states that prioritize conservation and community forest management have lower forest deforestation rates than Arunachal Pradesh.

We found that both formal and informal community rights can lead to positive outcomes for forest conservation. The relative success in Nepal and 2 of the Indian states, Himachal Pradesh and Uttarakhand, corroborate a rich body of evidence that secure community tenure and the community's right to manage resources are important

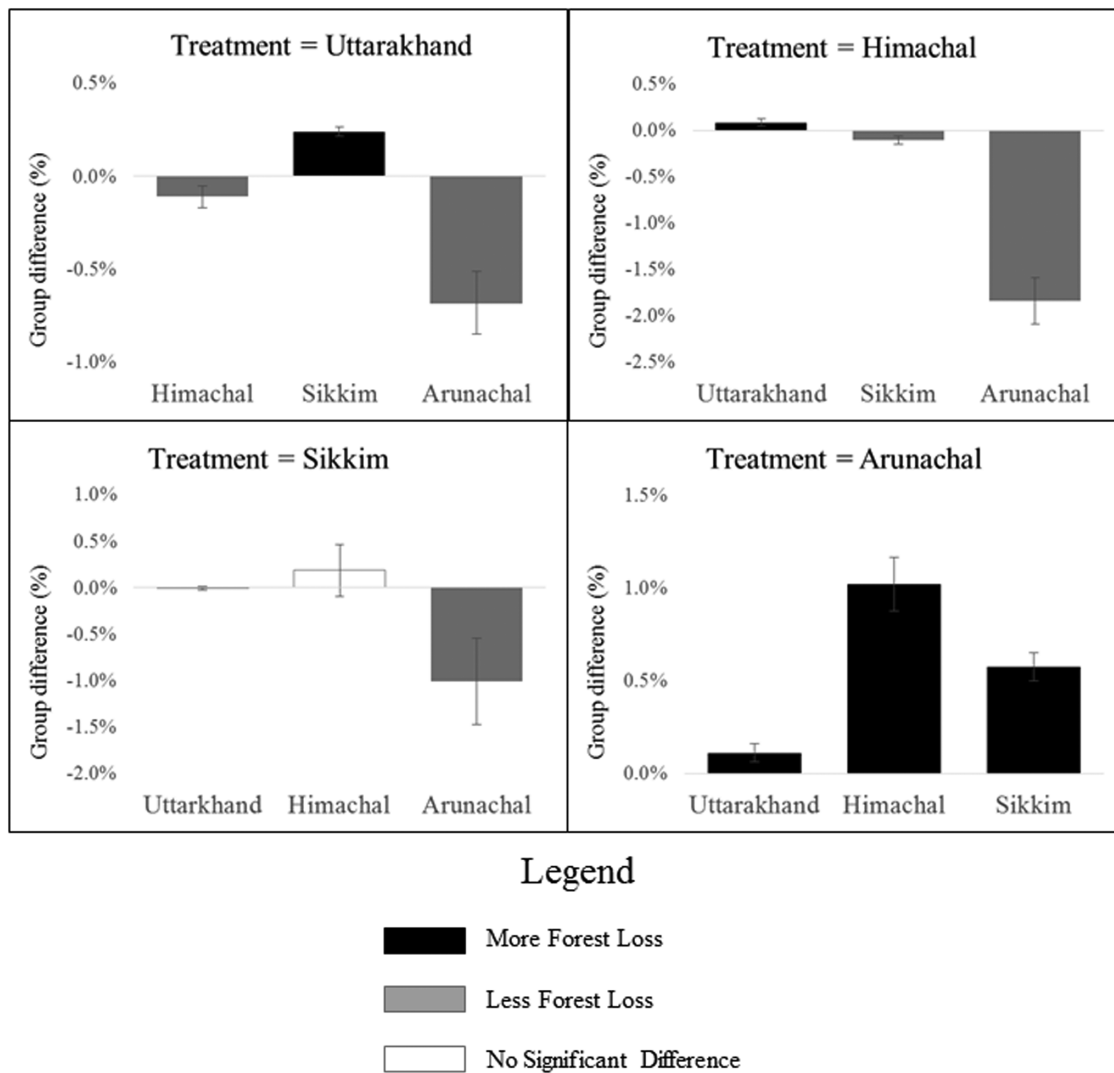


Figure 4. Matching-based estimates of differences in Himalayan temperate forest loss from 2000 to 2014 among states in India (error bars, 95% confidence intervals for each matched pairwise comparison; estimates significant at  $p < 0.05$ ) (control countries along x-axis; black, treatment state has higher deforestation than control state; gray, treatment has lower deforestation than control). Raw estimates are in Supporting Information.

for forest conservation (Agrawal & Ostrom 2001). In contrast, forest conservation is successful in Bhutan and Sikkim even though communities are not formally managing large areas of the forest. However, Bhutan and Sikkim's low rates of deforestation indicate that, despite a lack of formally recognized community management, they have functioning systems of monitoring and enforcement that protect forests, or at least timber, outside protected areas. The traditional management systems that the government informally recognizes and supports may also play a role in protecting forests (Thakur et al. 2005; Dorji et al. 2006; Buffum 2012).

The countries with the greatest percentage of land in protected areas had the lowest rates of deforestation of unprotected forests. The ability of a government to set aside protected areas can demonstrate social, reli-

gious, or cultural support for environmental conservation. In Bhutan, for example, the majority of people (99%) believe environmental conservation is very important and have knowledge of national environmental policy (75%) (Rinzin et al. 2007). In Nepal people are supportive of protected areas (Mehta & Heinen 2001), and Nepalese view protected areas more favorably than Indians (Karanth & Nepal 2012). Furthermore, Nepal and Bhutan established their protected-area systems originally under a Hindu and Buddhist monarchy respectively, which laid a foundation for people respecting and valuing protected areas (Lhundup 2002; Bhatt 2003; Allendorf et al. 2007). Sikkim was also a Buddhist monarchy until the 1970s, when it became an Indian state. Thus, culture likely contributes to the degree of commitment that a country and its people have to conservation.



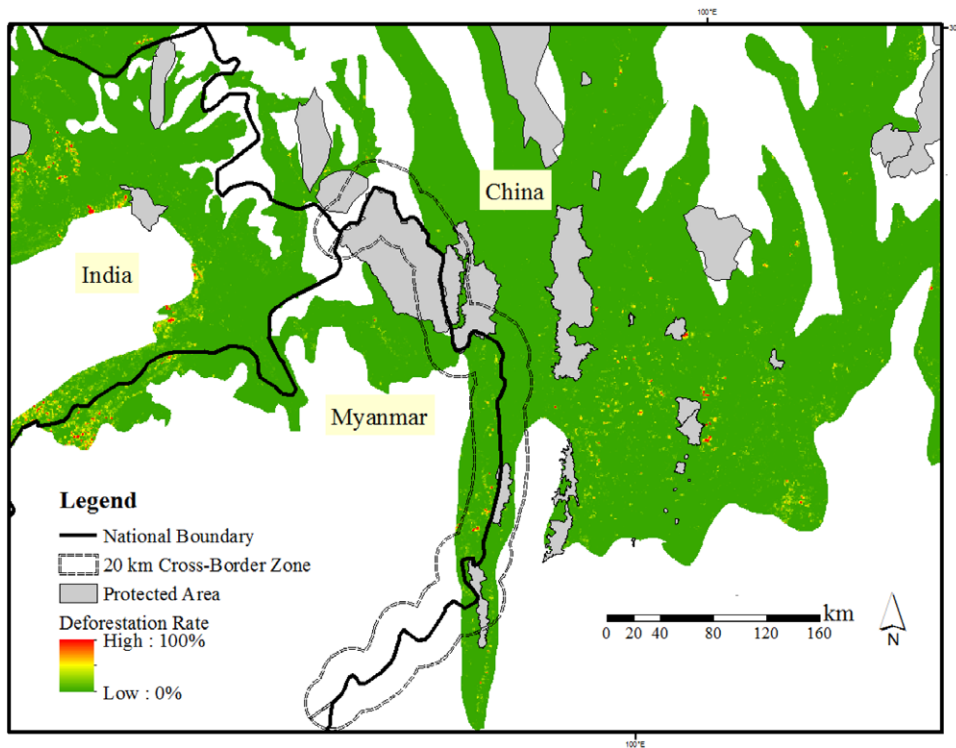


Figure 5. Deforestation rates from 2000 to 2014 in a 20-km zone along the border between China and Myanmar and in surrounding areas (mean deforestation rate in Myanmar's cross-border zone, 1.3%; mean deforestation rate in China's zone, 0.3%) (white, not temperate forest).

That China, with the highest proportion of community forestry of any country (61% of forests in collective forestry), had the second-highest deforestation rate was unexpected. Two characteristics of community forestry in China may contribute to this. First, the overarching goal of collective forest management is timber extraction, not sustainable use (Weyerhaeuser et al. 2006; Yang et al. 2015). Second, land tenure under community forestry has been unstable, and in practice land rights and responsibilities are often not given to communities (Baohua 2006; He 2016). Decentralized resource management can lead to undesirable outcomes when transfer of power is incomplete (Ribot et al. 2006) and local participation is limited (Brooks et al. 2012).

Myanmar, where timber extraction is emphasized and effective forest policies and management are lacking (Lin 2004; Woods 2015), had the highest deforestation rate. Government forests that have insufficient monitoring and enforcement mechanisms are often equivalent to open-access areas (Hayes 2006; Porter-Bolland et al. 2012; Sikor et al. 2013). In India, Arunachal Pradesh is most similar to Myanmar in that its forest management focuses on timber extraction (Mitra 1998) and does not support traditional practices (Poffenberger et al. 2006).

Factors other than national forest-management regime could have influenced the observed differences in deforestation. For example, the 5 countries in our sample have different economic growth rates, global-market engagement, overarching political regimes, and historical-cultural dynamics. Previous work suggests that national

socioeconomic conditions (Gutierrez et al. 2011) and governance quality (Miller et al. 2015) can affect conservation outcomes. Governance quality may be a particularly important area for future research. Although proconservation policies are important, they also need to be translated into action through good environmental governance, which encompasses a broad set of regulatory processes, institutions, traditions, and mechanisms that can influence decisions and outcomes (Lemos & Agrawal 2006; Lockwood et al. 2010). Some components of governance are captured by our review of forest management regimes, and preliminary evidence suggests that governance quality may also affect deforestation (Wendland et al. 2014). For instance, Bhutan ranks first in 4 of the 6 governance indicators developed by the Worldwide Governance Indicators (WGI) project (Kaufmann et al. 2011), and Myanmar ranks last for 5 indicators (Supporting Information). The WGI indicators and other tools (Lockwood et al. 2010) with a larger sample of nations could be used to explore the effects of governance quality on forest conservation outcomes (Bhattarai & Hammig 2004; Lee & Jetz 2008). Furthermore, national policies may not have the same effect in all communities, which suggests that future research should examine how forest policies interact with local conditions to affect forest outcomes (Wright et al. 2016).

Our analysis represents an exciting methodological advance for comparisons of cross-national forest-conservation regime. Cross-national comparisons are confounded by inherent differences among countries in

terms of deforestation risk. Ours is the first analysis that we know of in which a quasi-experimental matching approach was used to investigate effects of national forest regimes. Our matching estimates were remarkably similar to those from a cross-border approach. However, the matching approach is an improvement because it allows for comparisons among countries that do not share a border. Furthermore, our use of counter-factual methods to compare deforestation rates among countries is an important step toward more rigorous policy-impact assessments (Law 2016).

Globally, the majority of forests exist outside of legally protected areas. We found that national forest-management regimes affect forest conservation outcomes. We identified 2 factors that contribute to successful forest conservation: policies that prioritize biodiversity conservation and community management and use of forests. Our results were consistent with results of site- and regional-scale studies that show community forestry leads to positive forest conservation (Agrawal & Ostrom 2001; Agrawal & Chhatre 2006; Coleman 2009). Studies that explore how national forest-management regimes influence deforestation are needed to complement the rich literature on the effectiveness of specific conservation policy mechanisms.

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## Supporting Information

Detailed results from the matching analysis (Appendices S1-S10) and a detailed list of publications included in the national forest management regime literature review (Appendix S11) are available online. The authors are solely responsible for the content and functionality of these materials. Queries (other than the absence of material) should be directed to the corresponding author.

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