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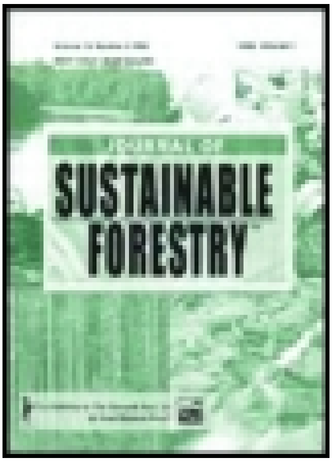

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Evaluating the Impacts of Forest Management Policies and Community-Level Institutions in the Buffer Zone of Chitwan National Park, Nepal

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Evaluating the Impacts of Forest Management Policies and Community-Level Institutions in the Buffer Zone of Chitwan National Park, Nepal

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A Master Plan for Nepal's Forestry Sector (MPFS), enacted in 1989, and subsequent legislation laid the foundation for modern community-based forest management in Nepal. In 2014, the MPFS reached the end of its 25-yr lifespan, after successfully ushering in significant institutional changes that fundamentally transformed the management of Nepal's forests, mostly through devolving management and benefits from the national level to local communities. Here, we use the 25-yr anniversary of the MPFS to explore forest cover trends in the buffer zone surrounding Chitwan National Park (CNP). Landsat imagery was used for the years 1989, 2005, and 2013 to compute a normalized difference vegetation index (NDVI) to analyze trends in forest cover for 36 buffer zone village development committees (VDCs). The analysis, covering approximately 1,267 km^2, found that since the MPFS was enacted, there was first a continued decrease in forest cover, followed by a significant recovery. These data offer insight into the success of modern community-based forest management policies and supporting

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institutions, and provide a model for other efforts to conserve forest resources in Nepal and elsewhere.

KEYWORDS community forestry, deforestation, forest policy, normalized difference vegetation index (NDVI), Nepal, remote sensing, sustainable forest management

INTRODUCTION

Tropical forests are being cleared, converted, and degraded on a global scale (Achard et al., 2002; Hansen et al., 2013). Forests, which today cover roughly one-quarter of Nepal, have witnessed a long history of decline and degradation due to rising human populations, agricultural expansion, and timber harvest. The concern over tropical forest loss has led countries such as Nepal to reconsider the way in which they manage and use forest resources. Today, Nepal is considered one of the best examples of successful community-based forest management in the world (Gautam, Shivakoti, & Webb, 2004).

Elinor Ostrom, in her 1990 book *Governing the Commons: The Evolution of Institutions for Collective Action*, discussed the complexities and fragility of successful self-governed and self-organized institutions for the management of common pool resources (CPRs). Her later work explored the effectiveness of decentralized approaches to CPR management in Nepal, as well as similar initiatives in other parts of the world (see, e.g., Ostrom, Schroeder, & Wynne, 1993; Agrawal & Ostrom, 2001; Shivakoti & Ostrom, 2002; Andersson & Ostrom, 2008). The importance of institutional structure has since been widely discussed in the human dimensions of natural resource management and economics literature. Indeed, under various ecological and social conditions, decentralized community-level forest management has shown promise in reversing forest loss and degradation in Nepal (see, e.g., Chakraborty, 2001; Agrawal & Gupta, 2005; Gautam & Shivakoti, 2005; Nagendra, Karmacharya, & Karna, 2005; Gautam, 2007; Gurung et al., 2013).

Modern community forestry in Nepal, however, began only after a long history of political instability and rigid and hierarchical centralized forest management institutions. During the mid-20th century, the lowland forests of southern Nepal were rapidly cleared in response to national policies promoting timber harvest, agricultural expansion, and malaria eradication (Schweik et al., 2003). The eradication of malaria in the south, along with the construction of more improved road systems increased migration into the Terai, development, and more profitable commercial forestry. Increasing settlements made agriculture more important in the region, as the Terai is known as the fertile "bread basket" of Nepal. Also, increased clearing for agriculture made more land available for migrants from less productive regions of the country (Pravat, 2006).

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An important milestone in Nepal's forest management policy was the 1957 Nationalization Act, which established the government's ownership of all forested land in the country. The Act, which was implemented to ensure that the state had complete control of the country's commercial timber market (Agrawal & Ribot, 1999; Jones, 2007), was adopted to usurp control of privately owned forests and lands following the collapse of the Rana regime in 1951. Privatized ownership ceased and control was placed in the hands of the central state to oversee commercial timber harvesting and management of forest resources. An unintended consequence was that the Act undermined community-level management practices, which significantly accelerated the trend of deforestation (Guthman, 1997; Agrawal & Ostrom, 2001; Pravat, 2006; Upadhyay, 2012; Pandit & Bevilacqua, 2011). Bajracharya (1983) quotes the FAO/World Bank report (1979) by stating that:

> . . . after nationalization of the forest, the people considered that the state was taking away their rights in the forests and lost their sense of responsibility; they did not feel there was any necessity to conserve the forests. . . . The effect of the Nationalization Act was to accelerate forest degradation. (p. 233)

A major factor fueling deforestation was the inability of the Nepali government to oversee all of the country's forested land—especially in remote rural areas. Additionally, rural communities wanted the power to manage their own forested lands (Upadhyay, 2012), and their traditional management practices were challenged and replaced by a centralized management system. In 1961, King Mahendra implemented the Panchayat system – a partyless system of government, guided by the monarchy – which overthrew the brief democratic system that had been formed for one year. Extensive forest clearing and timber exports occurred until the return of a multi-party, democratic government in 1990. As much as 25% of forests in the Terai region were harvested in this time, with much of the wood sold to India (Pravat, 2006).

Between 1961 and 1970, the Nepali government worked to prevent rural populations from having any forest-related rights (Agrawal & Ostrom, 2001). This changed in 1976, when the National Forestry Plan was enacted which, for the first time, highlighted the need for collective action in Nepal. Before this, collective action was not considered a necessary part of the solution to resource problems. In a marked departure from past policy, the Nepali government stated that "protection, maintenance, and development of forests scattered all over the kingdom is neither possible nor even practical through government efforts alone" (Bajracharya, 1983, p. 234). Henceforth, decentralized natural resource management was official policy. Nepal, like many other struggling, developing countries, devolved power from centralized control to citizens in an attempt to better meet common needs (Jones, 2007).

The Master Plan for the Forestry Sector (MPFS), established in 1988 by the Ministry of Forests and Soil Conservation (MFSC) and enacted in 1989, set in place a 25-yr forest management framework for Nepal. The MPFS had four primary objectives:

> (1) to meet the people's basic needs for forest products on a sustained basis; (2) to conserve ecosystems and genetic resources; (3) to protect land against degradation and other effects of ecological imbalance; and (4) to contribute to local and national economic growth. (Forestry Nepal, 2014, p. 1, citing Government of Nepal, 1988)

Attention was focused on building programs that benefited community-managed forests, such as reforesting community-managed parcels of forest and subsidizing tree seedling production and nurseries. There were implications for the commercial forest industry in Nepal as well. Under the Plan, foresters were to seek training in new forest management approaches, and the Ministry invested in research and development on sustainable silvicultural methods.

The Forest Act of 1993 and the Forest Rules and Regulations of 1995 were subsequently passed to establish regulations for government-managed forests, protected forests, private and leasehold forests, and community forests (Government of Nepal, 1995). Importantly, the National Parks and Wildlife Conservation Act was passed in 1973 by Nepal's Department of National Parks and Wildlife Conservation (DNPWC), and the Act's 4th Amendment, passed in 1993, officially designated a buffer zone around Chitwan National Park (CNP) and gave limited rights to inhabitants to manage forests therein (Spiteri & Nepal, 2008, citing Heinen & Mehta, 2000; Nepal & Weber, 1995). The Act implemented official buffer zone policies for those living around CNP to help address problems with resource management in and around the park. For example, in 1993, there was severe flooding in CNP from the Rapti River. The Park Buffer Zone Program contributed trees to be planted in the area to help reforest and stabilize the degraded floodplain, helping to protect against future flooding, as well as expanding habitat for wildlife (Nagendra, Pareeth, Sharma, Schweik, & Adhikari, 2008).

In addition, the Buffer Zone Management Regulations of 1996, and the Buffer Zone Management Guidelines of 1999, were implemented "for the design of programs compatible with national park management and to facilitate public participation in the conservation, design and management of buffer zones" (Budhathoki, 2004, p. 335, citing Government of Nepal, 2002). CNP's buffer zone includes approximately 750 km^2 and is home to more than 300,000 people (Straede & Treue, 2006). In part, buffer zones were established to mitigate anthropogenic harm to national parks from communities living nearby by giving residents alternatives for economic self-sufficiency through managing resources outside park boundaries and alleviating use

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of protected resources. Thirty to 50% of (CNP) revenues are distributed to buffer zone communities to support development programs designed to improve health, living, and sanitation conditions; education; and awareness of environmental issues (Budhathoki, 2004). In addition, the law supports the formation and use of user group committees (UGCs) to further local involvement and distribute responsibility. Overall, the goal of these buffer zone programs is to mitigate potential negative impacts that protected areas may have on adjacent communities, and to lessen the negative impacts that communities might have on protected areas in return (Budhathoki, 2004). The 1993 amendment to the National Parks and Wildlife Conservation Act, the Buffer Zone Management Regulations of 1996, and the Buffer Zone Management Guidelines of 1999 sought to preserve the natural environment with the help and participation of the communities living in the designated buffer zone. These communities work with park officials to improve socioeconomic conditions for both parks and communities, thus making CNP a noteworthy example of communities working together with the government to preserve the rich biodiversity and natural resources of a protected area (United Nations Educational, Scientific, and Cultural Organization [UNESCO], 2013).

Community forest user groups (CFUGs) and buffer zone community forest user groups (BZCFUGs; from here forward, "CFUGs" will be used interchangeably) were given limited authority to use and manage government forests in and around their communities, though forests were technically still owned by the state. CFUGs in nonbuffer zone community forests coordinate efforts with the Forestry Department and a District Forest Officer, who assists the group in writing rules/operational plans that dictate how the CFUG will manage forest resources. CFUGs in buffer zone community forests develop their constitution in accordance with operating rules set in place by CNP authorities and a Chief Warden who oversees buffer zone forest management programs. A second plan/constitution is created that sets rules for the internal management of the CFUG within the community. After state-owned land is approved for community forest use, a 5-yr management plan is developed for each parcel. Importantly,

> . . . the District Forest Officer can hand over any part of a national forest to a user group in the form of a community forest, entitling it to develop, conserve, use, and manage the forest, and to sell and distribute forest products by independently fixing the price in the market. (Agrawal & Ostrom, 2001, p. 499)

Nagendra et al. (2005) examined the operational differences between user groups in community forests and buffer zone forests around CNP, noting substantial differences in terms of property rights, monitoring effectiveness, rules for harvesting, the freedom to change rules in place, and economic support—both external and within the user group. A large portion of income generated from CFUGs in buffer zone community forests typically comes from tourism entrance fees, and, unlike CFUGs in nonbuffer zone community forests, proportionally less revenue is received from harvesting and membership fees paid to the forest user group (Nagendra et al., 2005). Additionally, in order to promote forest conservation, CFUGs were not permitted to convert forests into agricultural lands. Each CFUG elects community members to assist in various tasks such as guarding resources and controlling access and use, distributing revenues among CFUG members from the sale of forest products, improving forest conditions, and applying sanctions to violators. Monitoring within buffer zone community forests is typically done by hired forest guards with revenue generated from tourism entrance fees from CNP (Nagendra et al., 2005). Finally, as revenues are generated, 25% are returned to the community (beyond CFUG members) to promote broader development programs (Guthman, 1997). By 1999, there were 8,500 CFUGs operating in Nepal, representing nearly one million households and managing over 6,500 km^2 of forest—roughly 10% of Nepal's total forest area (Agrawal & Ostrom, 2001). Today, over 13,500 CFUGs are recognized nationwide (Federation of Community Forest Users, Nepal, 2014).

In combination, the core goal of the MPFS, The Forest Act of 1993, and the Forest Rules and Regulations of 1995 was to bestow access and management authority to recognized community groups that were willing to manage and rehabilitate degraded forests for the benefit of local communities. With the rules in-place, CFUGs received limited rights to grow, harvest, sell, and manage forests, in accordance with the Forestry Department, Chief Warden, and CNP authorities.

A growing body of evidence—both anecdotal and empirical—suggests that these policy changes have been effective in decentralizing management and reducing rates of forest loss. Many studies suggest that the emergence of community forestry has been an important driver in resolving forest resource issues over the last 25 yr (see, e.g., Straede and Treue, 2006; Gautam, 2007; Nagendra, 2007; Spiteri & Nepal, 2008; Nepal & Spiteri, 2011).

Here, we use remote-sensing techniques to examine trends in forest loss and gain over the last 25 yr, and set these trends within the context of the emergence of community-based management and modern forestry policies in the buffer zone of CNP. Remote sensing and geographic information system (GIS) techniques have been widely used to analyze forest cover dynamics in Nepal since the establishment of modern forestry legislation (see, e.g., Jackson, Tamrakar, Hunt, & Shepherd, 1998; Schreier et al., 1994; Virgo & Subba, 1994; Panta, Kim, & Joshi, 2008), and been found to provide a spatio-temporal perspective when analyzing the relative success of forest management policies (Nagendra et al., 2004).

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MATERIALS AND METHODS

Study Area

Chitwan National Park (CNP) is located on the southern border of Nepal, close to India in the Terai region (Figure 1). Established in 1973, CNP is a UNESCO-designated World Heritage Site. Covering 932 km^2, it is a sanctuary for a diverse tropical ecosystem with many species of endangered flora and fauna such as the one-horned Asian rhinoceros (*Rhinoceros unicornis*), the Royal Bengal tiger (*Panthera tigris tigris*), and the Asian elephant (*Elephas maximus*). It is considered subtropical lowland and lies at the foot of the Himalayan Mountains between two rivers, the Narayani and the Rapti. The park is surrounded by four districts: Chitwan, Parsa, Nawalparasi, and Makwanpur. Additionally, the Parsa Wildlife Reserve (PWR) is located to the east and adjacent to CNP, and in 2003, Beeshazar and its associated lakes located in the northern buffer zone of CNP were designated as a globally important Ramsar site (UNESCO, 2013). Together, CNP and PWR cover approximately 1,431 km^2 of mostly forested land.

CNP has a long history of human influence. It was originally named Royal Chitwan National Park, protected as a hunting preserve for the Nepali royal family and other elites to hunt large game such as tiger, rhinoceros, and elephant. Malaria was rampant until its eradication in the 1950s and 1960s. At that time, the park was fairly remote and inaccessible. New and improved roads were constructed to connect CNP with other areas of Nepal. Forests

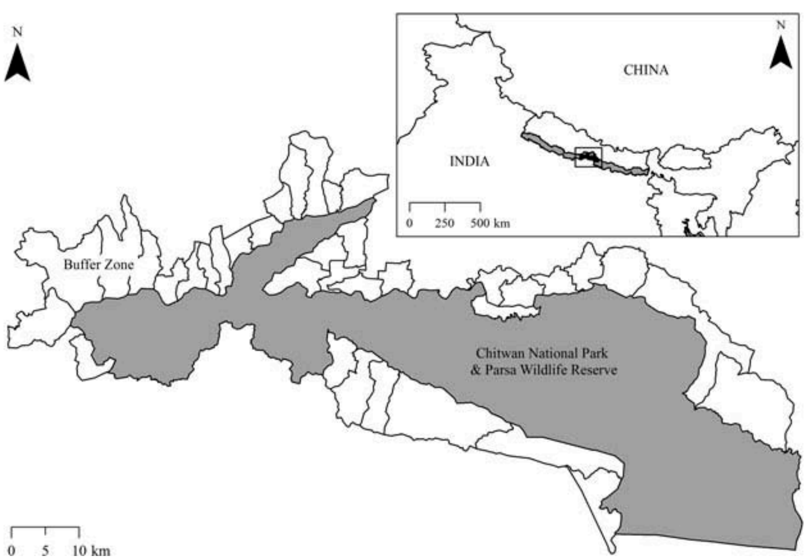

FIGURE 1 Terai region of Nepal, Chitwan National Park, and the 36 village development committees (VDCs) in the buffer zone.

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were cleared to provide land for agriculture, and a growing rural population increasingly impacted the landscape.

The dominant indigenous population endemic to the buffer zone of CNP is the Tharu people. The total population of the 36 village development committees (VDCs) in CNP's buffer zone rose from 292,000 in 2001 (Government of Nepal, 2001), to over 400,000 in 2011 (Government of Nepal, 2011). Importantly, the official buffer zone around CNP does not encompass the entirety of every VDC that is located within its vicinity (Straede & Treue, 2006). For this study, the whole area of each of the 36 VDCs in the CNP buffer zone was analyzed—approximately 1,267 km^2 compared to the 750 km^2 that technically falls within the designated buffer zone. The average annual income in the area is US$210 (Straede & Treue, 2006), relatively low when compared to the gross national income per capita—US$730 (World Bank, 2013). The average household contains 7.1 people with just 48% of working age; 41% are under the age of 15 (Straede & Treue, 2006). Low incomes, in-migration from India and other regions of Nepal, and large family sizes make subsistence resources very important.

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Data Used and Data Analysis

Using Landsat imagery, a normalized difference vegetation index (NDVI) was calculated for the years 1989, 2005, and 2013 to explore changes in forest cover over time. The United Nations' Collaborative Initiative on Reducing Emissions from Deforestation and forest Degradation (2014) estimated that overall forest loss in Nepal fell to zero percent annually between 2005 and 2010. Additionally, a 10-yr Maoist civil war in Nepal ended in 2006, greatly reducing political and social instability. For this reason an intermediate year—i.e., 2005—was used to demarcate two periods (1989–2005 and 2005–2013) to highlight the positive trend that has appeared in recent years. The analysis was conducted for the 36 VDCs in the buffer zone to identify which VDCs had experienced the greatest rates of forest loss and forest growth.

Shorea robusta is the dominant forest type in this region of the Terai region of southern Nepal, and the NDVI analysis was specifically designed to measure changes in cover of this important forest type. Importantly, the Landsat scenes that were used for this analysis were all from the same time of year, selected to be as close to one another as possible to minimize phenological differences in vegetation due to leaf fall or seasonal differences in vegetation moisture content. For detection of *Shorea robusta* forest, Panta et al. (2008) recommend the use of imagery from "October, November, and December, shortly after cessation of the monsoon but before leaf fall" (p. 1588). In addition to Landsat data, historical aerial photographs from 1989 and historical DigitalGlobe imagery via Google Earth Pro from 2005 and 2013 were used to verify NDVI classifications (Table 1).

TABLE 1 Remote Sensing and GIS Data Used for Normalized Difference Vegetation Index (NDVI) Analysis

Satellite and data	Path	Row	Date of acquisition	Bands (wavelength in micrometers)	Source
Landsat 5 TM	141	41	Oct. 31, 1989	Band 3 visible red (0.63–0.69 µm) Band 4 near-infrared (0.76–0.90 µm)	USGS Glovis
Landsat 5 TM	142	41	Nov. 7, 1989	Band 3 visible red (0.63–0.69 µm) Band 4 near-infrared (0.76–0.90 µm)	USGS Glovis
Landsat 5 TM	141	41	Nov. 12, 2005	Band 3 visible red (0.63–0.69 µm) Band 4 near-infrared (0.76–0.90 µm)	USGS Glovis
Landsat 5 TM	142	41	Nov. 19, 2005	Band 3 visible red (0.63–0.69 µm) Band 4 near-infrared (0.76–0.90 µm)	USGS Glovis
Landsat 8 OLI-TIRS	141	41	Nov. 25, 2013	Band 4 visible red (0.64–0.67 µm) Band 5 near-infrared (0.85–0.88 µm)	USGS Glovis
Landsat 8 OLI-TIRS	142	41	Dec. 4, 2013	Band 4 visible red (0.64–0.67 µm) Band 5 near-infrared (0.85–0.88 µm)	USGS Glovis
Historical aerial photographs			1989		Government of Nepal, 1989

Landsat imagery was acquired from the U.S. Geological Survey and preprocessed using ArcMap 10.2 (Esri, Redlands, CA, USA) before NDVI was computed. The digital number (DN) for each Landsat band was converted into top-of-atmosphere (TOA) spectral radiance, which is the amount of energy in watts at the satellite's sensor for each cell on the ground. The formula uses the DN, the highest and lowest cell values, and radiance values, which vary with the gain state of the sensor (Johnson, 2012). For Landsat 8, band-specific multiplicative and additive rescaling factors were also used in the radiance calculation (U.S. Geological Survey, 2013). TOA radiance was then converted to TOA reflectance, a normalized, unitless measure of the ratio of the amount of light energy reaching the earth's surface to the amount of light reflecting off the surface and returning to the top of the atmosphere and thus detected by the satellite's sensors. The formula considers spectral radiance, distance from the earth to the sun, the mean solar exoatmospheric irradiance, the day of year, and the solar zenith angle (Johnson, 2012; U.S. Geological Survey, 2013).

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All but one Landsat scene was cloud-free for the study area. The exception had very limited cloud cover, and virtually all clouds were located within the boundaries of CNP and not within the study area. A cloud mask was created to extract those areas from the scene. The same areas were omitted from all Landsat scenes used in the analysis, approximately 354 ha of the total 126,700 ha examined in the analysis, or 0.28%. Because the clouds were located almost entirely within CNP, the effect on this analysis was minimal.

NDVI was computed using model builder in ArcMap 10.2 using the following formula:

$$\text{NDVI} = (\text{near infrared - red})/(\text{near infrared + red}).$$

The formula uses the visible red and near infrared (NIR) bands. The bands allow the user to determine vegetation cover in an image, as vegetation has different spectral reflectance as compared to other land cover types. The NDVI value is based on the difference between the reflectance of NIR and red light. Where NIR reflectance is much higher than red reflectance, the value is closer to one, on a -1 to 1 scale. Dividing by the total amount of reflected light in both bands normalizes the data to allow comparisons between pixels.

Historic aerial photographs of the Chitwan District in 1989 (obtained from Panta et al., 2008; Government of Nepal, 1989) were scanned and georeferenced using first order transformation. These, in addition to historical images from DigitalGlobe, were used to ground-truth the classification of NDVI values for the years 1989, 2005, and 2013. One-hundred points were randomly generated in ArcMap 10.2 within the extent of the 1989 aerial photographs. For each point in the 1989 aerial image, land cover type was determined by visual inspection and compared with the NDVI classification for 1989 to check for accuracy of the classification. The same points were used with historic images from DigitalGlobe for the accuracy assessment of the 2005 and 2013 NDVI images. Overall, the classification accuracy was 97% with a 0.7% bias for forest and 2.3% bias for nonforest (Table 2).

Zonal statistics were computed with the overlaying VDC polygons to calculate the amount of forest present in each area for each year. Differences between years were calculated using the classified NDVIs, which were subtracted from one another to display areas of forest loss, no change, and gain. Statistical analysis was conducted using the "Stats Package" in version 3.1.2 of the R Statistical Computing Software (R Core Team, 2014). T-tests with a 95% confidence interval were computed to compare the difference in means for percent of total area forested and total number of forested hectares per VDC between 1989 and 2005, 2005 and 2013, and 1989 and 2013.

TABLE 2 Accuracy Assessment for Normalized Difference Vegetation Index (NDVI) Reclassification

		Classified in Landsat image as:						Number of ground truth points
		1989		2005		2013		
		Forest	Non-forest	Forest	Non-forest	Forest	Non-forest	
Ground truth points	Forest	56	1	46	3	47	3	156
	Non-forest	1	42	0	51	1	49	144
Accurate points		98		97		96		300
Total accuracy		97% (0.7% bias for forest; 2.3% bias for nonforest)						

TABLE 3 Forest Change Between 1989, 2005, and 2013 Based on Normalized Difference Vegetation Index (NDVI) Analysis

Overall % change in forest cover: 1989–2005		−9.9%
Overall % change in forest cover: 2005–2013		+7.5%
Overall % change in forest cover: 1989–2013		−3.1%
Mean hectares of forest per VDC: 1989		1,753.9 ha
Mean hectares of forest per VDC: 2005		1,581.3 ha
Mean hectares of forest per VDC: 2013		1,700.1 ha
Mean % of total area forested per VDC: 1989		34.5%
Mean % of total area forested per VDC: 2005		32.3%
Mean % of total area forested per VDC: 2013		36.5%
Mean population growth per VDC: 1991–2011		39.0%
***T*-test for % of total area forested among 36 VDCs**		
1989 & 2005	2005 & 2013	1989 & 2013
$p < .05$	$p < .05$	$p > .10$
***T*-test for number of forested hectares per VDC**		
1989 & 2005	2005 & 2013	1989 & 2013
$p < .05$	$p < .05$	$p > .33$

Note. VDC = village development committee.

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RESULTS

Analysis of NDVI revealed that in total, VDCs in the buffer zone lost 9.9% of total forest cover between 1989 and 2005, and regained 7.5% between 2005 and 2013; the net loss between 1989 and 2013 was 3.1% (Table 3). Significant differences were found in the percent of total area forested and total number of forested hectares per VDC between the years 1989 and 2005, and between 2005 and 2013 ($p < .05$). For example, mean hectares of forest per VDC declined from 1,753 in 1989 (34.5% of VDC area) to 1,581 ha in 2005 (32.3% of area). Mean VDC hectares increased to 1,700 by 2013, thus comprising 36.5% of total VDC area.

Interestingly, no significant difference between means was found between 1989 and 2013 for the percentage of total area forested among 36 VDCs ($p > 0.1$) or for the number of forested hectares per VDC ($p > 0.33$), suggesting that total forest cover in the area has largely regenerated to the levels that existed in 1989 (Table 3). Note, however, that the characteristics of regenerated forest seen today are likely to vary significantly from the 1989 conditions with respect to species, age, and ecological function. Moreover, this rebound in forested area has occurred despite a 39% increase in population between 1991 and 2011.

Figure 2 shows the temporal distribution of forest cover by VDC for years 1989, 2005, and 2013. In all years, high human populations are indicated by nonforest areas in the central region around CNP. Note that the occurrence of forest adjacent to CNP is mostly found in the eastern portions of the study area and the extreme west. Figure 3 shows forest cover change from 1989 to 2005, and from 2005 to 2013. The greatest levels of both loss and regeneration were found in the VDCs located to the north and south of the central portion of CNP (Figures 2 and 3). Notably, the north-central area of the buffer zone has seen high rates of human population growth, development, and ecotourism over the last 25 yr.

DISCUSSION AND CONCLUSIONS

Our NDVI analysis found that forest conditions within CNP's buffer zone have begun to stabilize between 2005 and 2013. Forests have seen significant regeneration in the study area, a trend consistent with other reports of current rates of deforestation and forest degradation in Nepal that suggest a deceleration in forest loss on a national level. Indeed, the total percentage of forest cover in Nepal was stable at 25.4% in 2005 (United Nations Collaborative Initiative on Reducing Emissions from Deforestation and Forest Degradation, 2014), and World Bank (2013) data indicate consistent levels in 2009, 2010, and 2011. While there have not been many recent forest cover NDVI analyses done for our study area, our results partially coincide with the results of another NDVI deforestation study conducted in the Chitwan District adjacent to CNP by Panta et al. (2008). The study found that between 1989 and 2001, forest cover in the Chitwan District fell 7.95%, whereas our study found that for all VDCs in the buffer zone of CNP, forest cover fell 9.9% between 1989 and 2005.

The cessation of forest loss in Nepal is likely due to a combination of factors. We suggest here that decentralized forest management institutions such as community forestry have played an important role in not just slowing, but halting and possibly reversing forest loss and degradation in areas of the buffer zone of CNP. Alongside this trend, the number of CFUGs is continually growing.

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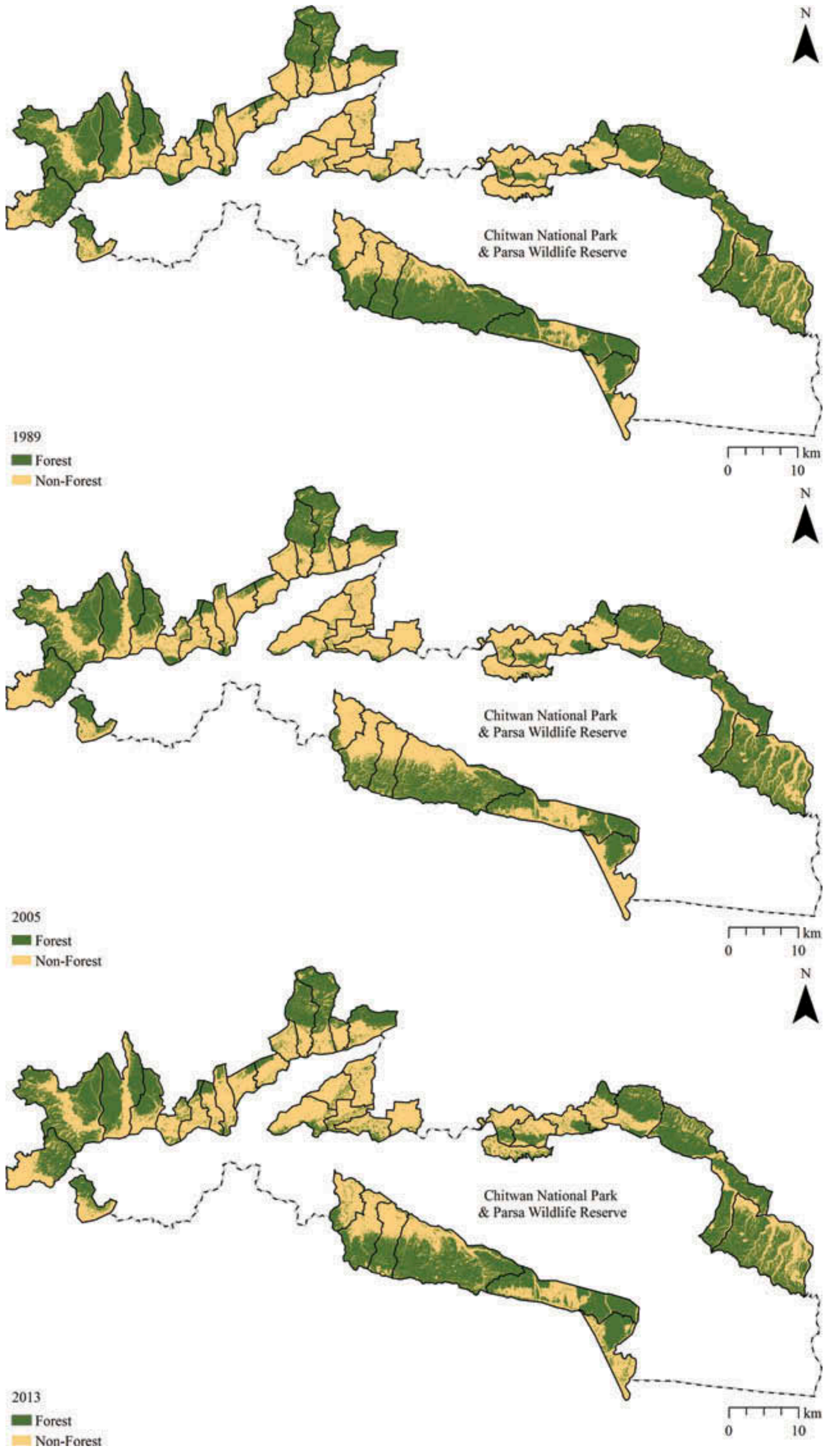

Figure 2 Forest cover in the buffer zone of Chitwan National Park (CNP) in 1989, 2005, and 2013.

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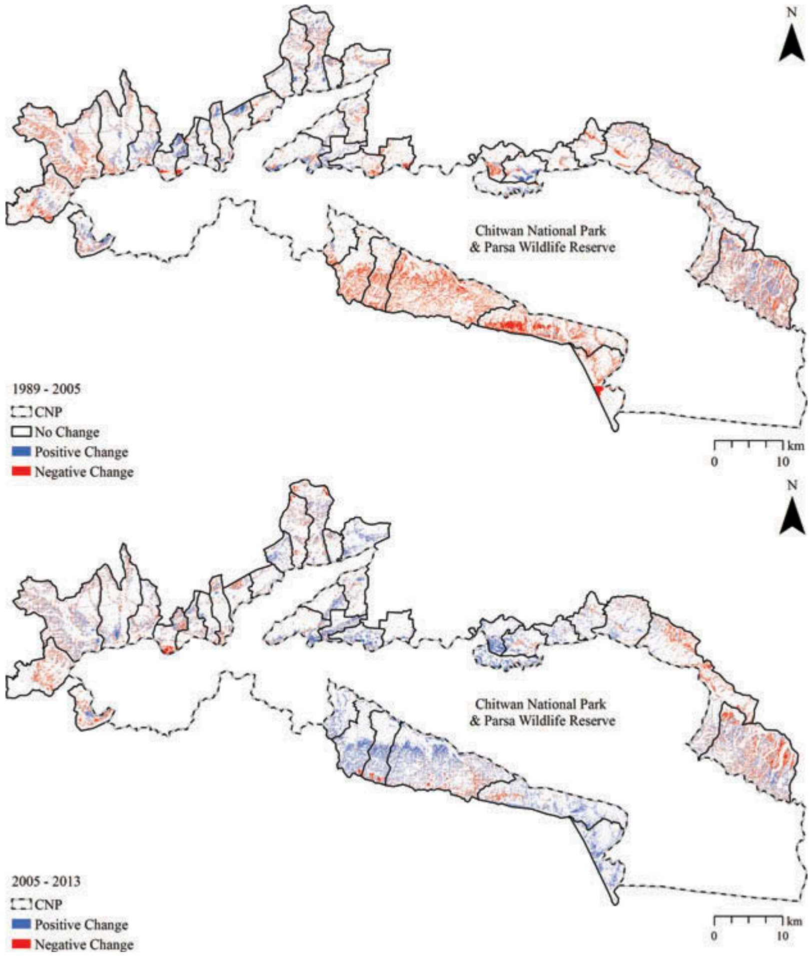

Figure 3 Forest cover change in the buffer zone of Chitwan National Park (CNP) between 1989–2005 and 2005–2013.

There are other factors that have likely contributed to the reversal of historic forest trends—e.g., the adoption of energy-efficient technologies such as home biogas systems; improved cooking stoves; and increased attention from international aid, donors, and NGOs. Moreover, a large array of groups and organizations have sought to promote community-based forest management as a method to devolve management authority from the state to local-level institutions to manage as they see fit the forests that contribute to the social, economic, and ecological health of communities. NGOs such as the World Wildlife Fund and SeedTree Nepal have helped implement energy-efficient technologies, establish tree seedling nurseries, and educate communities about how to sustainably manage local forests. Fuel efficient

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stoves and biogas are increasingly common in homes nationwide, partially due to NGOs and international aid.

These findings should be tempered by uncontrolled variables not considered in our NDVI study. Indeed, there are many factors, both natural and anthropogenic, which affect forest loss and regeneration in CNP's buffer zone. For example, the Rapti and Narayani Rivers border CNP, and because this area of the Terai region is subtropical lowland, it experiences a long annual monsoon season that begins in summer. The monsoon season brings heavy, consistent rains that can cause the rivers to flood and erode banks. Landslides and mudslides are also common during the monsoon season, and can have significant effects on the landscape, which increases as erosion-protecting forests are removed. As a result, when considering the changes in forest cover in Figures 2 and 3, it is important to realize that a small percentage of the change could be attributed to the monsoon season and changes in the two rivers' paths over time, particularly where the northern border of CNP meets the buffer zone. Also, when forests are regenerated, the quality of forest and the benefits it has on the ecosystem are likely limited when compared to original stands. Here, we examined human aspects of forest systems in the buffer zone of CNP, and further work needs to be done to enhance our knowledge about the relative quality of new forested lands in the area.

Importantly, this study does not distinguish between areas located within the buffer zone of CNP, but rather examines all forests located within the VDCs that lie within the buffer zone. Furthermore, this study does not examine the difference in forest loss and regeneration rates between regular community forests and buffer zone community forests, which operate quite differently in terms of property rights, monitoring effectiveness, rules for harvesting, the freedom to change rules in place, and economic support—both external and within the user group. Nagendra et al. (2005) conducted an NDVI remote sensing analysis of both community forests and buffer zone community forests around CNP, and found that between 1989 and 2000, the amount of forest loss was significantly lower and the amount of regeneration was significantly higher in buffer zone forests when compared with regular community forests. Perhaps the outcomes of our study would have been more congruent with these results had we distinguished between regular and buffer zone forests. However, we sought to examine the larger areas surrounding CNP considering both forest management regimes—i.e., community forests as well as buffer zone forests.

The indigenous Tharu people living in the buffer zone of CNP have a substantial impact on the forested landscape, and further studies are needed to better understand the Tharu people's traditional forestry system, and how it differs and resembles community forestry in Nepal today. Stevens (2003) examined the effects of protected areas on indigenous communities around Nepal's Sagarmatha National Park, noting that the indigenous

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Khumbu Sherpas of the area feared that the park, created in 1976, would hinder their traditional use and management of natural resources. “These fears soon proved justified when national park authorities announced new policies in 1979 that not only banned tourist campfires but also banned all felling of trees by Sherpas and enforced the new regulations with an army ‘protection unit’” (Stevens, 2003, p. 258, citing Stevens, 1983; Brower 1991a, 1991b; Stevens, 1993, 1997; Brower & Dennis, 1998). Baral and Heinen (2007) also found that the establishment of protected areas in Nepal’s Terai region alienated local populations and reduced much-needed access to resources. Moreover, the eventual liberalization of park regulations resulted in more supportive attitudes of local people.

Forest cover change in our study area is likely due in part to the effects of CNP on the ways that Tharu people manage and perceive forests since the establishment of CNP and the buffer zone around it. Further research is needed to better understand how these institutional changes toward indigenous management systems have influenced forest regeneration and loss trends in the Terai region.

Finally, and importantly, our analysis represents only a subset of the forested landscape that exists today in Nepal, albeit an ecologically and socially important region. However, when compared with data from sources such as the World Bank and United Nations, we suggest that the trends we found here could be representative of a much broader area. Although Nepal’s forests have historically experienced high rates of deforestation and forest degradation, there is hope for the protection and regeneration of these resources with decentralized control in partnership with community forestry programs.

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