Contributed Paper

Effects of ecotourism on forest loss in the Himalayan biodiversity hotspot based on counterfactual analyses

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Abstract: Ecotourism is developing rapidly in biodiversity hotspots worldwide, but there is limited and mixed empirical evidence that ecotourism achieves positive biodiversity outcomes. We assessed whether ecotourism influenced forest loss rates and trajectories from 2000 to 2017 in Himalayan temperate forests. We compared forest loss in 15 ecotourism hubs with nonecotourism areas in 4 Himalayan countries. We used matching statistics to control for local-level determinants of forest loss, for example, population density, market access, and topography. None of the ecotourism hubs was free of forest loss, and we found limited evidence that forest-loss trajectories in ecotourism hubs were different from those in nonecotourism areas. In Nepal and Bhutan, differences in forest loss rates between ecotourism hubs and matched nonecotourism areas did not differ significantly, and the magnitude of the estimated effect was small. In India, where overall forest loss rates were the lowest of any country in our analysis, forest loss rates were higher in ecotourism hubs than in matched nonecotourism areas. In contrast, in China, where overall forest loss rates were highest, forest loss rates were lower in ecotourism hubs than where there was no ecotourism. Our results suggest that the success of ecotourism as a forest conservation strategy, as it is currently practiced in the Himalaya, is context dependent. In a region with high deforestation pressures, ecotourism may be a relatively environmentally friendly form of economic development relative to other development strategies. However, ecotourism may stimulate forest loss in regions where deforestation rates are low.

Keywords: community-based forestry, environmental policy, Mahalanobis matching, quasi-experimental, sustainable development

Efectos del Ecoturismo sobre la Pérdida de Bosques en el Punto Caliente de Biodiversidad en el Himalaya con base en Análisis Contrafactuales

Resumen: El ecoturismo está desarrollándose rápidamente en los puntos calientes de biodiversidad en todo el mundo, pero existe evidencia empírica mixta y limitada de los resultados positivos que se logran con el ecoturismo. Valoramos si el ecoturismo influyó sobre las tasas de pérdida forestal y sus trayectorias entre el 2000 y el 2017 en los bosques templados del Himalaya. Comparamos la pérdida forestal en quince focos ecoturísticos con la pérdida forestal en las áreas sin ecoturismo de cuatro países del Himalaya. Utilizamos estadística correspondiente para controlar las determinantes a nivel local de la pérdida del bosque, por ejemplo, la densidad poblacional, el acceso al mercado y la topografía. Ninguno de los focos ecoturísticos estaba libre de pérdida forestal, además de que encontramos evidencia limitada de que las trayectorias de la pérdida forestal en los focos ecoturísticos eran diferentes a las trayectorias en las áreas sin ecoturismo. En Nepal y en Bután, las diferencias en la pérdida forestal entre los focos ecoturísticos y las áreas sin ecoturismo correspondidas no difirieron significativamente y la magnitud del efecto estimado fue menor. En la India, donde las tasas generales de pérdida forestal fueron las más bajas de cualquier país en nuestro análisis, las tasas de pérdida forestal fueron más altas en los focos ecoturísticos

que en las áreas sin ecoturismo correspondidas. Como contraste, en China, donde las tasas generales de pérdida forestal fueron más altas, las tasas de pérdida forestal fueron más bajas en los focos ecoturísticos que en donde no existe el ecoturismo. Nuestros resultados sugieren que el éxito del ecoturismo como estrategia de conservación del bosque, a como se práctica actualmente en el Himalaya, depende del contexto. En una región con presiones altas de deforestación, el ecoturismo puede ser una forma de desarrollo económico relativamente amigable con el ambiente comparado con otras estrategias de desarrollo. Sin embargo, el ecoturismo puede estimular la pérdida forestal en regiones en las que las tasas de deforestación son bajas.

Palabras Clave: correspondencia Mahalanobis, cuasiexperimental, desarrollo sustentable, política ambiental, silvicultura basada en la comunidad

摘要： 全球范围内, 生物多样性热点地区的生态旅游正在快速发展, 但缺少明确的实证证据来证明生态旅游对生物多样性保护有积极作用。本研究评估了生态旅游是否对 2000-2017 年间喜马拉雅温带森林的森林丧失率和森林丧失轨迹产生影响。我们比较了喜马拉雅地区四个国家的十五个生态旅游区与非生态旅游区的森林丧失情况。我们用配对的统计数据来控制当地影响森林丧失的其它因素, 如人口密度, 开放市场程度和地形等。我们发现所有生态旅游区都遭受了森林丧失, 且有限的证据表明, 生态旅游区与非生态旅游区森林丧失轨迹并不一致。在尼泊尔和不丹, 生态旅游区与相配对的非生态旅游区的森林丧失率没有显著差异, 我们估计的生态旅游影响程度也很低。在本研究中, 印度的森林总体丧失率最低, 生态旅游区的森林丧失率比相配对的非生态旅游区更高。相比之下, 在森林总体丧失率最高的中国, 生态旅游区的森林丧失率却比非生态旅游区的更低。我们的结果表明, 以目前喜马拉雅地区的实践为例, 生态旅游能否成为一种成功的森林保护策略要依据具体情况。在森林砍伐压力较大的地区, 生态旅游可能是相比于其它发展策略较为环境友好的经济发展形式, 但在森林砍伐率低的地区, 生态旅游则可能加速森林丧失。【翻译: 胡怡思; 审校: 聂永刚】

关键词: 环境政策, 马氏距离配对法, 社区林学, 可持续发展, 准实验

Introduction

Ecotourism is proliferating in biodiversity hotspots, and its proponents claim it can achieve conservation and economic development goals. Ecotourism has become a major driver of economic growth and socioeconomic transformation in many areas. The amount spent on ecotourism is estimated to be 10 times more than that spent by official aid agencies and the UN Global Environment Facility on conservation projects (Kirkby et al. 2011; Waldron et al. 2017). Ecotourism accounts for as much as 40% of gross domestic product (GDP) in some countries and is growing 10% per year in other countries (WTTC 2014). Despite this major investment, there is limited empirical evidence that ecotourism achieves biodiversity conservation goals in the long term and at the landscape scale.

It is difficult to ascertain whether ecotourism actually achieves biodiversity goals. In developing regions, ecotourism and its cumulative effects on biodiversity are unclear. Ecotourism may generate the same or more income in an area than the consumption of natural resources (Kirkby et al. 2010, 2011). Thus, ecotourism can provide an economic incentive to protect ecosystems and species tourists visit. For example, governments may establish protected areas or enforce wildlife protection to ensure revenue from international tourists (Buckley 2011). Similarly, community ecotourism projects in unprotected landscapes may dedicate a portion of ecotourism proceeds into conservation efforts to protect their natural assets (Nagendra et al. 2005; Buck-

ley 2009; Wyman & Stein 2010). A major justification for ecotourism investments by developed countries is the assertion that ecotourism may lead to biodiversity conservation because it provides economic rewards for doing so.

In contrast, ecotourism may lead to biodiversity loss because it can require or encourages economic development, which often entails strong, negative environmental outcomes (Mather et al. 1999). Ecotourism usually requires improved transportation networks (e.g., roads and airports), which can result in intensive natural resource exploitation, such as logging and poaching, because of increased accessibility to the area (Laurance et al. 2014; MoCTCA 2015*b*; Shui & Xu 2016). Increased local wealth can change residents' consumption patterns, adding pressure on local forest resources (Liu et al. 2001; Brandt et al. 2012). Tourism also stimulates population growth, in the form of seasonal tourists and economic immigrants, which can raise demand for forest resources (Hall & Lew 2009). Tourists essentially represent a form of population growth, and they typically consume more resources per capita than local residents (Buckley 2011). Finally, tourism inherently leads to an integration of local and regional markets, another factor strongly associated with increased resource extraction (Hall & Lew 2009; Wang & Buckley 2010; Lambin & Meyfroidt 2011).

Incentives for protection and economic development thus may either result in positive or negative biodiversity
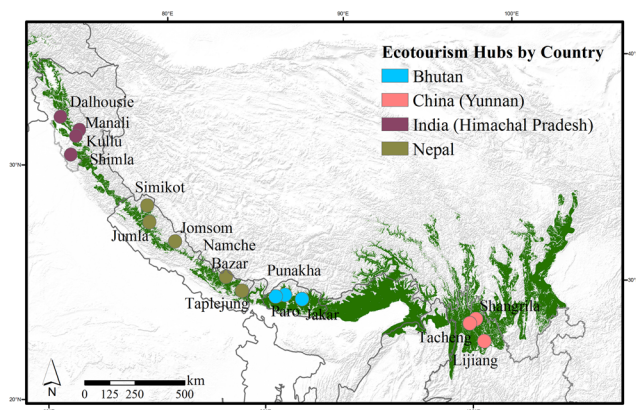
Figure 1. Ecotourism hubs across 4 countries in the Himalayan temperate forest zone (as defined by Olson et al. 2001) and with forest-cover data from Hansen et al. (2013).

outcomes. However, even if the net result of ecotourism is negative, it may still be beneficial as long as ecotourism leads to less biodiversity loss than would have occurred if an alternative economic development strategy had been implemented instead (i.e., ecotourism may not completely stop biodiversity loss, but it may be better than alternatives). Developing nations typically rely on extraction-based land uses for economic development, including the production of raw goods (e.g., mining timber) or the conversion of natural ecosystems to more economically productive uses (e.g., agriculture). Therefore, even if ecotourism stimulates economic development that leads to environmental degradation, it may lead to less biodiversity loss than more extractive models, such as palm oil production. Quantifying whether or not that is the case requires the application of a counterfactual approach to estimate rates of negative biodiversity outcomes had there not been ecotourism (Andam et al. 2008; Butsic et al. 2017).

We sought to measure environmental outcomes of ecotourism by comparing ecotourism hubs with other areas in which other development strategies had been implemented. Specifically, we measured the association between ecotourism and forest loss in the Himalayan temperate forest zone (Fig. 1) with a counterfactual approach. We identified 15 ecotourism hubs (i.e., areas where ecotourism is the primary strategy for economic development) across 4 countries with diverse tourism strategies: India, Nepal, Bhutan, and China. Our objectives were to characterize the type of ecotourism strategy implemented in each country; identify whether ecotourism hubs have rates and trajectories of forest loss distinct from nonecotourism areas; and quantify differences in forest loss rates between ecotourism hubs and nonecotourism areas.

Methods

Study Area

The Himalayan temperate forest zone extends 3000 km from southern Afghanistan to southwest China (Olson et al. 2001). It contains 2 of Earth's biodiversity hotspots (Myers et al. 2000), an extraordinary array of ecological niches in a relatively small area, and globally the highest fractions of endemic and threatened species in the world (Grenyer et al. 2006). Himalayan temperate forests have been used for thousands of years to support subsistence-based livelihoods. Forests are the primary source of fuel for cooking, heating, and construction; are intensively used for livestock grazing, hunting, food gathering, and traditional medicines; and provide raw materials for economic development. These same forests contain highly threatened, endemic biodiversity and provide essential ecosytem services, including climate and water-cycle regulation. Since the 1980s, demand for timber and fuelwood increased, resulting in forest loss and degradation (Pandit et al. 2014). Even though forest protection is a primary conservation target across Himalayan countries, forest loss has continued (Brandt et al. 2017).

The Himalayan region provides opportunity for a natural experiment to investigate ecotourism impacts because it contains countries in very different stages of economic and tourism development. Tourism has proliferated across the Himalaya as a way to balance economic development and forest conservation (Pandit et al. 2014).

We analyzed 4 Himalayan countries with active ecotourism industries: India, Nepal, Bhutan, and China. Nepal and Bhutan are relatively small and located primarily in the Himalaya and its foothills. India and China are mostly outside the Himalayas and have regional administrative units with distinct policies and contexts. Because of their large size, we focused on single administrative units located primarily in the Himalaya: Himachal Pradesh State, India, and Yunnan Province, China.

Forest Change Data

We defined *forest loss* as stand-replacing disturbance or a change from forest to nonforest. Forest cover and change data for 2000–2017 were derived from a publicly available data set of global forest dynamics (Hansen et al. 2013). The forest-cover data set contains canopy cover of each 30-m pixel in the baseline year of 2000. Each pixel is classified from 0 to 100 (0, no canopy; 100, 100% canopy cover). We considered a pixel with >50% canopy cover as forested.

Site Identification and Characterization of Ecotourism Strategies

To identify ecotourism sites and characterize ecotourism strategies and contexts, including the number, origin, and
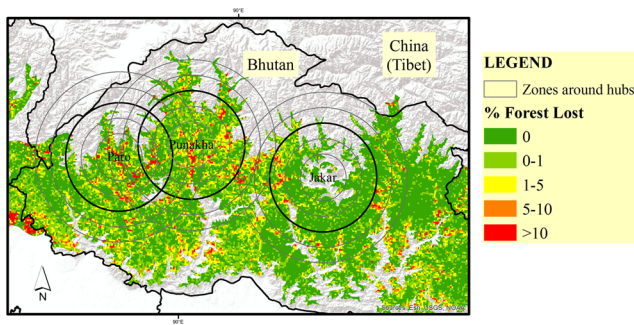
Figure 2. Ecotourism hubs with 15-, 25-, 35-, 45-, and 55-km circular zones surrounding each hub. The zone with the boldest outline is the 35-km zone, which was used for the counterfactual analysis. All areas within the 35-km circular zone are ecotourism hubs, and all areas outside this zone were nonecotourism areas.

purpose of tourists and economic wealth, we reviewed the peer-reviewed and gray literature on ecotourism for each country (Supporting Information). We compiled statistics when possible, but comparable and consistent statistics across sites were typically not available; thus, we relied on province-, state-, or country-level data. We obtained information about the overarching forest governance strategy and forest change in each country (Brandt et al. 2017). We also used information from studies published in the literature about tourism impacts on forests (see Brandt & Buckley 2018).

Tourism areas, unlike protected areas or administrative units, do not have delineated boundaries. However, tourism tends to be concentrated, and tourists typically visit an ecotourism hub (i.e., a population center where tourists concentrate for accommodation, food, guides, and other amenities). To identify our ecotourism hubs, we compiled a list of the most popular general tourism hubs based on official tourism statistics and other literature reviewed for each country; searched Google (search terms such as *ecotourism in Bhutan* and *ecotourism in Yunnan*) to identify hubs that advertised ecotourism; narrowed the list by asking regional experts to identify ecotourism hubs they considered the most popular; and overlaid our map of potential hubs on an ecoregion map (Olson et al. 2001) to identify sites that included forest in the Himalayan temperate zone (Fig. 1). Our selection of ecotourism sites was not designed to be a representative sample of all ecotourism hubs; rather, it was an attempt to select the most important ones. We identified 15 ecotourism hubs across 4 administrative units: Himachal Pradesh ($n = 4$), Nepal ($n = 5$), Bhutan ($n = 3$), and Yunnan ($n = 3$).

To determine the appropriate spatial boundary, we demarcated circular zones with 15-, 25-, 35-, 45-, and 55-km radii surrounding each ecotourism hub (Fig. 2). We summarized forest loss rates in these zones and their

respective nonecotourism areas (Fig. 3). For example, the 15-km ecotourism zone represented all forests 0–15 km from the hub, and the corresponding nonecotourism areas included all forests within the same country that were not within 0–15 km of any ecotourism hub in that country. When calculating deforestation at the hub level, forests included in >1 hub boundary were attributed to both hubs. When calculating deforestation at the country level, forests in areas of overlapping boundaries were included only once in the analysis to avoid overestimating deforestation rates at the aggregate scale. In all 4 countries, forest-loss rates in ecotourism and nontourism zones came close to convergence by the 35-km boundary and fully converged by the 55-km boundary. Thus, we used the 35-km zone for subsequent analyses. We designated areas within the 35-km boundaries as ecotourism hubs and areas beyond the 35-km boundaries as nonecotourism areas.

Trajectories of Forest Loss Area

We plotted trajectories of the area of forest loss for all forests in each ecotourism hub (35 km) and for all forests in the nonecotourism areas of each country. We calculated trend lines showing 2-year moving averages to smooth out errors in the annual forest loss measurements due to cloud compositing during remote-sensing analyses (Hansen et al. 2013). We also fitted a linear trend line for the entire trajectory to visualize whether each hub increased, decreased, or was stable from 2000 to 2017.

Counterfactual Analysis of Forest Loss Rate

An increasingly common counterfactual approach to determine the impact of conservation policies is quasi-experimental counterfactual matching analysis (Andam et al. 2008). Matching has been used, for example, to assess the effectiveness of certification policies (Miteva et al. 2015), national forest management regimes (Brandt et al. 2017), protected areas (e.g., Nolte et al. 2013), community forests (e.g., Brandt et al. 2015), and logging concessions (e.g., Brandt et al. 2016). To our knowledge, matching has not been used in the context of ecotourism.

Ecotourism hubs are typically located in remote places that have relatively few people, are less accessible, and have retained more forests than the country as a whole. The goal of our matching analysis was to find areas with similar population density, accessibility, and forest cover that only differed in whether they were associated with a major ecotourism hub or not. To do so, we matched treatment units (e.g., forested cells influenced by ecotourism) with control units (e.g., forest cells not influenced by ecotourism). With matched samples, it is possible to predict what outcomes would have been observed in forests with ecotourism had they not been subjected to ecotourism (Abadie & Imbens 2006). In essence, we asked: What
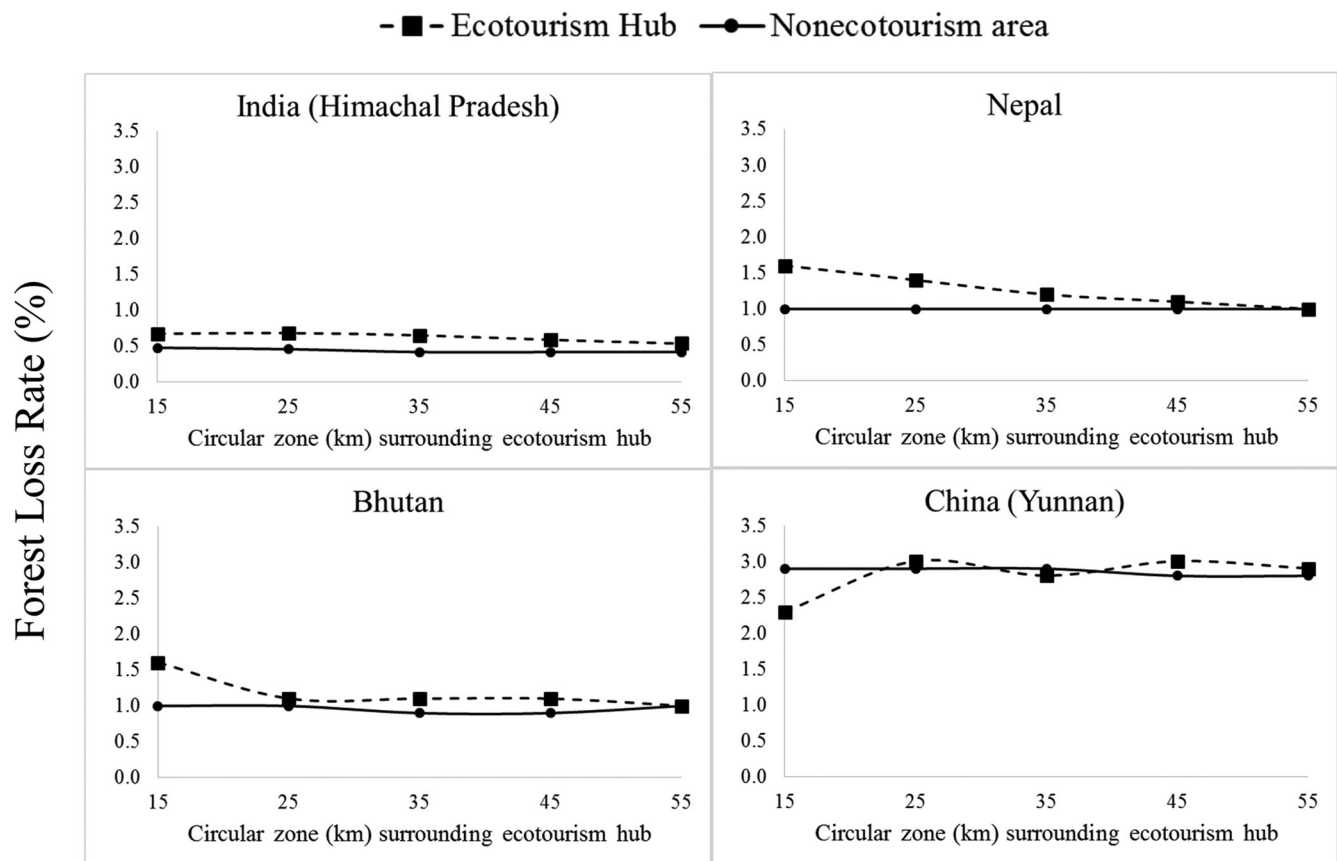
Figure 3. Forest-loss rates (2000–2017) within 15, 25, 35, 45, and 55 km of ecotourism hubs and nonecotourism areas for each country.

would be the rate of forest loss in ecotourism zones of country A if ecotourism had not been adopted and if that area had been developed like other nonecotourism areas? We also performed the opposite comparison by asking: What would be the rate of forest loss in nontourism zones of country A if ecotourism had been adopted?

We performed pair-wise comparisons of the forest-loss rate in ecotourism hubs and nonecotourism areas in each country by applying Mahalanobis matching with replacement and bias adjustment (Sekhon 2011). We aggregated annual forest cover and forest change 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; Brandt et al. 2017). We calculated an adjusted forest-loss rate, which is the total area of forest loss divided by the forested area in that cell in 2000. Cells that did not have any forest were excluded from the analyses. We matched treatment and control units based on 7 covariates (i.e., factors that influence forest loss): distance to market, population density, slope, elevation, precipitation, temperature, and percent forest cover in 2000. For each pairwise comparison, we randomly sampled 20% of the treatment parcels and matched them with control parcels. To determine the validity of the matches, we calculated balance statistics, which indicate

the extent to which the pool of potential controls contains units that are sufficiently comparable to treatment units. We dropped 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 (i.e., assigned nonecotourism areas as the treatment and found matches from the ecotourism hubs). We repeated this procedure for pairwise comparisons in each country for a total of 8 different pairwise comparisons. Matched treatment and control units were always from the same country. See Supporting Information for the full results of the matching analysis and balance statistics.

Results

Ecotourism Strategies

The 4 countries we analyzed differed considerably in terms of the types of ecotourism they implemented (Supporting Information). India is one of the most populous and rapidly developing countries in the world. Himachal Pradesh, the focus of our analysis, had the second-lowest GDP/capita of any unit in our analysis (US$2200), and the

lowest overall forest-loss rate from 2000–2017 (0.40%). Himachal Pradesh has a unique forest governance system of traditional, community-based forestry that is officially recognized by the federal government (Brandt et al. 2017). Tourism in Himachal Pradesh started in the colonial era in the form of seasonal vacation centers (i.e., Hill Stations), created by the British during the 19th century (Ahluwalia & Little 1998). Since the 1970s, the state government has implemented policies to encourage the development of both corporate and leisure tourism (Pandey & Wells 1997), and the number of tourist visitors grew from 8 million in 2006 to 15 million in 2011 (KPMG 2012), the vast majority of which were domestic (ACNielsen 2012). Nature-based, adventure, and religious tourism dominated (Singh 2002; Donovan 2013). We found 2 empirical articles about ecotourism and deforestation in the Indian Himalaya, both of which link ecotourism to deforestation and forest degradation because increased demand for timber and fuelwood was sourced from local forests (Singh et al. 2009; Mahapatra et al. 2012).

Nepal is among the poorest countries in the world with primarily community-based sustainable forest management (Brandt et al. 2017). Nepal had the lowest GDP/capita (US$835) and the second-highest rate of temperate forest loss (1.0%) of our study units. Nepal has been a popular international ecotourism destination since the 1970s, and tourism has been important for economic development (Schroeder & Sproule-Jones 2012). Nepal's tourism policy is designed to maximize the number of tourists and offers relatively inexpensive visas and few restrictions on travel and the length of time tourists may stay in the country (Schroeder & Sproule-Jones 2012). In 2014, Nepal hosted over 790,000 tourists, a 58% increase from approximately 500,000 in 2000 (*MoCTCA* 2015*a*, 2015*b*), and has a national goal of 2 million tourists per year by 2020 (Nepal & Karst 2017). The majority of tourists in Nepal are international and come to visit national parks and to trek (MoCTCA 2015*b*). Similar to Himachal Pradesh, we found 2 empirical articles for the Nepal Himalaya, both of which report more local deforestation and forest degradation due to ecotourism because of increased demand for timber and fuelwood (Stevens 2003; Garrard et al. 2016).

Bhutan is a small Buddhist kingdom, known for its gross domestic happiness (GDH) policy, where environmental protection and economic growth are equally prioritized, a sustainable development approach that is unique among developing nations (Brooks, 2010, 2013). Bhutan had the second highest GDP/capita of any unit in our study (US$3110) and the second lowest forest-loss rate (0.9%). Bhutan's national forest policy emphasizes forest conservation (Brandt et al. 2017), and tourism in Bhutan is a relatively recent phenomenon compared with India and Nepal. Tourism was introduced as a means of attaining foreign currency to help achieve economic development

and autonomy from donor aid (Nepal & Karst 2017), but, in contrast to Nepal, Bhutan has pursued a controlled approach. In 1974, Bhutan implemented a policy known as ''high value, low volume'' (Schroeder & Sproule-Jones 2012). Tourist visas are expensive and short, and travel permissions are tightly controlled, which limits both tourism numbers and the activities tourists can engage in. Although there is great potential for adventure-based tourism, such as climbing and trekking, it is limited due to the tight control (Gurung & Seeland 2008), and the primary activity of most tourists is "cultural sight-seeing" on designated tours to specific sites (Bhutan 2014; TCB 2015). In 2014, Bhutan hosted 133,480 tourists, about one-fifth as many as Nepal (Bhutan 2014). We found no empirical studies about ecotourism and forests in Bhutan.

China has had the fastest growing economy in the world in recent decades. Strong economic development policies for western China have stimulated high rates of economic growth in Yunnan (Xu et al. 2006). Yunnan's forest governance policy emphasizes for-profit use of forests (Brandt et al. 2017). Yunnan had the highest GDP/capita (US$5117) and the highest forest-loss rate (2.9%) of all of our study units. The most common economic development strategies include extractive-based activities, including cash crops, mining, and hydropower, except for specific areas where ecotourism has been implemented (Li & Han 2000; Donaldson 2007; Wang & Buckley 2010). The Himalayan region of Yunnan is designated as the premiere ecotourism destination in China and aggressively marketed to the growing middle class in eastern China (Nyaupane et al. 2006). Ecotourism has grown exponentially since 1990 and the vast majority of tourists are domestic (Jenkins 2009; Brandt et al. 2012; HKTDC 2017). For example, tourist visitors in Diqing Prefecture grew from 40,000 tourists in 1995 to 5.3 million visitors in 2009. We found 2 empirical studies from the Chinese Himalaya about the impacts of tourism on forests, both of which reported that ecotourism led to accelerated deforestation due to rapid economic development and population growth (Liu et al. 2001; Brandt et al. 2012).

Rates and Trajectories of Forest Loss in Ecotourism Hubs and Nonecotourism Areas

In simple comparisons, we did not find that forest loss differed clearly between ecotourism hubs and nontourism areas, but there were differences among countries (Fig. 4). India had the lowest forest-loss rates, ranging from 0.4% in Shimla and nonecotourism areas to 1.1% in Manali. The highest hub-level forest-loss rates occurred in China, ranging from 2.0% in Tacheng to 4.3% in Lijiang; nonecotourism areas had an intermediate forest-loss rate of 2.9%. Bhutan and Nepal's forest-loss rates were between those in India and China, and forest-loss rates in
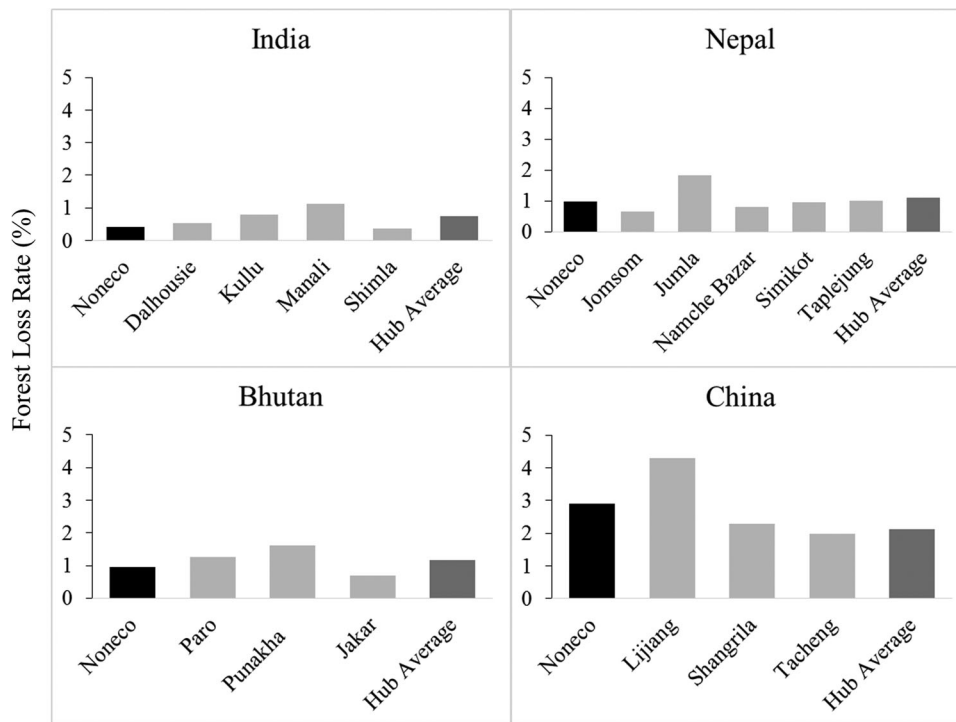
Figure 4. Forest-loss rates in each ecotourism hub and nonecotourism areas, and the average of all ecotourism hubs in each country.

nonecotourism areas were within the range of individual ecotourism hubs in the respective countries.

In terms of annual forest-loss trajectories, nontourism areas and ecotourism hubs in India all had a decreasing forest-loss trend from 2000 to 2017 (Fig. 5). Dalhousie had the highest forest loss of all sites and years (1.5 km^2 in 2002) but had no forest loss in the most recent years (2014–2017). Other Indian hubs and the nontourism areas also showed high interannual variability; there was no specific temporal pattern other than low or 0 forest loss after 2013. In Nepal, nontourism areas showed a stable to slightly increasing trend of forest loss, whereas 4 of 5 ecotourism hubs had a decreasing forest-loss trajectory. Bhutan displayed a unique temporal pattern that was consistent across the country; a spike in forest loss occurred in all 3 hubs and the nontourism areas in 2010 and rates increased steadily from 2012 to 2017. China's nonecotourism areas, similar to Nepal's, showed a slight increase in forest loss over the entire period, and the ecotourism hubs varied greatly: 1 (Lijiang) increased, 1 (Shangrila) decreased, and 1 (Tacheng) was stable.

Differences in Forest-Loss Rates in Ecotourism Hubs and Nonecotourism Areas Based on Counterfactuals

According to our counterfactual analysis, forest-loss rates in Nepal and Bhutan in ecotourism hubs were not significantly different ($p < 0.05$ threshold) relative to nonecotourism areas (Fig. 6 & Supporting Information). The difference in loss rates between ecotourism hubs and nonecotourism areas was +0.08% in Nepal and +0.12% in Bhutan. In India, ecotourism hubs had higher forest-loss

rates than matched nonecotourism areas; effect size was small but significant (+0.40%, $p < 0.001$). Similarly, when we matched cells in nonecotourism areas with those in ecotourism hubs, nonecotourism areas had less forest loss than ecotourism hubs; effect size was −0.74% ($p < 0.001$). China was the only country where ecotourism hubs had lower forest-loss rates than matched nonecotourism areas (effect size of −1.73%, $p < 0.001$). The inverse comparison was also significant; cells in nonecotourism areas matched with those in ecotourism hubs had +0.77% more forest loss ($p < 0.001$).

Discussion

We found little evidence that ecotourism reduces rates of forest loss, but also little evidence that ecotourism leads to higher forest-loss rates due to more rapid development. At first glance, our results seemed to suggest that ecotourism spurs forest loss because forest-loss rates themselves were in most cases higher in ecotourism hubs than in nonecotourism areas (i.e., Fig. 3). However, simple comparisons of forest-loss rates are only valid when ensuring that sites with similar deforestation pressure are compared. Indeed, when we controlled for deforestation pressure, we found that the effects of ecotourism varied among countries. We were surprised by our results because previous empirical studies in both India (Singh et al. 2009; Mahapatra et al. 2012) and Nepal (Stevens 2003; Garrard et al. 2016) found more deforestation in ecotourism hubs. However, none of these prior studies used counterfactual approaches to control for deforestation
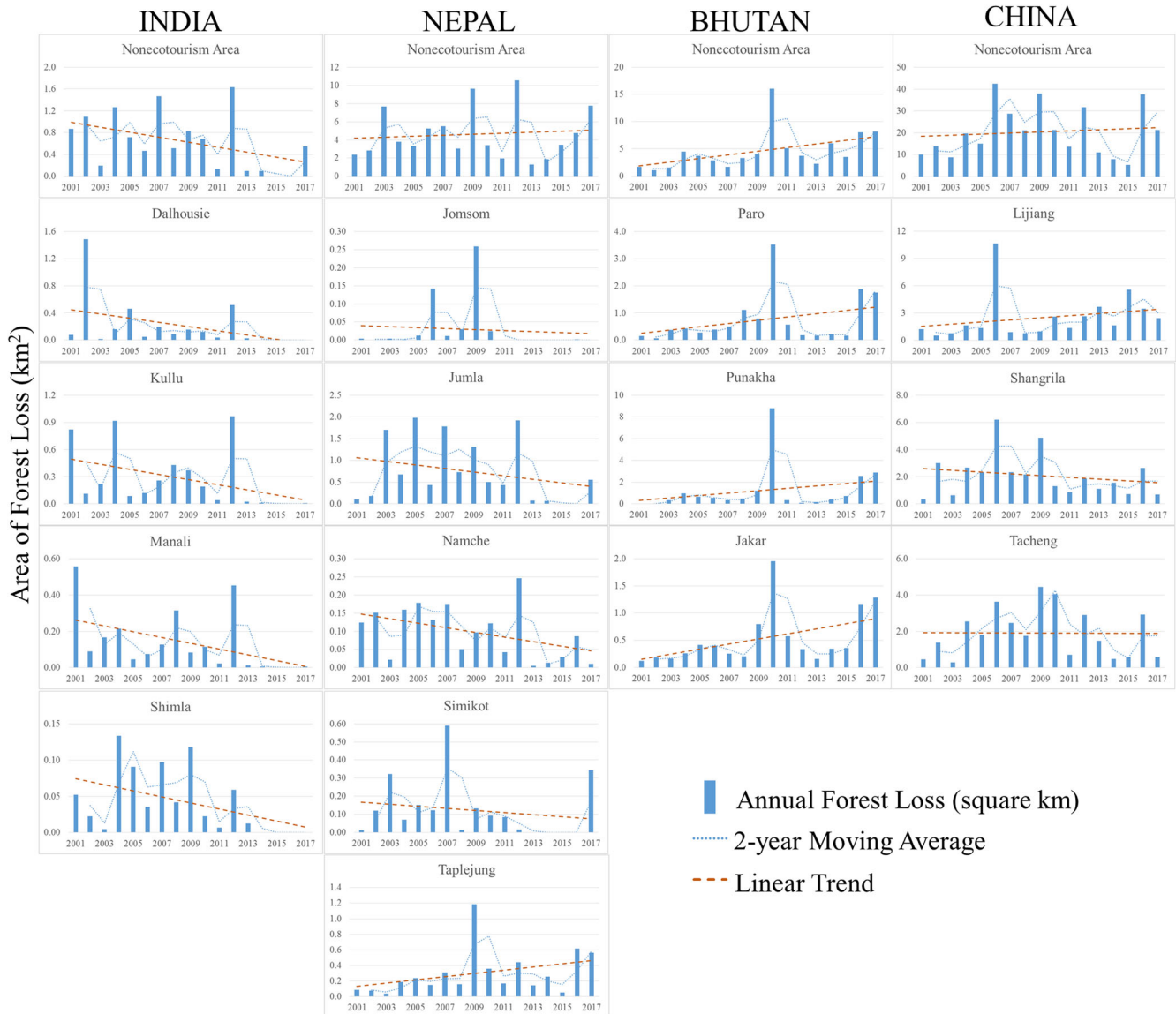
Figure 5. Annual forest loss, 2-year moving averages, and linear trend-lines from 2000–2017 in each ecotourism hub and nonecotourism areas in each country.

pressure, and their findings may reflect that ecotourism hubs are often located in places that inherently have higher deforestation pressure. Similarly, we expected that Bhutan's strategy of a tightly controlled ecotourism industry would result in better forest conservation outcomes compared with Nepal, which hosts many more tourists and exerts less control on where and how they travel (Schroeder & Sproule-Jones 2012). However, we found no evidence that ecotourism in Bhutan reduced deforestation pressures or differed in its impact from ecotourism in Nepal.

Yunnan was the only study unit where ecotourism hubs had lower forest-loss rates than nontourism areas, and even when comparing areas with similar deforestation pressure, the effect size was considerable (1.73%).

This result surprised us because prior case studies reported empirical evidence of accelerated deforestation after ecotourism started in the Chinese Himalaya (Liu et al. 2001; Brandt et al. 2012). However, our matching results suggest that in the context of rapid development in China as a whole, and in Yunnan in particular, ecotourism led to less forest loss than areas where tourism was not prominent. It is important to note that while forest-loss rates in Yunnan's ecotourism zones were less than that in China's nonecotourism areas, they were still 2 to 3 times higher than forest-loss rates in ecotourism hubs of Bhutan, Nepal, and India. Overall, forest-loss rates in Yunnan were very high due to China's national-level forest management policy that encourages for-profit use of forests instead of the sustainable use or
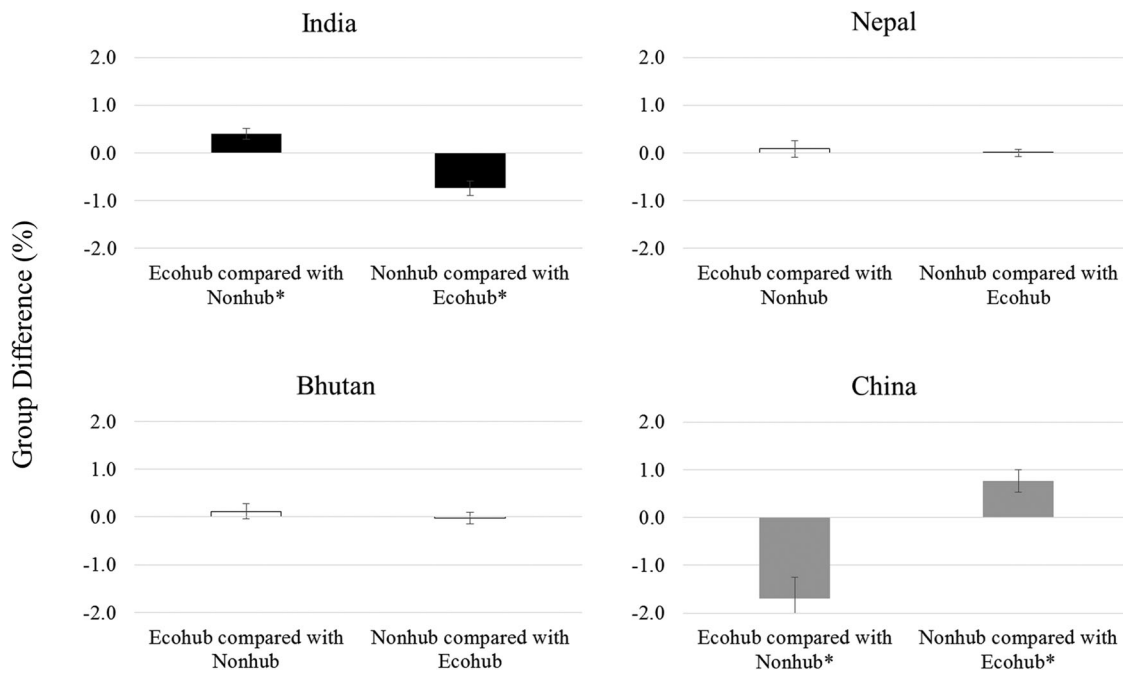
*Figure 6. Matched comparisons of forest-loss rates between ecotourism hubs and nonecotourism areas in each country (black, ecotourism hubs with higher forest-loss rates than nonecotourism areas; gray, ecotourism hubs with lower forest-loss rates than nonecotourism areas; no shading, no significant difference; *estimates significant at p < 0.001). See Supporting Information for full results.*

conservation-oriented policies implemented in the other 3 countries (Brandt et al. 2017). China's background forest-loss rates were 3–5 times higher than in the other 3 countries, suggesting intense forest loss pressures due to other economic development strategies in southwest China, including timber extraction from forests, mining, and hydropower development (Buckley 2010). When compared with these other development strategies, ecotourism may be a relatively environmentally friendly form of economic development in China.

Our empirical analysis highlights an urgent need for more rigorous, empirical, and multiscale analysis of the effects of ecotourism in biodiversity hotspots. To our knowledge, this analysis is the only multinational and the only counterfactual analysis that evaluates ecotourism outcomes. Because economic development is also a goal of ecotourism, there is an urgent need to analyze economic benefits concurrently with forest change, for example, by calculating a forest change per unit of economic growth among different economic development strategies. It is likely that, similar to other environmental governance interventions, the effects of ecotourism vary in space and time (Ostrom et al. 2007). Thus, case studies in diverse social-ecological contexts, and at different spatial and temporal scales, followed by rigorous meta-analyses will be essential to build a stronger knowledge base.

Our findings have important implications for policy makers because they highlight that forces of economic

development, even when stimulated by a nonextractive development strategy like ecotourism, can lead to environmental degradation. Specifically, our results suggest the rates of forest loss resulting from ecotourism are comparable to those resulting from other, more conventional, development strategies. The exception to this rule appears to be areas where deforestation pressures are very high. In these high deforestation areas, ecotourism may slow forest loss. More research, at finer spatial scales, and in other biodiversity hotspots, is necessary to build the evidence base about under what conditions ecotourism generates sustainable forest conservation outcomes.

Acknowledgments

Supporting Information

Covariates used in the analysis (Appendix S1), Full matching results and balance statistics (Appendix S2), articles reviewed for each country (Appendix S3) and summary of ecotourism types and context in each country (Appendix S4) 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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