Summer 8-15-2015

# Linking Attitudes, Policy, and Forest Cover Change in Buffer Zone Communities of Chitwan National Park, Nepal

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**LINKING ATTITUDES, POLICY, AND FOREST COVER CHANGE IN BUFFER**

**ZONE COMMUNITIES OF CHITWAN NATIONAL PARK, NEPAL**

By

Jared Richard Stapp

B.S. Utah State University, 2012

A THESIS

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Master of Science

(in Ecology and Environmental Sciences)

The Graduate School

University of Maine

August 2015

Advisory Committee:

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# THESIS ACCEPTANCE STATEMENT

On behalf of the Graduate Committee for Jared R. Stapp we affirm that this manuscript is the final and accepted thesis. Signatures of all committee members are on file with the Graduate School at the University of Maine, 42 Stodder Hall, Orono, Maine.

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Jared R. Stapp                                                                                          Date

# LINKING ATTITUDES, POLICY, AND FOREST COVER CHANGE IN BUFFER ZONE

# COMMUNITIES OF CHITWAN NATIONAL PARK, NEPAL

By Jared Richard Stapp

Thesis Co-Advisors: Dr. Robert J. Lilieholm & Dr. Christopher S. Cronan

An Abstract of the Thesis Presented
in Partial Fulfillment of the Requirements for the
Degree of Master of Science
(in Ecology and Environmental Sciences)
August 2015

Deforestation in Nepal threatens the functioning of complex social-ecological systems, including rural populations that depend on forests for subsistence, as well as Nepal's biodiversity and other ecosystem services. Reliance on forest resources, coupled with high population densities and rates of growth, highlights the importance of studying the relationship between human communities, forest cover and trends through time, and forest management institutions. A Master Plan for Nepal's Forestry Sector (MPFS), enacted in 1989, laid the foundation for modern community-based forest management in Nepal. In 2014, the MPFS reached the end of its 25-year 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 examine the effectiveness of the MPFS to offer insight into this complex coupled human and natural system. Using remote sensing techniques and Landsat satellite imagery, the 25-year anniversary of the MPFS was used to explore forest cover trends in the buffer zone Village Development Committees surrounding Chitwan National Park (CNP). An in-country household survey was then conducted to: (1) understand how local attitudes toward forest conservation-related behaviors correlated with empirical forest cover trends; and (2) understand which socio-demographic variables influenced supportive attitudes. The survey was conducted in two rural communities in southern Nepal—one that has experienced significant forest loss, the other forest gain—compare with forest cover trends as indicated by the results from Chapter 1. Lastly, we used an agent-based model (ABM) to explore what effect village attitudes toward forest conservation would have on the extent of forest cover if improved policies are implemented, population growth rate fluctuates, and villages are able to cooperate by mimicking each other's attitudes and behaviors.

Results suggest that since the MPFS was enacted, there was first a continued decrease in forest cover, followed by a significant increase overall. Survey results suggest a significant difference in attitudes toward forest conservation in the two areas studied, and in both study sites, participation in community forestry strengthened support for conservation, supportive forest conservation-related attitudes aligned with forest cover gain in recent years, and a negative relationship was found between economic status and having supportive attitudes. Additionally, on average, respondents did not feel that the current national political climate in Nepal supported sustainable forestry. The results from the ABM suggest that improving forest-related policies would have a dramatic

effect on the forest cover over time, the ability for villages to cooperate will likely have little effect on forest cover, and population growth rate will likely have a significant effect on forest extent. We also found that despite clear strengths, there are challenges with using ABM to model forest conservation dynamics and land use/land cover change at different scales. These data offer insight into the success of modern community-based forest management policies and supporting institutions, and are especially important as Nepal's Master Plan for the Forestry Sector has expired and the country is in the process of structuring a new Forestry Sector Strategy.

**DEDICATION**

This thesis is dedicated to the people living in the buffer zone of Chitwan National Park, Nepal. Never have I experienced such kindness, warmth, and generosity as I did while conducting the field work for this project. Despite the 110 degree heat, countless motorcycle rides on undeveloped, muddy roads with more elephants than cars, and a constant language barrier, I was greeted in every village with hibiscus flowers, smiles, and a genuine willingness to help me in any way I needed—viewing me as young, curious student, eager to learn more about how they live their lives in a place so different than my own home. The underlying motive for this work has been to not just shed light on the benefits and functionality of decentralized community-based natural resource management, but to highlight areas—through listening to people's concerns and experiencing their livelihoods first-hand—where the system can be improved to better meet their everyday needs. I anticipate the day when I can return to Nepal and share this work in its completion with the people I have worked with over a strong pot of Nepali tea.

submitted as an 'Insight' article to Ecology and Society. Since writing has been

completed, our goal is to submit the manuscript on July 20th, 2015. I thank Rob

Lilieholm, Tim Waring, Jessica Leahy, and Emily Silver for their help with this chapter.

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

**INTRODUCTION**

After decades of deforestation in the latter part of the 20<sup>th</sup> Century, Nepal is now

regarded by some as one of the world's leading examples of successful community-based

forest management (Gautam et al., 2004). Nepal was one of the earliest adopters of

community forestry in Asia (Pandit & Bevilacqua, 2011 citing Arnold, 1992), and

modern community-based forest management grew from a Master Plan for the Forestry

Sector (MPFS) enacted in 1989, followed by related legislation in 1993 and 1995

(HMGN, 1993, 1995; HMGN, ADB, & FINNIDA, 1988). In combination, the core goal

of these three pieces of legislation was to grant limited management rights and authority

to established community user groups to rehabilitate degraded forest parcels in order to

better meet the needs of local people. Community Forest User Groups (CFUGs) and

Buffer Zone Community Forest User Groups (BZCFUGs; from here forward, 'CFUGs'

will be used interchangeably) were granted limited authority to manage forests in their

communities.

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-20<sup>th</sup> 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 improved road systems, increased migration into the Terai,

development, and intensified commercial forestry. Increasing settlements made

agriculture more important in the region, as the Terai is known as the fertile bread basket

of Nepal. And, increased clearing for agriculture made more land available for migrants from less-productive regions of the country (Pravat, 2006).

Today, forests cover approximately 25.4% of the country (World Bank, 2013) and there are 1.7 million ha of community forest—about 29% of all forests in Nepal and supporting approximately 2.25 million households (GoN, 2014). Although community forestry has been highly influential in Nepal, there have been varying levels of success among communities in the last 25 years in terms of reversing historic deforestation trends, granting representation to various socio-demographic and ethnic groups, providing local employment, and promoting efficient bureaucratic structures (GoN, 2014). A growing body of evidence—both empirical and anecdotal—suggests that modern forest-related policy changes have been effective in decentralizing management and reducing rates of forest loss (GoN, 2014), and some studies suggest that community-based forest management has been effective in combatting forest degradation in Nepal over the last 25 years (Gautam, 2007; GoN, 2014; Nagendra, 2007; Nepal & Spiteri, 2011; Spiteri & Nepal, 2008; Stræde & Treue, 2006).

The following three chapters incorporate different methodologies to examine the effectiveness of the MPFS and community-based forest management, and to offer insight into this complex coupled human and natural system. Chapter 1 uses remote-sensing techniques to examine trends in forest loss and gain over the last 25 years, and sets these trends within the context of the emergence of community-based management and modern forestry policies in the buffer zone of Chitwan National Park (CNP). Remote sensing and GIS techniques have been widely used to analyze forest cover dynamics in Nepal since the establishment of modern forestry legislation (see e.g., Jackson et al., 1998; Schreier et

al., 1994; Virgo and Subba, 1994; Panta et al., 2008), and have been found to provide a spatio-temporal perspective when analyzing the relative success of forest management policies (Nagendra et al., 2004).

Chapter 2 describes the results of a household survey in two Village Development Committees (VDCs) located adjacent to CNP. The VDCs were purposively selected based on the results from Chapter 1, which identified buffer zone communities experiencing high levels of forest loss and regeneration between 2005 and 2013. Chapter 2 had two objectives. First, we sought to understand how household attitudes toward forest conservation-related behaviors correlated with empirical forest cover trends. Second, we were interested in which socio-demographic variables influenced supportive attitudes toward forest conservation-related behaviors.

Chapter 3 uses an agent-based model (ABM) to examine what effect village attitudes toward forest conservation have on the future landscape and extent of forest cover if improved forest conservation-related policies are implemented, population growth rate fluctuates, and villages are able to mimic one another's attitudes toward forest conservation-related behaviors. In the Discussion, we give an overview of some of the challenges we encountered with modeling land use/land cover change (LULCC) in the place-specific context of Bachauli, Nepal. ABM allows users to conceptualize these ideas by examining how individual agents in a system (e.g., villages in Bachauli) are influenced differently by, and adapt in response to, input variables, which then aggregate to produce emergent, landscape-level outcomes. The model integrates remotely-sensed land cover data from Chapter 1 and household attitudes toward forest conservation, community forestry, and forest governance institutions in Nepal from Chapter 2. By

coupling qualitative survey data and quantitative land cover data to model future LULCC

scenarios, we hope that stakeholders—from NGOs, government agencies, to local

communities—are better able to understand how improved forest policies, population

growth, collective action, and household attitudes affect LULCC in Nepal.

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# CHAPTER 1

# EVALUATING THE IMPACTS OF FOREST MANAGEMENT POLICIES AND

# COMMUNITY-LEVEL INSTITUTIONS IN THE BUFFER ZONE

# OF CHITWAN NATIONAL PARK, NEPAL

## CHAPTER ABSTRACT

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-year 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-year anniversary of the MPFS to explore

forest cover trends in the buffer zone surrounding Chitwan National Park. Landsat

imagery was used for the years 1989, 2005, and 2013 to compute a Normalized

Difference Vegetation Index to analyze trends in forest cover for 36 buffer zone Village

Development Committees. 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 overall. These data offer insight into the success of

modern community-based forest management policies and supporting institutions, and

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

**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 et al., 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 et al., 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 et al., 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.

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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. And, increased clearing for agriculture made more land available for migrants from less productive regions of the country (Pravat, 2006).

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; Upadhaya, 2010; Pandit & Bevilacqua, 2011). Bajracharya (1983) quotes FAO (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 (Upadhaya,

2010), and their traditional management practices were challenged and replaced by a

centralized management system. In 1961, King Mahendra implemented the Panchayat

system — a party-less 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-

year 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 HMGN, ADB, & FINNIDA, 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 (HMGN, 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 et al., 2007).

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

HMGN, 2002). CNP's buffer zone includes approximately 750 km$^2$ and is home to more

than 300,000 people (Stræde & 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 of protected resources. 30-50% of (CNP) revenues

are distributed to buffer zones 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 (UGC) 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 socio-economic 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 (UNESCO, 2013).

Community Forest User Groups (CFUGs) and Buffer Zone Community Forest User Groups (BZCFUGs; from here forward, 'CFUG' 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 non-buffer 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 five-year 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 non-buffer 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 CFUGs 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 (FECOFUN, 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 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 years (see, e.g., Stræde 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 years, 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 GIS techniques have been widely used to analyze forest cover

dynamics in Nepal since the establishment of modern forestry legislation (see e.g.,

Jackson et al., 1998; Schreier et al., 1994; Virgo & Subba, 1994; Panta et al., 2008), and

been found to provide a spatio-temporal perspective when analyzing the relative success

of forest management policies (Nagendra et al., 2004).

**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 1.1). 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.
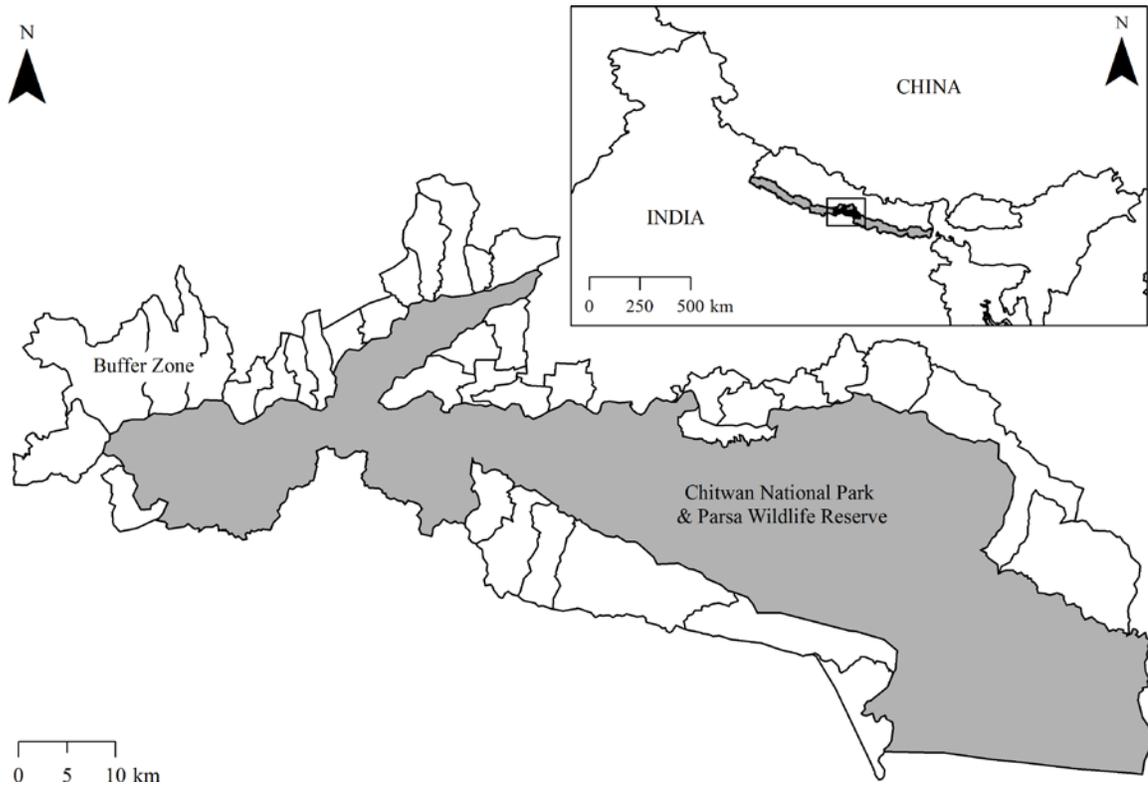
Figure 1.1. Terai region of Nepal, Chitwan National Park, and the 36 village development committees (VDCs) in the buffer zone.

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 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 (HMGN, 2001), to over 400,000 in 2011

(GoN, 2011). Importantly, the official buffer zone around CNP does not encompass the

entirety of every VDC that is located within its vicinity (Stræde & Treue, 2006). For this

study, the whole area of each of the 36 VDCs in the CNP buffer zone was analyzed —

approximately 1267 km$^2$ compared to the 750 km$^2$ that technically falls within the

designated buffer zone. The average annual income in the area is $210 USD (Stræde &

Treue, 2006), relatively low when compared to the gross national income per capita —

$730 USD (World Bank, 2013). The average household contains 7.1 people with just

48% of working age; 41% are under the age of 15 (Stræde & Treue, 2006). Low incomes,

in-migration from India and other regions of Nepal, and large family sizes make

subsistence resources very important.


**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 (REDD, 2014) estimated that overall forest loss in

Nepal fell to zero percent annually between 2005 and 2010. Additionally, a 10-year

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, p. 1588) recommend the use of imagery from "October, November, and December, shortly after cessation of the monsoon but before leaf fall." 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 1.1).

Table 1.1. Remote sensing and GIS data used for NDVI analysis.

| Satellite & 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)<br>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)<br>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)<br>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)<br>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 - 0.67µm)<br>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 - 0.67µm)<br>Band 5 near-infrared (0.85 - 0.88 µm) | USGS Glovis |
| Historical aerial photographs | | | 1989 | | GoN, 1989 |

Landsat imagery was acquired from the US Geological Survey and pre-processed using

ArcMap 10.2 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, 2013). 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, 2013; U.S. Geological Survey, 2013).

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:

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

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; HMGN, 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 non-forest (Table 1.2).

Table 1.2. Accuracy assessment for NDVI reclassification.

| | | Classified in Landsat image as: | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1989 | | 2005 | | 2013 | | Number of ground truth points |
| | | 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 non-forest] | | | | | |

23

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.

**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 1.3). 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 ($p$ <0.05). For example, mean hectares of forest per VDC declined from 1,753 in 1989 (34.5% of VDC area), to 1,581 hectares in 2005 (32.3% of area). Mean VDC hectares increased to 1,700 by 2013, thus comprising 36.5% of total VDC area.

Table 1.3. Forest change between 1989, 2005, and 2013 based on 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 | | 1753.9 ha |
| Mean hectares of forest per VDC: 2005 | | 1581.3 ha |
| Mean hectares of forest per VDC: 2013 | | 1700.1 ha |
| Mean % of total area forest per VDC: 1989 | | 34.5% |
| Mean % of total area forest per VDC: 2005 | | 32.3% |
| Mean % of total area forest 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 |
| $p<0.05$ | $p<0.05$ | $p>0.1$ |
| T test for number of forested hectares per VDC | | |
| 1989 & 2005 | 2005 & 2013 | 1989 & 2013 |
| $p<0.05$ | $p<0.05$ | $p>0.33$ |

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 1.3). Note, however, that the characteristics of regenerated forest seen today are likely to vary significantly from 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 1.2 shows the temporal distribution of forest cover by VDC for years 1989, 2005, and 2013. In all years, high human populations are indicated by non-forest 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 1.3 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 1.2 and 1.3). Notably, the north-central area of the buffer zone has seen high rates of human population growth, development, and ecotourism over the last 25 years.
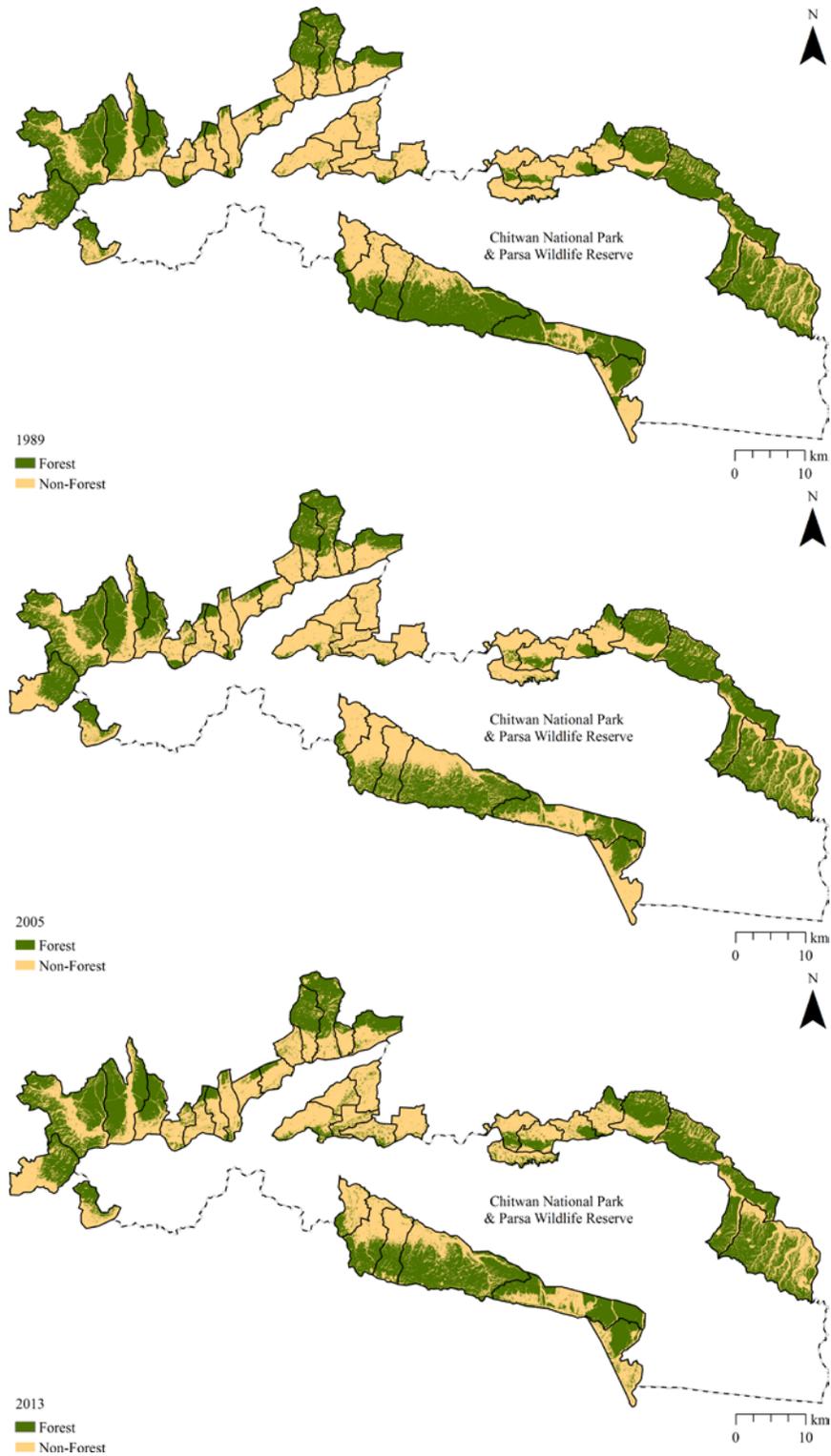
Figure 1.2. Forest cover in the buffer zone of Chitwan National Park (CNP) in 1989,

2005, and 2013.
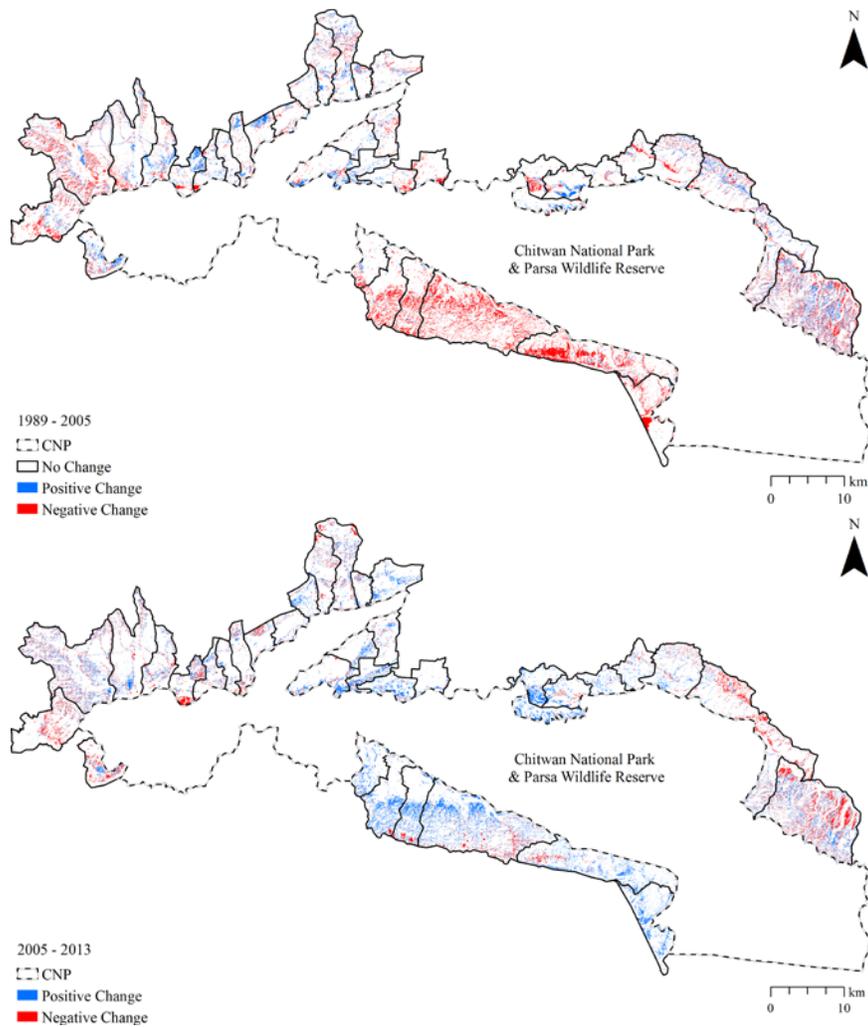
Figure 1.3. Forest cover change in the buffer zone of Chitwan National Park (CNP) between 1989–2005 and 2005–2013.

## DISCUSSION AND CONCLUSION

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 (REDD, 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 percent, whereas our study found that for all VDCs in the buffer zone of CNP, forest cover fell 9.9 percent 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.

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

29

manage local forests. Fuel efficient 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

1.2 and 1.3, 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 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; Brower, 1991b; Stevens, 1993; Stevens, 1997; Brower & Dennis,

1998). Baral & 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 towards 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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# CHAPTER 2

## LINKING ATTITUDES, POLICY, AND FOREST COVER CHANGE IN BUFFER ZONE COMMUNITIES OF CHITWAN NATIONAL PARK, NEPAL

## CHAPTER ABSTRACT

Deforestation in Nepal threatens the functioning of complex social-ecological systems, including rural populations that depend on forests for subsistence, as well as Nepal's biodiversity and other ecosystem services. Nepal's forests are particularly important to the nation's poorest inhabitants, as many depend upon them for daily survival. Two-thirds of Nepal's population relies on forests for sustenance, and these pressures are likely to increase in the future. This, coupled with high population densities and growth rates, highlights the importance of studying the relationship between human communities, forest cover trends through time, and forest management institutions. Here, we used surveys to explore how household attitudes associated with conservation-related behaviors in two rural communities – one that has experienced significant forest loss, the other forest gain – compare with forest cover trends as indicated by satellite-derived forest loss and regeneration estimates between 2005 and 2013. Results found a significant difference in attitudes in the two areas, perhaps contributing to and reacting from current forest conditions. In both study sites, participation in community forestry strengthened support for conservation, forest conservation-related attitudes aligned with forest cover trends, and a negative relationship was found between economic status and having supportive forest conservation-related attitudes. Additionally, on average, respondents

were not satisfied with their district forest officers and did not feel that the current

political climate in Nepal supported sustainable forestry. These findings are important as

Nepal's Master Plan for the Forestry Sector has expired and the country is in the process

of structuring a new Forestry Sector Strategy.

**INTRODUCTION**

After decades of deforestation in the latter part of the 20th Century, Nepal is now

regarded by some as one of the world's leading examples of successful community-based

forest management (Gautam et al., 2004). Nepal was one of the earliest adopters of

community forestry in Asia (Pandit & Bevilacqua, 2011a citing Arnold, 1992), and

modern community-based forest management was formalized in the Master Plan for the

Forestry Sector (MPFS) enacted in 1989, followed by related legislation in 1993 and

1995 (HMGN, 1993, 1995; HMGN, ADB, & FINNIDA, 1988). In combination, the core

goal of these three pieces of legislation was to grant limited management rights and

authority to established community user groups to foster the rehabilitation of degraded

forest parcels and better meet the needs of local people.

Community Forest User Groups (CFUGs) and Buffer Zone Community Forest

User Groups (BZCFUGs; hereafter, "CFUGs" will be used interchangeably) were

granted limited authority to manage forests in their communities. Before this, in 1957,

Nepal nationalized all forests in the country to ensure centralized control over timber

markets (Agrawal & Ribot, 1999; Jones, 2007), but the Act undermined community-level

management practices and significantly accelerated deforestation trends (Agrawal &

Ostrom, 2001). In addition, increased centralization and control over forest management created distrust between forest users and government forest-sector institutions – a condition that persists (Pandit & Bevilacqua, 2011a; Pandit & Bevilacqua, 2011b; Shrestha & McManus, 2007).

Today, there are 1.7 million hectares of community forest – about 29% of all forests in Nepal. These forests support approximately 2.25 million households (GoN, 2014). Although community forestry has been highly influential in Nepal, there have been varying levels of success among communities in the last 25 years in terms of reversing historic deforestation trends, granting representation to various socio-demographic and ethnic groups, providing local employment, and promoting efficient bureaucratic structures (GoN, 2014).

A growing body of evidence – both empirical and anecdotal – suggests that modern forest-related policy changes have been effective in decentralizing management and reducing rates of forest loss (GoN, 2014; Chapter 1), and some studies suggest that community-based forest management has been effective in combatting forest degradation in Nepal over the last 25 years (Gautam, 2007; GoN, 2014; Nagendra, 2007; Nepal & Spiteri, 2011; Spiteri & Nepal, 2008; Stræde & Treue, 2006).

Ostrom's (1990) seminal work examined how community-level self-governance of common pool resources (CPRs) can yield successful outcomes, especially as compared to centralized management institutions. In Nepal, as well as in many other parts of the world, her work also explored the complexities and fragility of management institutions, and what components of a CPR system are critical for it to function sustainably (e.g.,

Agrawal & Ostrom, 2001; Agrawal & Ostrom, 2008; Andersson & Ostrom, 2008; Ostrom et al., 1993; Shivakoti & Ostrom, 2002).

Many studies have since examined the potential for successful self-governance of CPRs, particularly for forest resources in Nepal under varying social and biophysical conditions. These studies have reinforced the importance of Ostrom's design principles for managing CPRs (Ostrom, 1990), as well as common property institutions, group size, heterogeneity, and the presence of collective action (see, e.g., Agrawal & Gupta, 2005; Gautam, 2007; Gautam & Shivakoti, 2005; Chakraborty, 2001; Gurung et al., 2013; Nagendra et al., 2005; Shrestha & McManus, 2007). Still needed, however, is a better understanding of how household attitudes associated with forest conservation-related behaviors aggregate to community-level decision-making and, ultimately, landscape outcomes.

Earlier work has shown that household surveys focused on community-based resource management have been an effective method in making connections between household perceptions and empirical trends (see, e.g., Jones, 2007; Mehta & Kellert, 1998; Nepal & Spiteri, 2011; Spiteri & Nepal, 2008; Stræde & Treue, 2006). Here, we describe the results of a household survey in two Village Development Committees (VDCs) located in the buffer zone of Chitwan National Park in southern Nepal (Figure 2.1). The VDCs were purposively selected based on a remote sensing analysis which identified buffer zone communities at two ends of a spectrum – one VDC experiencing high levels of forest loss between 2005 and 2013, the other VDC significant gains in forest cover (Chapter 1). Our first research objective sought to understand how household attitudes toward forest conservation-related behaviors correlated with empirical forest

cover trends. Our second research objective explored which socio-demographic variables influenced supportive attitudes toward forest conservation-related behaviors.

## METHODS

### Study Area

Chitwan National Park (CNP), established in 1973, is a UNESCO-designated World Heritage Site. CNP is located close to the southern border of Nepal in the low-lying Terai region adjacent to India (Figure 2.1). CNP is considered subtropical lowland and is located at the foot of the Himalayan Mountains, adjacent to two rivers – the Narayani and the Rapti. The Park area extends over four administrative districts: Chitwan, Parsa, Nawalparasi, and Makwanpur. In addition to CNP, the Parsa Wildlife Reserve (PWR) is located to the east, and Beeshazar and its associated lakes are located to the north of the Park (UNESCO, 2013).

CNP and PWR together cover approximately 177,000 hectares of mostly forested land. CNP has a long history of human influence. When first established, it was named Royal Chitwan National Park, and was used by the royal family and other elites to hunt large animals such as Royal Bengal tigers (*Panthera tigris*), Asian one-horned rhinoceros (*Rhinoceros unicornis*) and Asian elephants (*Elephas maximus*). At the time, the Park and surrounding areas were fairly remote and inaccessible, and malaria was rampant. New roads were built in the 1950s and 1960s to improve access to the region, and forests were cleared to mitigate malaria and provide land for agricultural expansion and a growing population.

46

Today there are 36 VDCs adjacent to CNP. The total population of these administrative units increased from 292,000 in 2001 (HMGN, 2001), to over 400,000 in 2011 (GoN, 2011). Note that CNP's official buffer zone does not include the entirety of the surrounding VDCs (Stræde & Treue, 2006). For this study, the entire area of VDCs adjacent to the Park is considered, which includes areas beyond the official buffer zone of CNP. The annual per capita income in the Central Terai region is $647 USD – slightly lower than the national per capita income of $718 USD (Sharma et al., 2014). The average household size is 7.1, with 48% of people being of working age, and 41% under the age of 15 (Stræde & Treue, 2006, citing Banskota et al., 1996).

**<u>Survey Design and Development</u>**

We used a purposive sampling approach (Mahat, 2009; Tashakkori & Teddie, 1998) to better understand how household attitudes toward forest conservation-related behaviors correlate with empirical forest cover trends in areas that are on opposite ends of the spectrum with regards to forest loss and gain in recent years. Previous remote sensing work (Chapter 1) quantified the amount of forested land that had been deforested and regenerated within all 36 VDCs adjacent to CNP between the years 2005 and 2013. Two VDCs were purposively selected from this pool to meet these criteria – (1) Narayani, which had seen significant forest cover loss in recent years, and (2) Bachauli, which had seen significant forest regeneration (Figure 2.1).

Similarities between Bachauli and Narayani such as size, geographic location, and population allowed for comparison (Mahat, 2009). Narayani and Bachauli are approximately 17.7 km$^2$ and 19.5 km$^2$ in size, respectively. Bachauli's population rose approximately 23.5% between 1991 and 2011, from 8,338 to 10,905; whereas the

population in Narayani rose approximately 20%, from 7,234 to 9,047 (HMGN, 1991; GoN, 2011). One difference is that Narayani is characterized by an agriculture-based economy, while Bachauli's economy relies heavily on ecotourism from CNP. In fact, the north entrance to CNP is located in the village of Sauraha, located within Bachauli.
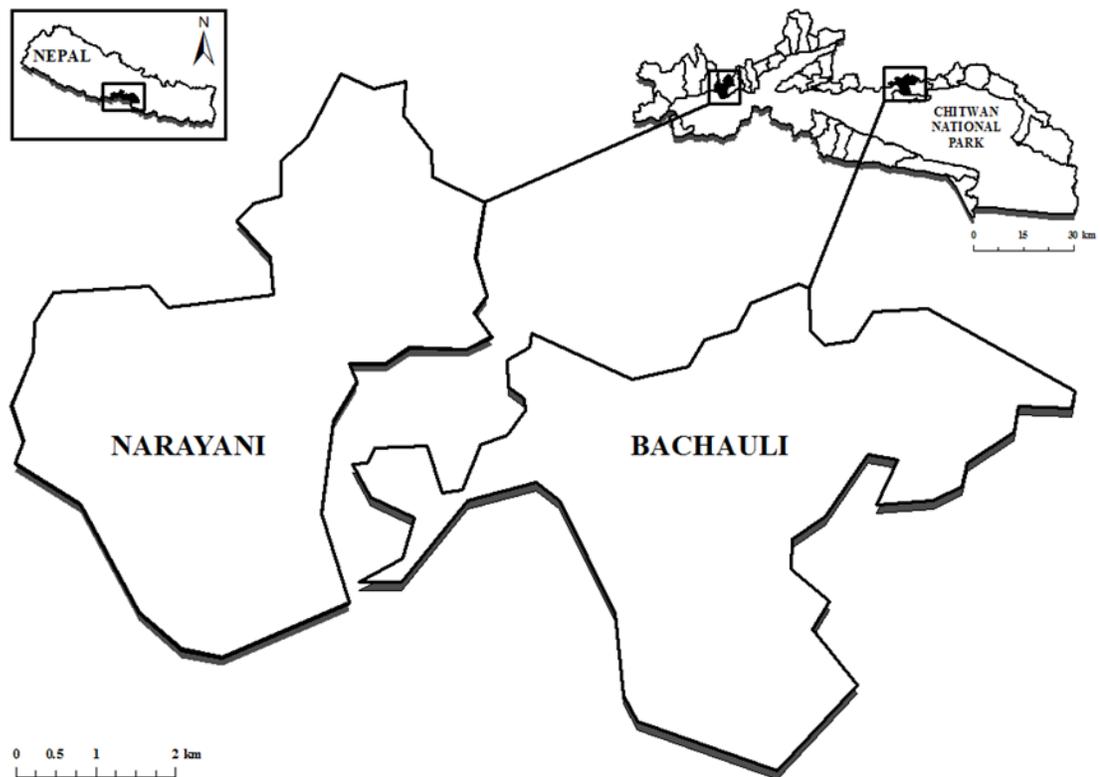


Figure 2.1. Location of Chitwan National Park and the VDCs of Bachauli and Narayani.

To better understand how household attitudes toward forest conservation-related behaviors correlate with empirical forest cover trends, we define attitudes which support forest conservation by considering a household's: (1) dependence on forests and perception of forest trends; (2) its willingness to support collective action and community

forestry; (3) its willingness to support non-governmental organizations (NGOs) that promote forest conservation; (4) its willingness to adopt energy-efficient technologies which decrease pressure on forests; and (5) its willingness to support existing forest-related institutions and policies.

Survey development was assisted by SeedTree[1] (ST), a US-based NGO that has been engaged in reforestation and environmental education outreach in Nepal for the past two decades with a special emphasis on the Chitwan region. ST has developed innovative approaches to reforestation that combine community forestry with native/indigenous species protection to conserve and restore native trees, shrubs, and grasses in 23 of Nepal's 75 districts. ST has also worked to install improved cooking stoves and home biogas systems in many areas of Nepal.

The household survey used a five-point Likert scale, where 1 denoted "strongly agree" and 5 denoted "strongly disagree (De Vaus, 2002), as well as socio-demographic and economic questions. Additionally, two open-ended forest policy questions were included to provide information for further interpretation of the data (Oppenheim, 1992). After development, the survey was approved by the University of Maine Institutional Review Board (Application #2014-02-14; Figure A.1). It was then translated into Nepali and tested on a small group of residents in Bachauli to assure that the translation was accurate, and the questions were understandable.

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[1] For more information about SeedTree, visit: http://www.seedtree.org/

**Data Collection**

A purposive survey sample was selected because of the absence of databases for households and household information such as addresses, telephone numbers, and household-level census data that would allow other types of sampling (Barber et al., 1997). We employed a two-stage approach to select survey participants. Individuals were selected in both VDCs using a network sampling approach (Sudman, 1988; Bernard, 2002). First, with the assistance of World Wildlife Fund–Nepal and SeedTree, village leaders in Bachauli and Narayani were contacted and asked to help in selecting individuals within their village who were willing and available to take the survey. These individuals then suggested others who would be willing to participate.

Additional respondents — as many as time and resources allowed — were selected using a random walk technique (Jones, 2007; Lyon, 2000). While not truly random, this is an efficient method for identifying individuals able and willing to participate in surveys in large, geographically remote areas (Jones, 2007). Additionally, some suggest that, although ideal, probability sampling methods are less-suited to small surveys (Benoit et al., 2005; Kish, 1965; Moser & Kalton, 1971). Participation was not limited to any demographic, so long as the individual was an adult.

The survey was administered with the help of three translators, all fluent in Nepali as well as Tharu – a language endemic to the Terai region. Tharu is both the dominant ethnicity and language spoken in the area, making one-on-one translation essential for the completion of each survey. In total, 114 individuals were surveyed – 60 in Bachauli and 54 in Narayani. Each survey took approximately one hour to complete. The response rate was 100%.

**Statistical Analyses**

Our first objective was to examine whether household attitudes toward forest

conservation-related behaviors were consistent with empirical forest cover trends. Two

analyses were performed to determine whether the overall survey results from Bachauli

and Narayani were statistically different from one another – a critical step in determining

whether the different forest cover trends in the two VDCs, as revealed through remote

sensing in Chapter 1, were consistent with differences in local attitudes. All statistical

tests were conducted using the 'Stats Package' in version 3.1.2 of the R Statistical

Computing Software (R Core Team, 2014).

First, the total responses for each Likert scale item for both samples were

compared against one another using a Pearson's Chi-squared test ($\alpha = 0.05$). There is

considerable debate over whether Likert scale data should be analyzed as ordinal or

interval. This is due to the fact that on a discrete 1-to-5 scale, a respondent is not allowed

to respond with, for example, 1.5 or 2.7. For this reason, we used both parametric and

non-parametric tests to examine whether there was a significant difference for each

question between the two study areas. Both a Welch two-sample t-test and a Mann-

Whitney-Wilcoxon test for distribution were used to compare the difference in each

response ($\alpha = 0.05$). However, only the means and results of the t-tests are presented here

because, although there is statistical value in checking for congruency between

parametric and non-parametric tests, treating the data as interval allows for more

powerful and sophisticated statistical analysis (Nepal & Spiteri, 2011, citing De Vaus,

2002).

In order to check for internal consistency of responses, Cronbach's coefficient alpha was computed for all responses for Bachauli and Narayani (De Vaus, 2002). The scores were 0.69 and 0.71, respectively, which both surpassed the minimum threshold requirement which must be met in order to confirm significant consistency (i.e., > 0.65) (DeVellis, 1991; Nepal & Spiteri, 2011). The raw scores for each respondent for all questions was converted into an attitude index score by summing response values for all questions and then dividing by the number of questions (De Vaus, 2002). For Bachauli, the mean score was 1.90 (on a 1-to-5 scale, where 1 denotes "strongly agree" and 5 denotes "strongly disagree). For Narayani, the mean score was 2.48.

Our second objective was to examine which demographic and economic variables influence supportive attitudes toward forest conservation-related behaviors. Here, logistic regression using economic and socio-demographic variables was used to examine which variables explained the variation in attitudes. In order to use the attitude index scores as the dependent variable in the logistic regression models, they were first converted to a dichotomous dummy variable by separating the "supportive" scores from the "unsupportive" scores at the mean value (on 1-to-5 scale where 1 equals "strongly agree," indicating support for the questions asked). For Bachauli, scores below the mean were recoded as "1" (supportive), with all other values as "0." The opposite was done for Narayani, recoding the values above the mean index score as "1" (unsupportive), with all other values as "0." This was done to examine which independent variables explained the variation in positive attitudes in Bachauli and negative attitudes in Narayani – a key question given the significant difference between the two areas in terms of both forest cover change over the last decade and overall survey responses (Chapter 1).

In addition to the intercept coefficient, we also computed standard error, p-value, Wald statistic and goodness-of-fit values for each explanatory variable in the models to test the variable's individual and relative significance. The Wald statistic was calculated by dividing the intercept coefficient by the standard error coefficient and squaring the result. Hierarchical partitioning, using R2 as goodness-of-fit, was used to sum each variable's independent and joint contribution in explaining the variance of the response variable (Chevan & Sutherland, 1991). This method is well-suited for applications in conservation and ecology because it takes into account all of the relationships between predictor variables and mitigates multicollinearity issues commonly encountered in multivariate regression analyses (Mac Nally, 2002).

## RESULTS

### Socio-Demographic Characteristics of Respondents

In Bachauli, 13.3% of respondents were male and 86.7% were female, while in Narayani, 31.5% of respondents were male and 68.5% were female. The mean household size was 7 persons in Bachauli and 6.3 in Narayani. The age of respondents ranged from 18 to 80 years, with an average age of 40. Ages were classified into three categories: younger (16 to 35), middle-aged (36 to 55), and older (56+) (Mehta & Heinen, 2001). For Bachauli and Narayani, respectively, 38.3% and 46.3% were younger, 45% and 44.4% were middle-aged, and 16.7% and 9.3% were older. In total, 67.4% of respondents reported being a member of a Community Forest User Group (CFUG) in their community, with 53.3% in Bachauli and 81.5% in Narayani. Respondents were asked to state whether or not they were are able to support their household's livelihood on a daily basis. This

served as a proxy for "wealthy" or "poor" (Mehta & Heinen, 2001; Spiteri & Nepal, 2008). In Bachauli and Narayani, 25% and 66.7%, respectively, were categorized as wealthy, with 75% and 33.3% categorized as poor.

Because the average annual income is so low in this region of Nepal, two additional economic variables were collected – the amount of land and livestock each respondent owned. Nepali standards of area measurement were used in the field and later converted to hectares with the help of local translators. The average amount of land owned in Bachauli and Narayani was 8.6 ha and 9.1 ha, respectively. The survey asked each person to include head counts for each type of livestock they owned. This number was re-scaled using the Tropical Livestock Unit (TLU) measurement system developed by the Food and Agricultural Organization of the United Nations to create a continuous, rather than categorical, variable (FAO, 2003). The TLU system administers a score for each type of livestock based on each country's continent, with Asian values ranging from 0.01 for a chicken, to 0.50 for a cow or buffalo. TLU scores were summed and ranged from 0 to 6.5 in Bachauli and 0 to 5 in Narayani. Households in Bachauli reported owning more livestock compared to Narayani, i.e., a livestock score of 1.12 compared to 0.72.

The use of both fuel-efficient stoves and household biogas has been influential drivers in the reduction of forest loss in Nepal, and the adoption of both has consistently risen over the last 25 years. In Bachauli and Narayani, 25% and 51.9% of respondents indicated that they use fuel-efficient stoves, while 46.7% and 20.4% use home biogas energy systems, respectively. Finally, level of education was collected for each respondent with the choices of "none," "primary," "lower secondary," "secondary," and

"university." 18% of respondents in Narayani and 31.7% of those in Bachauli had no education, while close to half of respondents (40.7% and 46.7%, respectively) had a primary education, 11.1% and 0% had a lower secondary education, 24.1% and 3.3% had a secondary education, and 5.6% and 16.7% had attended a university.

Ethnicity was broken-down into three categories: (1) Tharu, the dominant ethnicity; (2) Hindu higher castes such as Brahmin and Chhetri; and (3) others, including castes such as Magar, Newar, Kumal and Kurmi (Sah & Heinen 2001 citing Bista 1987). Overall, one-third of all respondents belonged to "other" castes, 63.2% were Tharu, and very few – only 3.5% – belonged to a higher class.

**Distribution and Difference in Attitudes between Bachauli and Narayani**

For all Likert questions, there was a significant difference between the two VDCs ($p <$ 0.001) (Table 2.1). For both parametric and non-parametric tests, a significant difference ($p = <0.05$) was found between the two VDCs for every question except for Question 4, "I am satisfied with the current condition of forests in my community" (see Table 2.2). In addition, the mean responses for all but two questions were more supportive of behaviors that support forest conservation in Bachauli than Narayani (i.e., values closer to 1 on a 1-to-5 scale). The two questions that were less supportive in Bachauli than Narayani were Questions 5 and 8 (see Table 2.2) – "I am actively involved in the operation and effectiveness of the Community Forest User Group in my area," and "It is important that all community members receive benefits from the way that forests are managed in my community." In Table 2.2, the survey questions and results are categorized into five separate classes, representing the five concepts which were used to define attitudes hypothesized to support forest conservation.

Informal interviews with respondents, combined with responses provided on the optional open-ended survey questions, contribute additional insight. For example, in Narayani, community forests reportedly provide habitat for CNP wildlife such as the one-horned rhinoceros, which lives and breeds in forests along the Narayani River. Without forests, rhinos and other CNP wildlife may feed and take refuge in croplands. The people of Narayani hope to attract more ecotourists in the future, and projects are underway to expand tourism infrastructure such as picnic areas and lodging facilities. In Bachauli, revenue from some community forests was being used for development projects such as constructing a new women's center, which was to offer free literacy classes. In Bachauli, CFUGs were almost entirely comprised of poorer women, and were viewed as a positive opportunity to incorporate women in community responsibilities and decision making. However, of the two CFUGs we met with in Narayani, one was comprised of a large group of mostly women, while the second — which oversees and manages considerably more forested land in the area — was comprised entirely of a small group of men.

Table 2.1. Distribution of responses to all survey questions in Bachauli and Narayani.

| | Likert scale responses on 1-to-5 scale | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| | (1) Strongly Agree | (2) Agree | (3) Neutral | (4) Disagree | (5) Strongly Disagree | Total obs. |
| Bachauli | 396 (44.0%) | 321 (35.7%) | 109 (12.1%) | 35 (3.9%) | 39 (4.3%) | 900 |
| Narayani | 188 (23.2%) | 321 (39.6%) | 114 (14.1%) | 95 (11.7%) | 92 (11.4%) | 810 |
| Total obs. | 584 | 642 | 223 | 130 | 131 | 1,710 |

*Chi square = 118.922, n = 1,710, df = 4, α = 0.05, p-value <0.001*

Table 2.2. Mean survey responses and t-test results for Bachauli and Narayani.

| Questions on 1-to-5 scale (1= strongly agree) [a] | Bachauli | | | Narayani | | | |
|---|---|---|---|---|---|---|---|
| | $\bar{x}$ | SE | G $\bar{x}$ | $\bar{x}$ | SE | G $\bar{x}$ | WT $p$ |
| *Household need for forests and perception of forest trends* | | | 1.82 | | | 2.9 | |
| 1. My household relies on local forests for fuelwood | 1.86 | 0.89 | | 3.31 | 1.12 | | <0.001 |
| 2. My household relies on local forests for fodder for livestock | 1.91 | 0.92 | | 4.13 | 1.28 | | <0.001 |
| 3. Forests in my community have improved in recent years | 1.53 | 0.87 | | 2.00 | 0.75 | | 0.002 |
| 4. I am satisfied with the current condition of forests in my community | 1.96 | 0.41 | | 2.16 | 0.79 | | 0.24 |
| *Willingness to support collective action and community forestry* | | | 1.65 | | | 1.73 | |
| 5. I am actively involved in the operation and effectiveness of the Community Forest User Group (CFUG) in my area | 1.75 | 0.89 | | 1.20 | 0.45 | | <0.001 |
| 6. Efforts by our CFUG have improved the condition of forests in my community | 1.61 | 0.76 | | 2.48 | 0.81 | | <0.001 |
| 7. Forest condition in my community has improved because of community-wide cooperation | 1.66 | 0.89 | | 1.96 | 0.67 | | 0.046 |
| 8. It is important that all community members receive benefits from the way that forests are managed in my community | 1.56 | 0.69 | | 1.27 | 0.68 | | 0.027 |
| *Willingness to work with NGOs that promote forest conservation* | | | 1.54 | | | 2.24 | |
| 9. Non-governmental organizations (NGOs) that promote reforestation efforts have improved forests in my community | 1.63 | 0.93 | | 2.55 | 0.94 | | <0.001 |
| 10. I am willing to work with and receive help from NGOs to improve forest conditions in my community | 1.45 | 0.74 | | 1.92 | 0.77 | | 0.001 |
| *Supportive of forest-related institutions and policies in place* | | | 2.81 | | | 3.52 | |
| 11. I am satisfied with current forest policies in Nepal | 2.08 | 0.92 | | 3.11 | 1.23 | | <0.001 |
| 12. I am satisfied with my District Forest Officers | 3.05 | 1.12 | | 3.57 | 0.98 | | 0.009 |
| 13. Nepal's political climate today supports sustainable forest management | 3.31 | 1.26 | | 3.88 | 1.36 | | 0.022 |
| *Supportive of the use of energy-efficient technologies* | | | 1.46 | | | 1.83 | |
| 14. Fuel-efficient stoves are important in sustaining forests in my community | 1.46 | 0.65 | | 1.77 | 0.63 | | 0.011 |
| 15. Household biogas is important in sustaining forests in my community | 1.45 | 0.64 | | 1.88 | 0.81 | | 0.002 |

[a]N = 60 in Bachauli, 54 in Narayani. $\bar{x}$ = mean, SE = standard error, G $\bar{x}$ = mean for question group, WT $p$ = significance of Welch Two Sample t-test for means ($\alpha$ = 0.05).

## Logistic Regression Analysis

Logistic regression was used to determine which socio-demographic variables influenced supportive attitudes toward forest conservation-related behavior. The results for Bachauli and Narayani are shown in Tables 2.3 and 2.4, respectively. In Bachauli, having supportive attitudes toward forest conservation was positively correlated with participating in a CFUG ($p = 0.01$), and household size ($p = 0.03$). Supportive attitudes were negatively correlated with being wealthy ($p = 0.03$). A second economic indicator, the amount of livestock owned, was also found to have a negative correlation with supportive attitudes toward forest conservation (i.e., more livestock, less supportive of conservation). In Narayani, being wealthy was also found to be negatively correlated with supportive attitudes toward forest conservation ($p = 0.02$), while the other two economic indicators – hectares of land owned and amount of livestock owned – were positively correlated ($p = 0.04$ and $p = 0.02$, respectively).

Table 2.3. Logistic regression examining correlation between socio-demographic variables and positive attitudes toward forest conservation-related behavior in Bachauli.[a]

| Variable | B | SE | Wald | $p$ | R |
|---|---|---|---|---|---|
| Age | 0.05 | 0.03 | 2.78 | 0.13 | <0.001 |
| Gender (female) | 2.53 | 1.44 | 3.09 | 0.07 | 0.09 |
| CFUG member (yes) | 2.62 | 1.06 | 6.11 | 0.01* | 0.21 |
| Economic status (wealthy) | -1.96 | 0.95 | 4.26 | 0.03* | 0.11 |
| No. of persons in household | 0.42 | 0.20 | 4.39 | 0.03* | 0.06 |
| Hectares of land owned | 0.006 | 0.01 | 1.44 | 0.26 | 0.1 |
| Livestock owned | -1.16 | 0.51 | 5.17 | 0.02* | 0.005 |
| Education | 0.41 | 0.39 | 1.11 | 0.30 | 0.001 |
| Caste (Tharu) | 1.33 | 0.90 | 2.18 | 0.14 | 0.05 |

[a]$N = 60$, B = logistic regression coefficient, SE = standard error, Wald = Wald statistic. $p$ = significance, $R$ = $R^2$ statistic (the sum of the variable's independent and joint contribution in explaining the variance of the dependent variable).

Table 2.4. Logistic regression examining correlation between socio-demographic variables and negative attitudes toward forest conservation-related behavior in Narayani.[a]

| Variable | B | SE | Wald | p | R |
|---|---|---|---|---|---|
| Age | -0.008 | 0.03 | 0.07 | 0.81 | 0.01 |
| Gender (female) | 0.45 | 1.07 | 0.18 | 0.67 | 0.06 |
| CFUG member (yes) | -1.57 | 1.10 | 2.04 | 0.15 | 0.01 |
| Economic status (wealthy) | 2.26 | 1.01 | 5.01 | 0.02* | 0.08 |
| No. of persons in household | 0.13 | 0.15 | 0.75 | 0.37 | 0.001 |
| Hectares of land owned | -0.005 | 0.002 | 6.25 | 0.04* | 0.05 |
| Livestock owned | -0.94 | 0.40 | 5.52 | 0.02* | 0.05 |
| Education | 0.66 | 0.46 | 2.06 | 0.15 | 0.01 |
| Caste (Tharu) | 1.23 | 0.77 | 2.55 | 0.11 | 0.01 |

[a]N = 54, B = logistic regression coefficient, SE = standard error, Wald = Wald statistic. $p$ = significance, $R$ = $R^2$ statistic (the sum of the variable's independent and joint contribution in explaining the variance of the dependent variable).

## DISCUSSION

Community-based forest management has been influential in reducing forest degradation rates and conserving local biodiversity in many regions of the globe. Despite this general finding, household characteristics, attitudes, and socio-demographic variables of stakeholders involved have not been closely examined in community forestry systems in Nepal (Acharya et al., 2004; Adhikari et al., 2004). Because community forestry has been established in Nepal for a relatively longer time than most countries, it provides an ideal location to study household perceptions (Adhikari et al., 2004). Our research sought to explore how household attitudes toward forest conservation-related behaviors correlated with empirical forest cover trends. We also sought to better understand the socio-demographic variables that influence supportive attitudes toward forest conservation-related behaviors in our two study locations.

Supportive attitudes included having a need for forests in their community, being cognizant of current forest conditions, supporting their local CFUG, being willing to work with NGOs that promote sustainable forest practices, supporting forest-related policies and management institutions in Nepal, and recognizing the importance of energy-efficient technologies such as fuel-efficient stoves and biogas in reducing forest degradation.

Of the 36 VDCs adjacent to CNP, Bachauli and Narayani are on opposite ends of the spectrum in terms of reversing forest trends between 2005 and 2013. Bachauli has not just ceased the rapid rate of forest loss that it experienced prior to 2005, but in the last decade it has reversed it to a rate of significant regrowth (Chapter 1). The opposite is true for Narayani. The relative success of other communities in Nepal in terms of forest conservation and community forestry varies as well (see, e.g., Gautam & Shivakoti, 2005). A clear difference was found between the overall attitudes of respondents toward forest conservation in Bachauli and Narayani, and it appears that attitudes between the areas of interest reflect forest cover trends – i.e., they are distinctly different, with attitudes in Bachauli being more supportive of forest conservation.

Although the overall differences between the two VDCs, and between almost every question, were significantly different, many interesting connections can be drawn between Bachauli and Narayani. Both populations reported being unsatisfied with their district forest officers (DFOs), and both expressed that Nepal's current political climate does not support sustainable forest management. Iversen et al. (2006) conducted a study about the high-value Sal (*Shorea robusta*) forests and institutions in place regarding community forest user groups in the Terai region and found that "Terai user groups face

60

serious challenges in terms of monitoring the actions of office-holders," and that "the local leverage of the DFO is strong and may create problems" (p. 104).

Interestingly, the only question on the survey which did not show a significant difference between the two communities was "I am satisfied with the current condition of forests in my community" (Question 4 in Table 2.2). Although Narayani has seen significant loss in total forest cover between 2005 and 2013 (Chapter 1), respondents did not view these trends as negative. After all, Narayani's economy is agriculture-based, and hence land use may be prioritized for crops – not community forests. However positive this might be for the people of Narayani, it raises a challenge for future forest conservation efforts in Nepal. Indeed, as population rises, there will likely be increased pressure to convert forests to agricultural uses.

Additionally, there was a large difference in mean responses between Narayani and Bachauli for Question 11: "I am satisfied with current forest policies in Nepal" (see Table 2.2). Respondents from Bachauli were somewhat satisfied, while those in Narayani were somewhat dissatisfied. The questions grouped under "Household need for forests and perception of forest trends" had overall large differences between Bachauli and Narayani, with Bachauli having strongly more supportive responses than Narayani for Questions 1 through 3 (see Table 2.2). Three conclusions can be inferred from these data. First, the perception of forest improvement in recent years reinforces the results of previous remote sensing results (Chapter 1). That is, Bachauli has seen dramatic improvement in terms of forest cover in recent years, and Narayani has seen much loss, both of which are accurately reflected in responses to Question 3: "Forests in my community have improved in recent years." Second, households in Bachauli are

significantly more reliant on forests for fuelwood in their community. Third, households in Bachauli are significantly more reliant on forests for livestock fodder in their community (Table 2.2). These results can perhaps be explained in part by the percentage of respondents in both Bachauli and Narayani who use energy-efficient technologies. For example, respondents in Bachauli owned significantly more livestock and used home biogas systems more often than those in Narayani, which reinforces Bachauli's reported reliance on community forests for fodder. Households with livestock, such as in Bachauli, would logically use biogas more, because they have a more readily-available supply of animal waste that can be used to fuel the units and generate energy.

In Bachauli, the strongest positive correlation in the logistic regression analysis was found between being a member of a CFUG and having supportive attitudes toward forest conservation (Table 2.3). Although intuitive, this finding supports the hypothesis that community forestry in Nepal has had a positive influence in reversing forest loss over time. Being wealthy and owning more livestock was shown to negatively affect attitudes in Bachauli, and poorer households were more supportive of forest conservation. In Narayani, the same was true for wealth – i.e., being wealthy was correlated with less-supportive attitudes toward forest conservation. However, the amount of land and livestock a Narayani household owns was positively correlated with having supportive attitudes.

It is difficult to interpret this difference between the two communities in this regard, although it is perhaps influenced by Narayani's primarily agricultural economy. Adhikari et al. (2004) examined a pattern linking household resources such as land and livestock to dependence on community forests and found that farming households

required substantially more tree and grass fodder – noted as an important product of community forests by Thomas (2008) – for their livestock than those without land or livestock. Also, those with farms and livestock in Narayani are the working class of the area, and although most people are farmers, one-third of respondents reported not being able to support their family's livelihood on a daily basis (Table 2.4). For comparison, 75% of Bachauli respondents also reported not being able to support their family on a daily basis. Although farming households rely on community forests more than non-farmers, the poorest households are unable to afford sufficient land and livestock and therefore require less fodder and other forest products (Adhikari et al., 2004). These results suggest that households with more livestock in Bachauli, and households with agricultural lands in Narayani, are both reliant on forests in their community to support their livelihoods.

Informal interviews with respondents, combined with responses provided on the optional open-ended survey questions, describe a desire for forests in both communities to provide habitat for CNP animals in order to mitigate crop destruction by wildlife. Perhaps for this reason, farming households that own land and livestock might value forest conservation more than households that do not. Karanth and Nepal (2012) found that all survey respondents supported tourism in CNP, and 97% expressed a supportive attitude of the Park. There is also a consensus in both Bachauli and Narayani that forests support ecotourism. Forests provide habitat for CNP's endangered wildlife, which is primarily what attracts tourists to the area, as well as aesthetics and shade for lodging facilities and picnic areas.

In Bachauli, CFUGs were almost entirely comprised of poorer women, and were viewed as a positive opportunity to incorporate women in community responsibilities and decision making. This is a progressive exception to the norm, as a recent REDD study by Khadka et al. (2014) found that women only represent about 15% of leadership positions in CFUGs studied in Nepal. While positive, barriers still exist in the decision-making processes of CFUGs for marginalized groups such as women (Adhikari et al., 2014). Although women participate in most forest management tasks, they are typically not included in decision-making processes (Khadka, 2010; Poudel et al., 2014).

Community forestry in Nepal has the potential to contribute to social capital in many forms such as new schools, academic scholarships for children from marginalized groups, and new roads (Gautam, 2009; Pokharel et al., 2012). In Bachauli, revenue from some community forests was being used for development projects such as constructing a new women's center, which was to offer free literacy classes. One of the two CFUGs that were visited in Narayani, however, was comprised of a handful of wealthier men and appeared to poorly represent the overall demographics of the area — a problem viewed by some studies as widespread in Nepal (see, e.g., Chhetri et al., 2012; Lund et al., 2014; Malla et al., 2003).

**CONCLUSION**

Although this study was conducted in a small area of Nepal, it examined communities experiencing some of the highest and lowest rates of forest degradation in the area. Our comparison provides insight on the current status of decentralized, community-based

forest management in the country, and offers specific policy recommendations. These

findings are especially important as Nepal's Master Plan for the Forestry Sector expired

in 2011, and the country is in the process of developing a new Forestry Sector Strategy.

In addition to our findings, the Review Summary Report (MFSC) of the MPFS, released

in April 2014, discusses many areas where the MPFS has struggled, many of which —

such as a lack of marginalized population inclusion and inefficient government forestry

sector institutions — reinforce our findings.

Our results suggest several forest policy recommendations. First, we found

significant differences in attitudes in the two communities we studied, perhaps

contributing and responding to their respective current forest condition and trends.

Attitudes toward forest conservation parallel empirical forest cover trends in both

Narayani and Bachauli, with generally supportive attitudes toward forest conservation

reported from Bachauli, and less-supportive attitudes from Narayani. This gives insight

into how to best target populations who might be supportive of efforts to improve forest

conditions by better understanding how attitudes correspond with empirical forest cover

trends.

We found that attitudes which support forest conservation are correlated with

wealth, with poorer households in both study sites being more supportive of forest

conservation. Although the MFSC report states the MPFS has "enhanced the livelihoods

of the rural people who have been involved whilst giving special focus to the needs of

poor and disadvantaged households," it also cautions that the policy has "failed to have

significant impacts on rural employment and the local economy," noting that "a clear

policy for the allocation of national forest to the various community-based forest

management regimes is lacking – especially for the Terai" region – i.e., the area of our study (GoN, 2014 p. 2).

Decentralized, community-based forest management conceptually allows traditionally underrepresented populations to participate in the responsibility, social benefits, and revenue that come with managing forests. However, underrepresented populations are often marginalized within community-based forest management in Nepal (McDougall et al., 2013). The MFSC report sheds further light on the lack of progress toward social inclusion and poverty alleviation, stating that stakeholders

such as women, poor people and disadvantaged groups (including marginalized indigenous communities), although usually nominally represented in various decision-making forums, have little genuine power and voice and there is still a tendency towards unilateral decisions and lack of transparency on the part of government and more powerful civil society actors (GoN, 2014 p. 20).

Indeed, Pandit and Bevilacqua (2011b) found that the wealthy group in their study (i.e., elite castes) generally perceived user participation in CFUG activities to be more balanced and evenly-distributed than women and other marginalized groups. KC et al. (2014) found that in recent years, community forestry in Nepal has shifted from providing forest products for community use to maximizing revenues, which is happening through elite dominance and marginalization of poorer community members

66

and castes. Furthermore, when marginalized people are included in community forestry tasks, they are typically attending meetings and doing volunteer jobs — which become costly to the individual — such as patrolling the forest (Pokharel et al., 2012).

It is concerning that even in Bachauli – where forest conditions have improved and the consensus among respondents is generally supportive of forest conservation – there is dissatisfaction with district forest officers and a general belief that Nepal's political climate today does not support sustainable forest management. These views were shared in Narayani. Informal interviews and discussions revealed a general distrust toward national-level governmental institutions regulating community forestry. The MFSC report reinforces this perception by stating that, "The legal autonomy of forestry groups has been eroded by a series of administrative orders, circulars and other decisions that have increased the transaction costs of better forest utilization and has hindered the growth of forest based enterprises" (GoN, 2014 p. 2).

Here, we suggest two areas of need to be considered as Nepal develops its new Forestry Sector Strategy. The first is to ensure increased distribution of rights, responsibilities, and revenue for poorer, underrepresented populations. Participatory forest management has proven to be effective in reducing forest loss in Nepal, and it is imperative that women, the poor, and other disadvantaged groups share in these responsibilities and benefits. The second is for government institutions and representatives to become more transparent, consistent, and considerate in their management practices and relationships with communities and CFUGs. In Nepal, "government forestry sector institutions are viewed as archaic and largely ineffective in meeting the needs of a changing society" (GoN, 2014 p. 7). Although equal participation

alone is not a panacea (KC et al., 2014 citing Cohen & Uphoff, 1980), the state of forests in Nepal can only improve if better relationships are built between all stakeholders.

**ACKNOWLEDGMENTS**

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# CHAPTER 3

## USING AGENT-BASED MODELING TO EXAMINE VILLAGE-LEVEL LAND USE/LAND COVER CHANGE DECISION-MAKING: A FOREST CONSERVATION CASE STUDY IN BACHAULI, NEPAL

## INTRODUCTION

In recent decades, the Hindu Kush Himalayas (HKH) region of Asia—which spans eight countries and provides essential natural resources to 210 million inhabitants within its boundaries and an additional population of 1.3 billion people downstream (Molden & Sharma, 2013; Uddin et al., 2015)—has witnessed substantial land use/land cover change (LULCC), which can lead to changes in ecosystem services (Koschke et al., 2012; Uddin et al., 2015). To Nepal's rural poor, especially in the Terai region, forests are an important part of everyday life. Because rural communities comprise the majority of Nepal's population, they play an important role in the nation's overall social, human, and biophysical systems (Bohra & Massey, 2009). The buffer zone (BZ) Village Development Committees (VDCs) surrounding Chitwan National Park (CNP) are at the forestry and agriculture epicenter of Nepal. Those living here primarily engage in subsistence agriculture, farming small plots of the land and earning low annual incomes. 98 percent of energy use in this area comes from biomass, largely contributing to the 25.8 million metric tons of fuel wood needed each year to meet the forest needs of Nepali people (INSE, 2005). In this region, the amount of forest resources available in ratio to the population is a growing concern. In the last 25 years, the Terai has seen both loss and

gain in terms of forest cover, and although forest loss appears to have slowed in recent years (see Chapter 1), forests will continue to compete with pressing needs for development and agricultural expansion as rural populations grow. Community-based forest management in Nepal has been shown to be one of the most successful forest conservation programs in the developing world (Chapters 1, 2; Niraula et al., 2013), however, few studies have examined the consequences of forest conservation, as well as other initiatives, on LULCC in Nepal (Uddin et al., 2015).

The mechanisms behind deforestation are complex (Bhattarai et al., 2009; Ehrhardt-Martinez, 1998; Henderson-Sellers & Gornitz, 1984; Fearnside, 1985; Malanson et al., 2006; Richards & Tucker, 1988; Rolfe et al., 2000). Incorporating complexity theory has been increasingly utilized to study social ecological systems (SES) and LULLC such as deforestation (see e.g., Evans and Kelley, 2004; Lambin et al., 2003; Mena et al., 2011; Veldkamp & Lambin, 2001; Walsh et al., 2008). Simon Levin (1998; 1999; 2003) describes ecosystems as multi-level, nonlinear, complex adaptive systems (CAS) in which evolutionary forces at lower, individual levels produce emergent patterns at higher, macroscopic levels (see e.g., Holland, 1992; 1995). This is perpetuated by anthropogenic disturbances, which can lead to outcomes such as a loss of biodiversity on a global scale (Levin, 1999). Rindfuss et al. (2008) define CAS as:

systems that exhibit (a) macro-level outcomes manifested as emergent spatial or temporal regularities, (b) decision-making with specified behaviors, (c) heterogeneity in characteristics or behavior of actors, (d) social or other interactions that affect their attributes or decisions, and (e)

feedback mechanisms that can produce nonlinear system behaviors (p. 3;

see. e.g., Axelrod & Cohen, 1999; Holland, 1995; Waldrop, 1992).

Agent-based models (ABM) allow users to conceptualize these ideas by examining how

individual agents in a system (e.g., villages in Bachauli) are influenced differently by,

and adapt in response to, input variables, which aggregate to produce emergent,

landscape-level outcomes.

Epstein's 1999 paper, *Agent-Based Computational Models and Generative Social Science,* contributed greatly to the ways ABM is used today by presenting the tool as a

robust, new-age discipline. ABM allows for more advanced exploration into the complex

functionality of social systems by examining how heterogeneous and boundedly rational

individuals interact and adapt in a simulated, parameterized world (see e.g., Epstein,

2006; Epstein, 2009; Epstein & Axtell, 1996). In recent years, ABM has increasingly

been used in these ways to enhance our understanding of coupled human and natural

systems, complexity theory, human decision-making, cooperation, and demographic and

socioeconomic influences on behavior (see e.g., An, 2012; An & Liu, 2010; An et al.,

2005; An et al., 2006; Liu et al., 2007; Matthews et al., 2007; Riolo et al., 2001; Waring

et al., 2015).

Here, we create an ABM to examine what effect village attitudes toward forest

conservation have on the future landscape and condition of forest cover if improved

forest conservation-related policies are implemented, population growth rate fluctuates,

and villages are able to mimic one another's attitudes toward forest conservation-related

81

behaviors, and give an overview of some of the challenges we encountered with modeling LULCC in the place-specific context of Bachauli, Nepal (see Discussion). The model integrates remotely-sensed land cover data (Chapter 1) and a community survey of household attitudes toward forest conservation, community forestry, and forest governance institutions in Nepal (Chapter 2). By coupling qualitative survey data and quantitative land cover data to model future LULCC scenarios, we hope that stakeholders—from NGOs, government agencies, to local communities—are better able to understand how improved forest policies, population growth, collective action, and household attitudes affect LULCC in Nepal. The recent literature supports the use of ABM to model the effects that policies might have on coupled human and natural systems (see e.g., Berger, 2005; Lempert, 2002; Zellner et al., 2008), forest management scenarios (Purnomo et al., 2005; Villino, 2014), socio-demographic variables in Nepal (Janmaat & Lapp, 2014; Zvoleff & An, 2014), the effects of perceptions and decision making in coupled human and natural systems (Wandersee et al., 2012), and the effects of individual cooperation and interaction on LULCC (see e.g., Bakker & Doorn, 2009; Zvoleff & An, 2014).

**METHODS**

*This section is formatted according to the ODD (Overview, Design concepts, Details) Protocol, developed by Grimm et al. (2010). The full, documented model code is available in Table D.1.*

## Purpose

The purpose of this model is to predict what effect villager attitudes toward forest conservation will have on the future landscape and condition of forest cover if forest conservation-related policies are implemented, population growth rate fluctuates, and villages are able to cooperate by mimicking each other's attitudes and behaviors. The percentage of the landscape that is forested is used as a metric to measure LULCC over time.

## Entities, State Variables, and Scales

The agents in this model are the five villages located in Bachauli Village Development Committee (VDC)—Sauraha, Jankauli, Bachauli, Jhuwani, and Tarauli—which are each assigned to their respective location and population size. The agent set is called *villages*, and *village* is a breed and each village has a unique ID and name (ex. *village 1/Bachauli*). A description of all agent state variables assigned to each village is provided in Table 3.1.

Table 3.1. Descriptions of all agent and patch variables in the model.

| Type | Name | Description | Bounds |
|------|------|-------------|--------|
| Agent | forestneed | Attitude: Household need for forests and perception of forest trends | 1-5 |
| | cacf | Attitude: Willingness to support collective action and community forestry | 1-5 |
| | policy | Attitude: Supportive of current forest-related institutions and policies | 1-5 |
| | name | Name of each village to be displayed as a label | N/A |
| | population | Current population of each village | 10,905-17,097 |
| | pop-original | Original population of each village | 600-4,495 |
| | village-score* | Combined, mean score from all three input attitude variables | 0-1 |
| | support-f? | Describes whether or not the village supports forests | True, False |
| | pop-patches | Number of patches a village is able to convert to either forest or agriculture | 1-6 |
| Patch | bachauli | LULCC GIS data assigned to patches | 1-4 |
| | agriculture | Patch type is agriculture | True, False |
| | forest | Patch type is forest | True, False |
| | shrub | Patch type is shrub | True, False |
| | river | Patch type is river | True, False |

*Formula for calculating *village-score*: (((forestneed + cacf + policy) / 3) / 5)

Patches are categorized into four LULCC types—forest, agriculture, shrub, and rivers

(Table 3.1). Agriculture patches also incorporate development in the study site. This is

done because the two LULCC types go hand-in-hand and are virtually indistinguishable

in terms of boundaries. The shrub patches are defined as areas which are not covered in

river, forest, or agriculture, and represent floodplains and land covered in non-agricultural

vegetation. Each patch in the model has a corresponding value ranging from 1 to 4, which

is used to assign one of the four LULCC types upon Setup. In total, at Setup, there are

8,997 total forest patches, 28,116 total agriculture patches, 6,867 total shrub patches, and

797 total river patches—or, 20.1% forest, 63% agriculture, 15.2% shrub, and 1.7% river.

A description of all patch state variables is provided in Table 3.1, and all global and local

variables are explained in Table 3.2.

Table 3.2. Descriptions of all global and local variables in the model.

| Global | bachauli-dataset | GIS raster layer | 1-4 |
|---|---|---|---|
| | grow-f | Stores the number of forest patches to change | 1-14 |
| | grow-a | Stores the number of agriculture patches to change | 1-14 |
| | gov-policy | If "True," there is a probability of increasing *policy* by a random amount | True, False |
| | equal rights-policy | If "True," there is a probability of increasing *cacf* by a random amount | True, False |
| | mimic-neighbors | Slider that determines the probability of villages mimicking the other four villages | 0-0.5 |
| | population-growth-rate | population growth rate per time step | 0.05-0.15 |
| Local | forest-percent | Percentage of forest patches in the model world compared to percentage at Setup | 0-176% |
| | nearest-neighbors | All other villages | N/A |
| | their-fn-scores | Mean *forestneed* of all other villages | 0-5 |
| | fn-difference | Difference between a village's *forestneed* and *their-fn-scores* | 1-14 |
| | their-cacf-scores | Mean *cacf* of all other villages | 0-5 |
| | cacf-difference | Difference between a village's *cacf* and *their-cacf-scores* | 0-5 |
| | their-policy-scores | Mean *policy* of all other villages | 0-5 |
| | policy-difference | Difference between a village's *policy* and *their-policy-scores* | 0-5 |
| | random-grow-f-patches | Number of patches to be changed into forest during the present time step | 1-14 |
| | random-grow-a-patches | Number of patches to be changed into agriculture during the present time step | 1-14 |
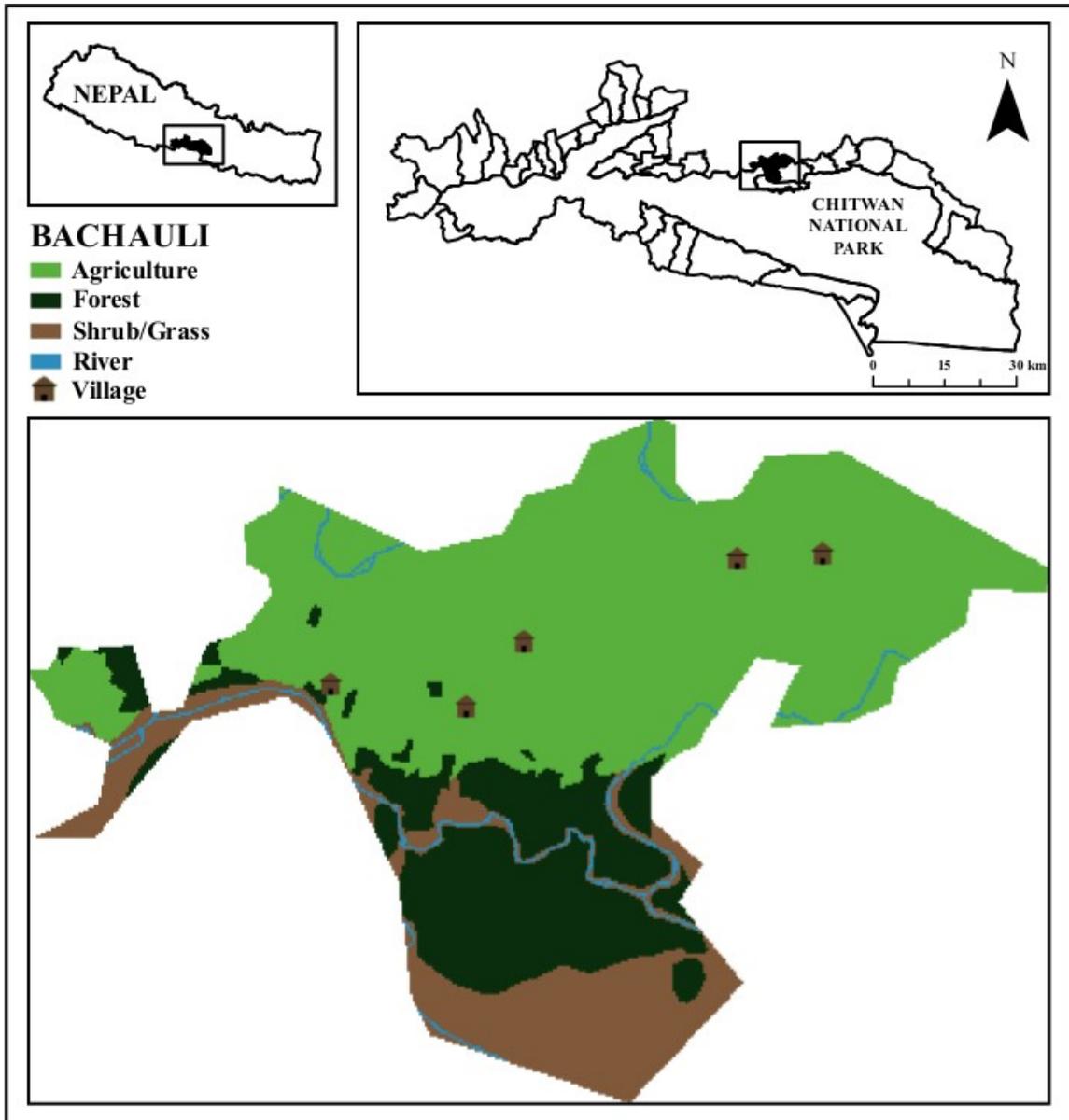
Figure 3.1. Location and NetLogo model image showing land cover of Bachauli upon Setup.

## Process Overview and Scheduling

The world is comprised of 409 x 275 patches. However, because the shape of Bachauli

VDC is not rectangular, only 44,777 of the total 112,475 patches in the world, or ~40%,

are used in the model (Figure 3.1). One tick represents one month, and the model stops

after 300 ticks, in 2040, when 25 years have elapsed. Below is the complete Setup

procedure and the Go procedures (i.e., the processes which happen every time step/tick).

**Setup Model World**

- Clear world.

- Load GIS extension data and apply that data to patches in the world.

- Resize the world to the dimensions of the GIS layer.

- Update patch color.

- Create five villages.

- Assign population, name, label, and location to five villages.

- Set base *forestneed*, *cacf*, and *policy* values.

- if *gov-policy* is "*True*," there is a probability of increasing *policy*.

- if *equal-rights-policy* is "*True*," there is a probability of increasing *cacf*.

- Set base *pop-patches*.

- Reset ticks.

**Calculate Village Score**

- Change *forestneed* based on *remaining-forest*.

- Change *forestneed* based on the percentage of population growth.

- Ask each village to figure out who their 4 neighbors are.

87

- Change attitude scores based on neighbors' scores.

- Recalculate *village-score* after changes to three variables have been made.

- If *village-score* is higher than 1 (on a 0-1 scale), then change it to 1.

**Calculate Support for Forests**

- For each village, if *village-score* is >= 0.582, set *support-f?* = "True," otherwise, set it to "False".

**Calculate Patch Conversions**

- Every village adds its allotted number of patch changes (*pop-patches*) to the local variables *grow-a* and *grow-f*. If the village supports forestry, it adds its patches to *grow-f*, and if it does not, it adds them to *grow-a*.

**Convert Patches**

- Locate random patches equivalent to the value of *grow-a*. Patches to be converted to agriculture must be either forest or shrub, and border an existing agriculture patch.

- Locate random patches equivalent to the value of *grow-f*. Patches to be converted to forest must be shrub, and border an existing forest patch.

- Convert located patches to forest and agriculture, accordingly.

**Grow Population**

- Population increases by a percentage determined by the *population-growth-rate* parameter slider.

**Update Patch Color**

- Change newly-converted patches to the correct color based on LULCC type.

## Design Concepts

**Basic Principles**

The ABM was constructed to replicate the actual landscape in Bachauli, which is dominated by forested, agricultural, and developed land. The model analyzes a feedback loop where villager attitudes toward forest conservation directly affect LULCC, and in return, LULCC affects villager attitudes and decision-making (Figure 3.2). Two policies are used as input variables, which examine the effects of forest policy changes on LULCC and attitudes. The two forest policies are: (1) government entities and representatives become more transparent, consistent, and considerate in their management practices and relationships with communities; and (2) equal distribution of rights, responsibilities, and revenue for the poorer, marginalized local populations. A population growth rate variable is used to examine the effects that current, increased, and decreased population growth rates have on LULCC and forest conservation. Additionally, villages have the ability to mimic behavior decisions based on their neighbors' decisions, determined by a varying probability variable.

The model is designed to run for 25 years, ending in 2040. As the model runs, if forest cover declines, household need for forests increases, and inversely, as population increases over time, household need for agriculture (and development) increases, therefore decreasing the need for forests by villages. Attitude changes, policy reforms, population growth, and mimicking neighbors take place according to probabilities (see Stochasticity). In the model, LULCC is converted from one type to another according to

village attitudes and other input variables. Importantly, once a forest or shrub patch has

been converted to agriculture, it cannot be converted into any other LULCC type.

Additionally, rivers cannot be converted to other LULCC types, forests can only be

converted into agriculture, and shrub can be converted into either forest or agriculture.

There are no environmental conditions, collectives, prediction, or interactions in the

model.
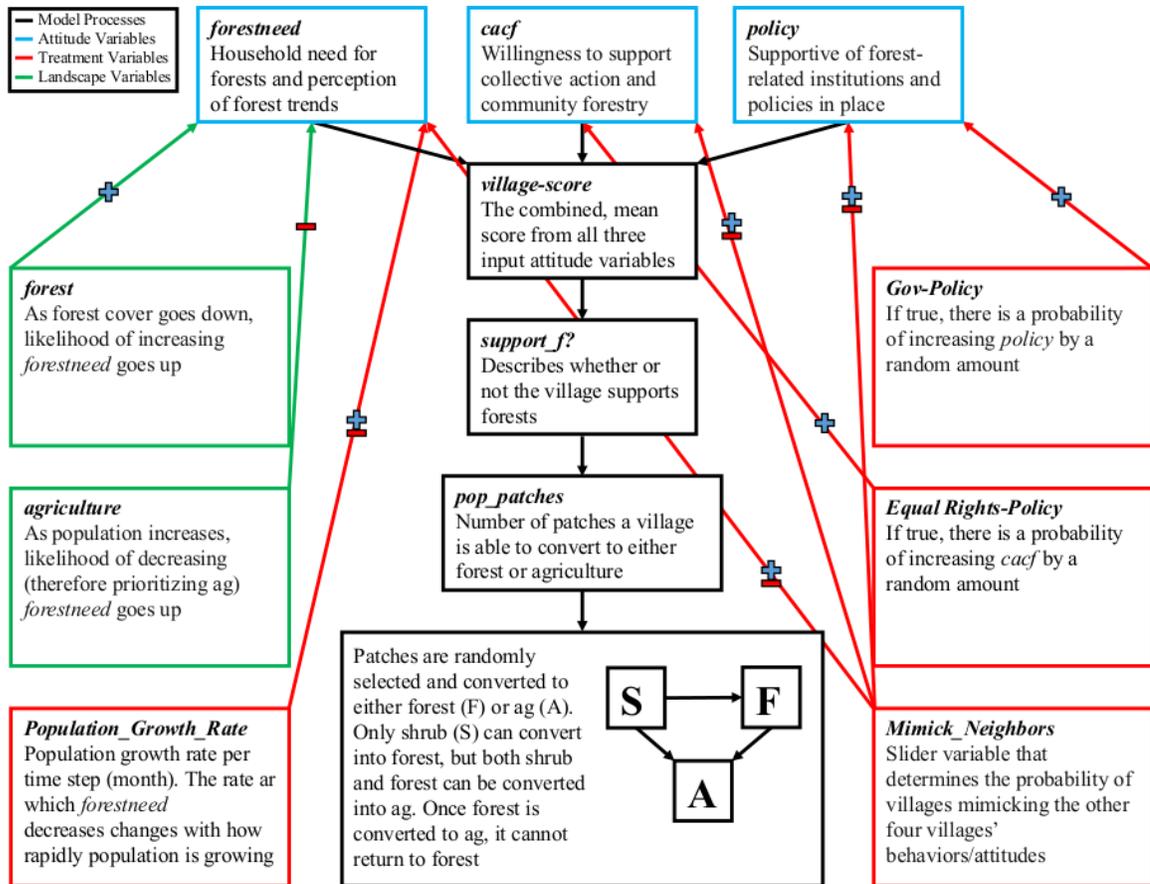


Figure 3.2. Flow chart of model variables and processes. Variables may positively and/or

negatively affect other variables as indicated by plus and minus symbols.

**Emergence**

Because it is unknown how or when forest, agriculture, and shrub cover will fluctuate over the next 25 years, the quantity of each LULCC type on the landscape over time is emergent. Whether or not villagers cooperate is also emergent. There is stochasticity in the ways in which villagers are able to mimic each other's attitudes, and the outcomes of this emerge as the model runs.

**Adaptation**

The two forms of adaptation in this model are that agents (villages) have the ability to mimic their neighbor's attitudes and support for forestry, and village attitudes adapt as land cover changes—i.e., as forest and agriculture cover fluctuates, each village's need for forest changes in response.

**Objective**

Population rises, years pass, and patches are converted to either forest or agriculture. The objective is to observe LULCC over 25 years.

**Learning**

The only learning in this model is that villages observe the attitudes of their neighbors, and can see whether or not they support forestry or not. This allows villages to mimic/learn from other agents in the study area.

**Sensing**

Agents are capable of sensing the attitudes of all other villages. With this knowledge, they are able to change their attitudes to better resemble their neighbors'.

**Stochasticity**

Stochasticity is used throughout this model and parameterization of variables. For each of the three attitude scores, a random-normal value is selected upon Setup, which uses the mean and standard deviation from the survey results from Chapter 2 (Table 3.3). For both policy variables—*equal rights-policy* and *gov-policy*—there is a 50% probability upon Setup that villages will increase two of their attitude scores—*policy* and *cacf*—by a random amount between 0-5%. *Policy* and *cacf* attitude scores are additionally influenced by the two policy variables each time step, based on whether or not each village supports forestry (i.e., whether their *village-score* >= .582). For each tick, if the village supports forestry, there is a 10% probability that their *policy* or *cacf* scores will increase by a random amount between 0-1%. If the village does not support forestry, there is a 50% probability that their *policy* or *cacf* scores will increase by a random amount between 0-5%.

During each time step, the percentage of forest cover on the landscape, relative to Setup, is reported (i.e., *forest-percent*). If random-float 100 is greater than this percentage, then villages increase their *forestneed* by a random amount between 0-25%. Each tick, the summed population of all five villages, relative to Setup, is reported as the percentage of population growth since the model began. If random-float 100 is less than this percentage, then villages decrease their *forestneed* by a random amount between 0-25%. The ability of agents to mimic their neighbors also incorporates stochasticity. Whether a village mimics their neighbors at all is based on a probability derived from the global parameter slider *mimic-neighbors* (see Submodels), and the amount a village will

change its score to better resemble its neighbors' mean scores is chosen as a random amount within the range of the difference of scores between the village and its neighbors.

**Collectives**

There is no collective action beyond the fact that collectively, all villages are either regenerating or depleting the landscape of forest resources. Collectively, their attitudes and behaviors have aggregate consequences on LULCC.

**Observation**

For every time step, the percentage of forest, agriculture, and shrub patches within the world, relative to the amount present at Setup, is collected. Also collected are total population, the *village-score* of each village, the mean *village-score* of all five villages, the number of patches being converted each tick, and the number of villages that support forestry.

**<u>Initialization</u>**

Upon initialization, five villages with a total population of roughly 11,000 are created and placed in their accurate location, based on their population and location in reality. Villages are assigned a value for each of the three attitude scores (Table 3.3). Patches are given either a true or false value for each LULCC type. The default setting for both policy parameters is *False*. The default setting for *population-growth-rate* is 0.1% based on actual national-level growth rate for the year 2013 (World Bank, 2013). *Mimic-neighbors* is initially set to 0.25 on a 0-.5 scale. This is done because it is the mid-range and base value for the parameter.

Table 3.3. Base values given to variables upon initialization.

| Type | Variable | Base Value | Initialization Source |
|------|----------|-----------|----------------------|
| Agent | forestneed | Random-normal value selected with mean of 3.18 and standard deviation of 0.94 | Chapter 2 |
| | cacf | Random-normal value selected with mean of 3.35 and standard deviation of 0.81 | Chapter 2 |
| | policy | Random-normal value selected with mean of 2.19 and standard deviation of 1.23 | Chapter 2 |
| | pop-original | 600-4495 (depending on village) | S. N. Chaudhary, personal communication, June 12, 2014 |
| | pop-patches | 1 - 4 (depending on village) | N/A |
| Patch | agriculture | True, False | DigitalGlobe |
| | forest | True, False | DigitalGlobe; Chapter 1 |
| | shrub | True, False | DigitalGlobe |
| | river | True, False | DigitalGlobe |
| Global | gov-policy | False | N/A |
| | equal rights-policy | False | N/A |
| | mimic-neighbors | 0.25 | N/A |
| | population-growth-rate* | 0.1% | World Bank, 2013 |

*Formula for converting annual population growth rate (r [annual]), to monthly (r [monthly]): (r [monthly]) = (r [annual]) $^{1/12}$ = .012$^{1/12}$ = 0.001 * 100 = *0.1%*


**Input Data**

This model uses data sourced from Chapters 1 and 2, a Bachauli village leader (S. N. Chaudhary, personal communication, June 12, 2014), the World Bank (2013), and DigitalGlobe. These data are used to initialize patch land cover type, initial attitude scores, initial population size, and the location of villages. Survey results (Chapter 2) were categorized and summed into three overall attitude categories—(1) household need for forests and perception of forest trends; (2) willingness to support collective action and community forestry; and (3) supportive of current forest-related institutions and policies. The mean of these three attitudes represent each village's overall *village-score*, which is then used to determine each village's support for forest conservation. Forest cover is empirically derived from the remote sensing analysis reported in Chapter 1, and the

agriculture, shrub, and river patches were all digitized within actual geographic

boundaries using ArcMap 10.2 and a DigitalGlobe base map.

**<u>Submodels</u>**

**GIS Extension Data and World Setup**

As explained above, the world is comprised four LULCC types, taken directly from GIS

raster values. In total, at setup, the model world is 20.1% forest, 63% agriculture, 15.2%

shrub, and 1.7% river. Colors are then assigned to the different LULCC types to better

convey land cover.

**Calculate Village-Score**

Initial *village-score* for each village is assigned based on survey results as explained

above, and is affected by landscape and treatment variables each time step (Figure 3.2).

The ability to mimic neighbor attitudes can positively or negatively affect all three

attitude scores of a village. The amount of forest on the landscape remaining, relative to

Setup, can positively affect *forestneed*. As forest cover decreases, probability of

increasing *forestneed* increases. Population growth can negatively affect *forestneed*

(Figure 3.2) – e.g., as population increases, probability of decreasing *forestneed*

(prioritizing agriculture) increases. Both policy treatment variables can positively affect

*cacf* and *policy* scores (see Stochasticity). During each time step, all of these factors are

taken into account and all three attitude scores are then used to calculate the *village-score*

by using the formula: (((forestneed + cacf + policy) / 3) / 5). With this, the *village-score*

is converted to a score on a 0 to 1 scale.

**Calculate Patch Changes**

First, it is decided whether or not each village supports forestry. If their *village-score* is greater than or equal to 0.582, than the village supports forestry, otherwise, it does not. This value is taken from the survey results as the mean attitude score for Bachauli. It is used as the benchmark score because the results of the survey suggest that Bachauli, with a mean score of 0.582, supports forestry in general, and forests are indeed regenerating (see Chapter 2). Next, each village is allowed to change a number of patches equivalent to one patch per 1,000 people in their population (rounded). This totals to 11 patches for all five villages upon Setup, and increases as the model simulation runs and population increases. Each village "casts their land use votes" by adding to the temporary local variables *grow-a* and *grow-f*. For example, if Village 0 (Sauraha) supports forestry, it will add its four patches (based on its ~4,000 population upon Setup) to the local variable *grow-f*, signifying that it will convert four patches on the landscape to forest during that time step.

**Convert Patches**

The patches to be converted into either forest or agriculture each time step are chosen at random, so long as they border an already-existing patch of the same cover type. For example, if 10 patches are to be converted into forest (i.e., *grow-f* = 10), then 10 random patches bordering forest will be selected. The 10 patches in this example would also have to border shrub since only shrub can be converted into forest patches.

**Mimic Neighbors**

Each time step, villages access the mean value for each of the three attitude scores—*forestneed, cacf,* and *policy*—of the other four villages in the model. If the mean for each

score is different than their own, and random-float 0.5 is less than the Global variable *mimic-neighbors*, then that village is asked to change its attitude scores to better resemble its neighbors by adding/subtracting a random amount within the range of the difference of scores (i.e., random-float *policy-difference, cacf-difference*, or *fn-difference*). Essentially, as the global parameter *mimic-neighbors* value increases, the more likely villages are to mimic one another's attitude scores.

**Population Growth**

Every tick, the population grows according to the *population-growth-rate* parameter slider, which can be set to range from 0.05 to 0.15% increase per year. With this change comes the potential for decreasing *forestneed* of each village by varying amounts, and increasing *pop-patches* of villages.

<u>**Validity and Experimental Conditions**</u>

**Simulation Experiments/Model Analysis**

Three experiments were conducted using nine different parameter treatments in NetLogo's Behavior Space to verify that the parameters and model were functioning the way they were intended, and to examine the relative effects of the three input variables independently of one another to examine model sensitivity. Experiments 1, 2, and 3 examine the effects of *gov-policy* and *equal-rights-policy*, *mimic-neighbors*, and *population-growth-rate*, respectively (Table 3.4). Three treatments were used for each experiment to measure the sensitivity of LULCC with the full range of each input variable. The minimum, maximum, and base (median) values were used for *mimic-neighbors* and *population-growth-rate*, and three combinations of the two policies (true or false; T/F) were examined, i.e., T/T, T/F, and F/F.

For each experiment, the same input variable was changed for each treatment, while the other two variables remained constant at their base value (Table 3.4). The two policies were interchangeable in the context of this analysis because g*ov-policy* positively affects the attitude variable *policy*, and *equal-rights-policy* positively affects the attitude variable *cacf*. These are the only two parameters that affect these two attitudes, so they essentially have the same positive effect on each agent's overall *village-score* and LULCC decision. Therefore, Treatment 2 could be hypothetically changed to make *gov-policy* false, and *equal-rights-policy* true, and the outcomes of the experiment would be arguably the same. For each treatment, 50 trials were run for 300 time steps (25 years) in NetLogo's Behavior Space. The data were then formatted in Microsoft Excel and analyzed using the "Stats Package" in version 3.1.2 of the R Statistical Computing Software (R Core Team, 2014).

Table 3.4. Treatment conditions for each experiment.

| Experiment | Treatment | gov-policy | equal-rights-policy | mimic-neighbors | population-growth-rate |
|---|---|---|---|---|---|
| 1 | 1 | F | F | 0.25 | 0.1 |
| 1 | 2 | T | F | 0.25 | 0.1 |
| 1 | 3 | T | T | 0.25 | 0.1 |
| 2 | 4 | F | F | 0.0 | 0.1 |
| 2 | 5 | F | F | 0.25 | 0.1 |
| 2 | 6 | F | F | 0.5 | 0.1 |
| 3 | 7 | F | F | 0.25 | 0.05 |
| 3 | 8 | F | F | 0.25 | 0.1 |
| 3 | 9 | F | F | 0.25 | 0.15 |

**Experiment 1**

Without varying levels of policy reform, how does forest cover and LULCC fluctuate over 25 years? This experiment using three treatments tests what would happen if neither,

just one, or both policies were implemented, when *mimic-neighbors* and *population-growth-rate* stay constant at their base values. We hypothesized that without either policy in-place, there will be a fine balance between conversion to forest and conversion to agriculture, but ultimately, forest cover will likely decline due to population growth and increased pressure on forests. With one policy in-place, we hypothesize that forest cover will increase slightly over time, and with both in place, forest cover will increase dramatically.

**Experiment 2**

With varying ability to mimic each other's attitudes and LULCC decisions, how does forest cover and LULCC fluctuate over 25 years? This experiment uses three treatments to test what would happen if villages were less likely, likely, and more likely to mimic one another's attitudes regarding forest conservation, while *gov-policy*, *equal-rights-policy* and *population-growth-rate* stay constant at their base values. We hypothesized that forest cover will not change dramatically between values for *mimic-neighbors*. It will only affect LULCC by unifying the five villages' decision to either prioritize forests or not. It will not increase the likelihood of slowing forest loss or regenerating forest cover.

**Experiment 3**

With varying rates of population growth, how does forest cover and LULCC fluctuate over 25 years? This experiment uses three treatments to test what would happen if population stayed at its current rate, was decreased by 50%, and increased by 50%, while *gov-policy*, *equal-rights-policy* and *mimic-neighbors* stay constant at their base values. We hypothesized that the lower the population growth rate, the more forest cover will be

present after 25 years. The amount of forest cover will be significantly different between

the two treatments which decreased and increased the growth rate by 50%.

**RESULTS**

**Experiment 1**

For 50 model runs, the mean percent forest cover for the year 2040 for Treatments 1, 2,

and 3 was found to be 14.66%, 22.29%, and 27.44%, respectively (Figure 3.3). Using

two-sample t tests with a 95% confidence interval ($\alpha = 0.05$), a significant difference was

found between the resulting forest cover percentages in 2040 between Treatments 1 and

2, Treatments 1 and 3, and Treatments 2 and 3 ($p < 0.001$) (Figure 3.4).

**Experiment 2**

For 50 model runs, the mean percent forest cover for the year 2040 for Treatments 4, 5,

and 6 was found to be 14.61%, 14.67%, and 14.83%, respectively (Figure 3.3). Using

two-sample t tests with a 95% confidence interval ($\alpha = 0.05$), no significant difference

was found between the resulting forest cover percentages in 2040 between Treatments 4

and 5 ($p < 0.77$), Treatments 4 and 6 ($p < 0.25$), and Treatments 5 and 6 ($p < 0.37$)

(Figure 3.4).

**Experiment 3**

For 50 model runs, the mean percent forest cover for the year 2040 for Treatments 7, 8,

and 9 was found to be 15.41%, 14.46%, and 14.13%, respectively (Figure 3.3). Using

two-sample t tests with a 95% confidence interval ($\alpha = 0.05$), a significant difference was

found between the resulting forest cover percentages in 2040 between Treatments 7 and 8 ($p = 0.001$), Treatments 7 and 9 ($p < 0.001$), and Treatments 8 and 9 ($p = 0.03$) (Figure 3.4).
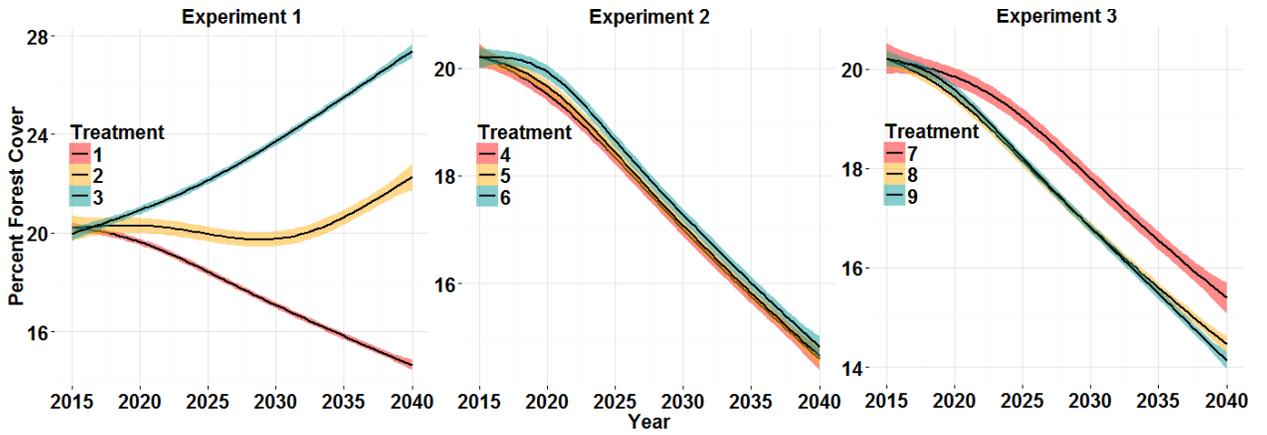


Figure 3.3. Mean percent forest cover and standard error between 2015 and 2040 for all nine treatments, for all 50 model runs.

**Forest Cover Percent, Year 2040**
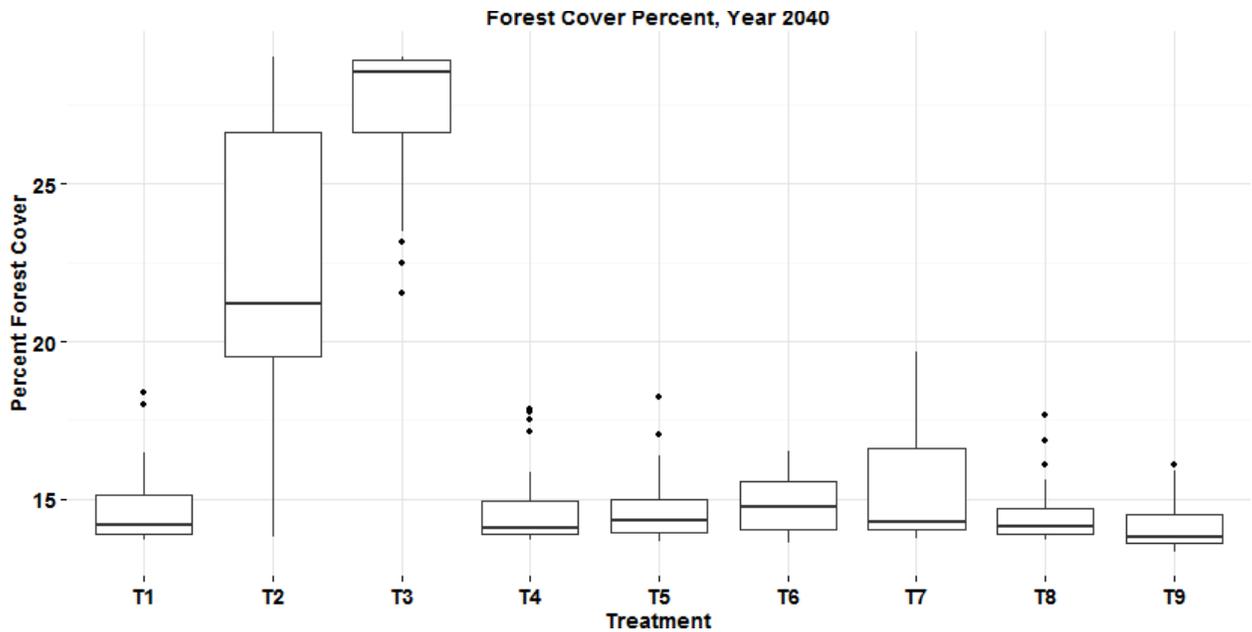


Figure 3.4. Boxplots for percent forest cover for the year 2040 for all nine treatments (T = treatment), for all 50 model runs of each treatment.

## DISCUSSION

The objective of this model was to explore what effect village attitudes toward forest conservation would have on the future landscape and extent of forest cover if improved policies—i.e., (1) government entities and representatives become more transparent, consistent, and considerate in their management practices and relationships with communities; and (2) equal distribution of rights, responsibilities, and revenue for the poorer, marginalized local populations— are implemented, population growth rate fluctuates, and villages are able to cooperate by mimicking each other's attitudes and behaviors. The percentage of the landscape that is forested was used as a metric to measure LULCC over time. Results from the three model experiments provide useful

data for forest sector representatives, policy-makers, and other forest resource stakeholders in Nepal.

Experiment 1 examined the effects of improving forest-related policies to examine how forest cover might fluctuate in the next 25 years with one or two key policies implemented (see Chapter 2, Discussion, for explanation of policies used). The results of this experiment suggest that implementing new policies, aimed at improving individual attitudes toward forest conservation-oriented behaviors, would have a dramatic effect on the forest cover in Bachauli over time.

The results from Experiments 2 and 3 were less profound than Experiment 1, although useful conclusions can be drawn nonetheless. Results show that the ability for villages to cooperate and mimic their neighbors, regardless of varying probabilities of occurrence, has little effect on forest cover after 25 years. This emergent result exemplifies the usefulness of ABM; incorporating agent interaction allows for results that a user might not have been able to determine with a standard computational or statistical model.

Experiment 3 examined the effects that different population growth rates will have on forest cover over time. Three rates of monthly growth were used in the experiment—the current growth rate of 0.1%, 0.05%, and 0.15%. A significant difference, although marginal, was found in the percentage of forest cover after 25 years between all three treatment values, suggesting that the rate at which population is growing in this SES has a significant effect on forest conservation.

Fundamentally, recent ABM literature supports the submodels used in this model, i.e., policy analysis (e.g., Florent & Enrico, 2015; Salle, 2015; Sauvageau & Frayret, 2015; Villino, 2014), population dynamics (e.g., Graciani Rodrigues et al., 2015; Mudimu & Engelbrecht, 2015; Wurzer et al., 2015), and agent cooperation (i.e., *mimic-neighbors*; e.g., Bausch, 2014; Bristow et al., 2014; Campennì & Schino, 2014; Wunder et al., 2013; Zhang et al., 2015). Although the data used for this model were empirically-derived, modeling human behavior is a complex and challenging task (Couclelis, 2001; Langevin et al., 2015; Parker et al., 2002; Smajgl & Barreteau, 2013; Turkay et al., 2011). ABMs are intended to be simplified representations of a real-world system, with boundedly rational agents (Epstein, 1999; Railsback & Grimm, 2012). However, the complexity of modeling LULCC in an SES elicits two questions: (1) are all relevant variables incorporated and empirically parameterized in a way that accurately resembles the real-world system in which the model resides? And (2) are the results and uncertainties explained by the scale at which the landscape and parameters are modeled?

Diedrich et al. (2003) describe four generalized approaches for understanding models of landscape change and form at different scales, which they introduce to help explain the varying levels of "realism" in a landscape model and are not intended to be adopted as modeling terminology per se. Figure 3.5 describes these four approaches— detailed realism, apparent realism, statistical realism, and essential realism—using paintings as metaphors for each. We introduce this idea of "realism" here to put the following discussion into context, suggesting that some challenges with modeling LULCC and behavior decisions are a product of scale and complexity, and are therefore inherent.

ABM is a discipline centered on using empirical and theoretical understandings of a system to model hypotheses about system processes and interactions. Detailed realism in landscape models would require an extremely fine-scale degree of knowledge about the interactions and stochasticity of a system, and is theoretically unrealistic to achieve. Statistical realism suggests that, while the landscape in the model is not necessarily recognizable, the information that we know about that system—i.e., the rules—is organized in a way that suggests organization representative of the real-world (Diedrich et al., 2003).

Essential realism is seen in a model that incorporates only broad, large-scale mechanisms and patterns of a system, which can be useful in enhancing general understanding, but is less valuable when trying to examine system intricacies or draw specific conclusions. Apparent realism is perhaps the most typical modeling approach used, and as the painting in Figure 3.5 suggests, it represents a detailed model, which resembles a real-world system to some degree, but at a coarser scale, and typically incorporates rules and parameters that are used to examine hypotheses about natural and human system processes.

> Because of computational demands, current lack of knowledge about how
> to scale up finer scale mechanisms, and a lack of quantitative morphology
> or dynamics data, those models that examine large-scale landscapes are by
> necessity approximate and create what can be called an apparent realism.
> Insight may nonetheless be gained (Diedrich et al., 2003, p. 7).

Figure 3.5. Art as metaphors for the varied modeling approaches: (A) Detailed Realism; (B) Apparent Realism; (C) Statistical Realism; (D) Essential Realism (modified from Dietrich et al., 2003).[2]

The following discussion outlines the key challenges that were experienced while using ABM to model SES in the place-specific context of Bachauli, Nepal. As Miller (2015) eloquently states:

> All methods have shortcomings. To temper earlier comments about the potential of agent-based modeling to contribute to theory building and testing in management and organization studies, some important limitations of the method—from a critical realist perspective—should be made explicit (p, 188).

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[2](A) A. Bierstadt, 1868, Among the Sierra Nevada, California (Smithsonian American Art Museum, DC). (B) D. Hockney, 2008, Bigger Trees Near Warter (© David Hockney). (C) P. Mondrian, 1943, Broadway Boogie Woogie (Museum of Modern Art, NY). (D) P. Cézanne, 1897-98, Le Mont Sainte-Victoire (The Hermitage, St. Petersburg, Russia).

**Data Availability and Parameter Inclusion in Developing Nations Such as Nepal**

When designing an ABM, the user must make choices about which parameters to incorporate, and which ones to exclude. These decisions are essential to the validity and overall success of a model (Azuaje, 2011; Chavali et al., 2008; Grimm & Railsback, 2006; Kaul & Ventikos, 2013; Kaul & Ventikos, 2015; Thorne et al., 2007a; Thorne et al., 2007b). Chosen parameters should be derived from empirical data, and their inclusion should be essential to the overall functionality of the model (Kaul & Ventikos, 2015). Thorne et al. (2007a; 2007b) suggest that the ability to incorporate all relevant data might not always be possible due to a "lack of relevant published data, unpublished experiments and absence of more advanced protocols/ apparatuses/ techniques needed to conduct a particular experiment" (Kaul & Ventikos, 2015, p. 144). We parameterized our model using data empirically-collected through remote sensing and in-country household surveys. Despite this, there are parameters which were either not included or could be improved upon if more reliable data were available.

Developing countries—including those in the Hindu Kush Himalayas (HKH) region (Bajracharya et al., 2010, Uddin et al., 2015)—are commonly faced with complex LULCC challenges and quite often lack empirical, reliable sources of information and data needed to evaluate alternative policies (Saqalli et al., 2010). The Intergovernmental Panel on Climate Change (IPCC, 2007a, 2007b) stated that the HKH region was a "data-deficit area" (Singh et al., 2011; Uddin et al., 2015), and other studies suggest that Nepal lacks sufficient socio-economic and forestry-related data (DFRS/FRA, 2014; Kandel, 2010), data regarding dead-wood (fuel-wood) use (Christensen et al., 2009), data about the social inclusiveness of Community Forest User Groups (CFUGs) in terms of

marginalized classes and revenue distribution (Khadka et al., 2014), and national forest cover data (DFRS/FRA, 2014; FAO, 2009).

Although institutions and researchers are continually acquiring new data (Singh et al., 2011), the HKH region is still considered data deficient eight years after the 2007 IPCC report was released (Gilani et al., 2015). Nepal's Department of Forest Research and Survey released a "Data Needs Assessment" in April of 2014 which detailed the need for data pertaining to the forestry sector (DFRS/FRA, 2014). The executive summary of the report states that:

> The extant forestry information cannot meet the need of the forestry sector of Nepal for reliable, accurate and up-to-date forestry information for use in strategic planning, policy and management decisions; for three key reasons: data is scattered across different organisations, there is neither policy nor action on periodic updating, and institutional capacity for data management is inadequate. The last national forest inventory (NFI) was carried out in the early 1990s and national-level data has not been updated since. In many case, the data collected do not comply with the national and international reporting requirements (DFRS/FRA, 2014, p. iv).

This statement refers to forest-related data at the national level, which accentuates the concern for data availability at smaller scales—which is needed for modeling LULCC at the individual or village level. The report furthers this sentiment by stating that "the data

demand of community-based forestry user groups (CFUGs) for use in management

planning was beyond [our] scope" (DFRS/FRA, 2014, p. iv).

**Challenges with Using Social Surveys in ABM**

With LULCC ABMs, i.e., modeling both human and natural systems, there are a

multitude of variables which play important roles in the way that humans interact with,

and change, the natural landscape. Additionally, the ways in which landscape-level

ecological systems—such as forests—function are invariably complex. When the

interactions between human and natural systems are incorporated into one model, the task

is especially complex (Berkes et al., 1998; Berkes et al., 2003; Couclelis, 2001;

Norgaard, 1994). Using survey data in ABM, such as we have done here, requires making

the assumption that upscaling survey results from the sample that was collected will be

representative of the population of the model study site, albeit simplified. This can be a

challenging assumption to make when certain behaviors, relevant to the study, are not

particularly common in the real world system. Two problems potentially arise from this:

(1) if less-common behaviors are represented in the survey results and upscaled, then they

could be overrepresented in the survey results and ABM parameterization; and (2) if the

behavior is not represented in the survey results, then it will not be incorporated into the

ABM, therefore excluding a relevant and potentially important component of the system

(Smajgl & Barreteau, 2013).


When modelers make simplifying assumptions, they position their work

along a continuum from concrete to isolated. A model is concrete to the

extent that it reflects details in the social process and isolated to the extent

that it reduces such details in order to focus on particular causal

mechanisms (Miller, 2015, p. 179; Windrum et al., 2007).

## Modeling Policy Change

For a myriad of reasons, predicting how local attitudes toward LULCC decisions will

change if improved resource-related policies are implemented is difficult. In the context

of forest resource conservation in rural Nepal, local people commonly believe strongly in

decentralized management authority of forests in their communities. Rural communities

have been using traditional methods for managing natural resources such as forests for

long periods of time (Nagendra & Ostrom, 2007), and when considering policy changes,

these experiences should be taken into careful consideration by policy-makers (Shivakoti

& Ostrom, 2008).

Regardless of whether a new policy is aimed at improving relationships between

local people and forest-sector representatives, or reducing the marginalization of

underrepresented social classes—which would likely be viewed as positive changes—

some might view any level of governing policy or institution as undermining to their

traditional management methods. Additionally, some Bachauli villagers, as well as

residents in other areas of the buffer zone of Chitwan National Park, are unlikely to

support any type of centralized forest management policy because they feel that they

have been alienated from once-available resources due to land protection (Agrawal &

Ostrom, 2006). Changing the perceptions and attitudes of these individuals poses

challenges. However, in order for government conservation efforts to be effective, local

people must support the problems being addressed, as well as formal policies in-place (Agrawal & Ostrom, 2006; Hayes & Ostrom 2005).

SES have been classified as: (1) nonlinear, which produces uncertainty (Berkes et al., 2003);(2) self-organized, which produces emergence (Garmestani, 2014; Levin et al., 2013); and (3) complex adapting systems (Berkes et al., 1998; Holland, 1992; Holland, 1995; Levin et al., 2013), which makes modeling policy effectiveness difficult (Levin et al., 2013). In SES, landscape outcomes are an aggregate effect of small-scale, local actions, which then feed back and affect individual behaviors and actions, usually over varyingly longer time scales (Levin et al., 2013). For this reason, "the possibilities of non-marginal changes, unobserved slow structural changes, spatial variation and strategic behavior are all examples of management and policy challenges related to the complex adaptive system properties of social-ecological systems" (Levin et al., 2013, p. 113).

Our findings here—that policy reform would dramatically improve forest cover over the next 25 years—should be viewed in light of these challenges. Anderies (2015) states that:

> Although simple deterministic models with mild nonlinearities generate important insights, they are insufficient for designing solutions. Real-world systems not only exhibit nonlinear dynamics but also exhibit complexity of a different sort: the sheer number of interacting elements that comprise them. This type of complexity brings with it deep uncertainty that makes policymaking very difficult in practice (p. 260).

**Heterogeneity at Different Scales**

All villages were given the same base attitude scores, when in reality, they are likely different from one another due to heterogeneity among individuals in each village and their respective distance from Chitwan National Park and available resources, among other social and natural factors. A recent study conducted by Pérez & Janssen (2015) suggests that spatial heterogeneity and landscape configuration play important roles in the level of cooperation and collective action between agents when modeling resource use. The results of their model suggest that the more heterogeneous the landscape is, the more cooperation emerges from agents. These findings, however, consider the location of resources and the movement capabilities of individuals in the model. In our model, while there is landscape heterogeneity, it is not effectively used as a variable in the decision-making abilities of agents (i.e., villages) because agents at the individual level were not incorporated.

Replacing villages with their respective populations would entail parameterizing heterogeneity in terms of variables such as movement capabilities, individual attitudes, and distance to resources, which would increase the model's complexity immensely. Increasing model complexity creates user and computational costs because it: (1) increases computational requirements; (2) reduces the ability to conduct sensitivity analyses; and (3) makes interpreting model behavior and linking it to the model's structure more challenging (Rahmandad & Sterman, 2008).

Regardless, our research question was designed to measure the aggregate effects of individuals (i.e., villages), not individuals themselves, to examine how villages interact with one another on the landscape level. Intuitively, the solution to the loss of individual-

level heterogeneity would be to reduce the scale of the model to the individual level. However, the model is already small in scale compared to modeling LULCC for the entire buffer zone of CNP, or ideally, in the future, at a national level. Modeling LULCC and attitudes and behavior at larger scales would mean incorporating hundreds of thousands, or even millions, of heterogeneous agents.

For these reasons, ABM in this context is seemingly well-suited for either more complex, small-scale, or generalized, larger-scale scenarios. This makes it challenging to incorporate both heterogeneity at the individual level in Bachauli, as well as at the village level, which is an aggregate product of the heterogeneous populations of each village. However, if the model were to remain as it is, individual-level heterogeneity would remain ignored, resulting in a model that is arguably unrepresentative of the real-world system. After all, the observed behavior in a model is a product of behavior and interactions at the individual (i.e., village) level (Matthews et al., 2007). Varughese & Ostrom (2001, citing Blair, 1996) found that excluding individual-level heterogeneity in the context of our study site could invalidate findings because:

> The sociocultural composition of a settlement or group of settlements may result in a difference of interests among forest users that influences the organization of forest governance and management. Differences in social class and ethnicity can make consensus-building and norm-enforcement difficult (p. 749).

113

The effect of cooperation (i.e., *mimic-neighbors*), and individual and aggregate attitudes and behaviors in our model would likely change if the scale at which heterogeneity was incorporated were to change, which poses validation concerns.

**Population Dynamics**

Resource depletion is commonly attributed in part to population growth (Poteete & Ostrom, 2004). Despite this, population growth and/or an associated increase in market pressure for resources such as forests is not universally correlated to their depletion (Agrawal, 1995). On the contrary, some studies suggest that an increase in population can lead to technological advancements, which can mitigate resources loss (Boserup, 1965; Poteete & Ostrom, 2004). The consequences of population growth are complicated, and many studies conducted in Nepal and elsewhere argue that there is no connection between population growth and forest resource depletion at the community level (Poteete & Ostrom, 2004; see e.g., Agrawal, 1995; Fairhead & Leach, 1996; Fox, 1993; Varughese, 2000).

In our model, population growth is parameterized to negatively affect village attitudes towards forest conservation with the rationale that an increase in population will: (1) increase the need for forest products and pressure on forests; and (2) increase the prioritization of agriculture and development over forests in order to meet the nutritional needs of more people. While likely realistic, these assumptions are based on observed patterns, not empirical data. In fact, while not necessarily correlated, the opposite pattern can be seen in Bachauli, whereas forest cover has increased alongside population growth in the last eight years (see Chapter 1). Even with empirical data of population dynamics and forest resource trends, assuming that the two variables are either positively or

negatively correlated in our study site—when using ABM to model future LULCC—would likely imply supposition.

**Climate Change**

Nepal is one of the world's most at-risk countries in regard to climate change (Ojha et al., 2015). Agricultural production in Nepal, and overall food security on a global scale, is highly susceptible to climate change (Bhatt et al., 2014; Malla, 2008; Olesen & Bindi, 2002; Palazzoli et al., 2015; Parry et al., 2004), and ecological factors, landscape diversity, and social instability in Nepal make the country particularly at-risk (see e.g., Aryal, 2011; Bharati et al., 2014; Chhetri & Nyaupanea, 2009; Eriksson et al., 2009; Karki & Gurung, 2012; NCVST, 2009; Maskey et al., 2011; Palazzoli et al., 2015; Rai, 2007). Uddin et al. (2015) states that:

> Climate change impacts, habitat fragmentation, and high population
> density are changing the way people in Nepal (and the HKH) are using
> land and causing land use conflicts. These multiple drivers of change and
> the interactions between them need to be understood so that policy makers
> and planners can better manage Nepal's natural resources (p. 82).

It is not possible to predict the outcomes of climate change with certainty (Collins et al., 2006). Projections assume some amount of uncertainty due to unknown future levels of greenhouse gasses, naturally-occurring climate variables, imperfections in model design and construction (Collins et al., 2006), the use of downscaling methods, and the internal

variability of climate systems (Agarwal et al., 2014; Hawkins & Sutton, 2011; Hu et al., 2013), the use of simplified and/or fixed models (Darbyshire et al., 2014), and because of uncertainty regarding nonlinear species behavior in response to change (Nelson et al., 2014).

The impacts of climate change on LULCC in Bachauli are not incorporated into this model because, although some studies have been conducted (see e.g., Thapa et al., 2013), there is not sufficient data about the consequences of climate change on forest conservation and agricultural expansion in Bachauli. If projections were available, there would still be significant uncertainty in using them as parameters due to social factors. The Nepal Climate Change Support Programme (NCCSP) currently has Local Adaptation Plans of Action (LAPAs), monitoring, and evaluation systems in only 14 of 75 districts in Nepal—all of which are located in the far-west and mid-west zones of the country (UNDP, 2014). As of spring, 2015, there are no government climate change programs in the central Terai region, which is where Bachauli is located, and where almost half of all Nepalese live. While uncertainty to some degree is unavoidable regarding both climate change modeling and ABM, climate change impact projections are especially uncertain at smaller, local scales (Devkota, 2014; Marin, 2010), which poses challenges for incorporating this as a parameter in our model.

**CONCLUSION**

From the literature, it is clear that ABM is a pragmatic and effective tool with innumerable scientific applications. It fills a much-needed niche in SES science for

modeling complexity theory, individual interaction, and heterogeneity in ways that traditional computational and statistical models cannot. Additionally, it allows the user to model theoretical, hypothetical, and complex systems in a way that is visually discernable to stakeholders.

The results of this model suggest that implementing new policies, aimed at improving individual attitudes toward forest conservation-oriented behaviors, would have a dramatic effect on the forest cover in Bachauli over time. The ability for villages to cooperate and mimic their neighbors, regardless of varying probabilities of occurrence, will likely have little effect on forest cover after 25 years. Additionally, the rate at which population is growing in this SES has a significant effect on forest conservation. Despite clear strengths, there are challenges with modeling forest conservation dynamics and LULCC in Bachauli at different scales. Importantly, when policy, development, or conservation-related recommendations are drawn from ABM findings, "norms of transparency should encourage sharing programs with other researchers for verification purposes. Independent replication is another important practice to detect and correct errors and check the robustness of findings" (Axelrod, 1997; Axtell et al., 1996; Miller, 2015; Wilensky & Rand, 2007).

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**CONCLUSION**

The remote sensing analysis in Chapter 1 suggests 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 cessation in forest loss on a national level. Indeed, the total percentage of forest cover in Nepal was stable at 25.4% in 2005 (REDD, 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). That study found that between 1989 and 2001, forest cover in the Chitwan District fell 7.95 percent, whereas our study found that for all VDCs in the buffer zone of CNP, forest cover fell 9.9 percent 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 the buffer zone of CNP. Indeed, the resource-dependent rural populations of Nepal are increasingly becoming involved in the management of local forest resources, and the number of CFUGs is continually growing.

In Chapter 2, we sought to explore how household attitudes toward forest conservation-related behaviors correlated with empirical forest cover trends. We also sought to better understand the socio-demographic variables that influence supportive attitudes toward forest conservation-related behaviors in our two study locations.

140

Supportive attitudes included having a need for forests in their community, being

cognizant of current forest conditions, supporting their local CFUG, being willing to

work with NGOs that promote sustainable forest practices, supporting forest-related

policies and management institutions in Nepal, and recognizing the importance of

energy-efficient technologies such as biogas in reducing forest degradation.

Of the 36 VDCs in the buffer zone of CNP, Bachauli and Narayani are on

opposite ends of the spectrum in terms of reversing forest trends between 2005 and 2013.

Bachauli has not just ceased the rapid rate of forest loss that it experienced prior to 2005,

but in the last decade it has reversed it to a rate of significant regrowth. The opposite is

true for Narayani. The relative success of other communities in Nepal in terms of forest

conservation and community forestry varies as well (see, e.g., Gautam & Shivakoti,

2005). Not surprisingly, there is a clear difference between the overall attitudes of

respondents toward forest conservation in Bachauli and Narayani, and it appears that

attitudes between the areas of interest reflect forest cover trends—indeed, they are

distinctly different, with attitudes in Bachauli being more supportive of forest

conservation.

The results of Chapter 3 suggest that implementing new policies aimed at

improving individual attitudes toward forest conservation-oriented behaviors would have

a dramatic effect on the forest cover in Bachauli over time. The ability for villages to

cooperate and mimic their neighbors, regardless of varying probabilities of occurrence,

will likely have little effect on forest cover after 25 years. Additionally, the rate at which

population is growing within this SES has a significant effect on forest conservation.

Despite clear strengths, there are challenges with modeling forest conservation dynamics and LULCC in Bachuli at different scales.

We suggest two areas of need that should be considered as Nepal develops its new Forestry Sector Strategy. The first is to ensure increased distribution of forest-related rights, responsibilities, and revenue for poorer, underrepresented populations. Participatory forest management has proven to be effective in reducing forest loss in Nepal, and it is imperative that women, the poor, and other disadvantaged groups share in these responsibilities and benefits. The second is for government institutions and representatives to become more transparent, consistent, and considerate in their management practices and relationships with communities and CFUGs. Although equal participation alone is not a panacea (KC et al., 2014 citing Cohen & Uphoff, 1980), the state of forests in Nepal can only improve if better relationships are built between all stakeholders.

We conclude with a quote from Elinor Ostrom's Nobel Prize Acceptance speech (later published in *The American Economic Review*), in which she eloquently states:

> The most important lesson for public policy analysis derived from the intellectual journey I have outlined here is that humans have a more complex motivational structure and more capability to solve social dilemmas than posited in earlier rational-choice theory. Designing institutions to force (or nudge) entirely self-interested individuals to achieve better outcomes has been the major goal posited by policy

analysts for governments to accomplish for much of the past half century. Extensive empirical research leads me to argue that instead, a core goal of public policy should be to facilitate the development of institutions that bring out the best in humans. We need to ask how diverse polycentric institutions help or hinder the innovativeness, learning, adapting, trustworthiness, levels of cooperation of participants, and the achievement of more effective, equitable, and sustainable outcomes at multiple scales (Ostrom, 2010, p. 664-5).

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151

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# APPENDIX A: INSTITUTIONAL REVIEW BOARD DECISION LETTER

APPLICATION FOR APPROVAL OF RESEARCH WITH HUMAN SUBJECTS
Protection of Human Subjects Review Board
114 Alumni Hall, 581-1498

PRINCIPAL INVESTIGATOR: Jared Stapp
EMAIL: stappjared@gmail.com          TELEPHONE: (435) 757-1238
CO-INVESTIGATOR(S):
FACULTY SPONSOR (Required if PI is a student): Dr. Rob Lilieholm
TITLE OF PROJECT: Assessing the Likelihood of Buffer Zone Communities around Chitwan National Park, Nepal, to Adopt Conservation-oriented Behaviors
START DATE: May 25, 2014          PI DEPARTMENT: Ecology and Environmental Sciences
MAILING ADDRESS: 223 Nutting Hall
FUNDING AGENCY (if any):
STATUS OF PI:
          FACULTY/STAFF/GRADUATE/UNDERGRADUATE   Graduate Student

1.    If PI is a student, is this research to be performed:

          ☐   for an honors thesis/senior thesis/capstone?      ☒   for a master's thesis?
          ☐   for a doctoral dissertation?                       ☐   for a course project?
          ☐   other (specify)

2.    Does this application modify a previously approved project? N (Y/N).  If yes, please give assigned number (if known) of previously approved project:

3.    Is an expedited review requested?  Y (Y/N).

SIGNATURES:  All procedures performed under the project will be conducted by individuals qualified and legally entitled to do so.  No deviation from the approved protocol will be undertaken without prior approval of the IRB.

Faculty Sponsors are responsible for oversight of research conducted by their students.  By signing this application page, the Faculty Sponsor ensures that the conduct of such research will be in accordance with the University of Maine's *Policies and Procedures for the Protection of Human Subjects of Research*.

2/27/14        Jared Stapp                        Rob Lilieholm
Date           Principal Investigator  Jared Stapp    Faculty Sponsor  Rob Lilieholm


_____        _____
          Co-Investigator                Co-Investigator
**********************************************************************************
FOR IRB USE ONLY    Application # 2014-02-14 Date received 2/27/14    Review (F/E): E
                                                              Expedited Category: _____

ACTION TAKEN:

X    Judged Exempt; category 2 .  Modifications required? Y (Y/N) Accepted (date) 3/17/2014
____ Approved as submitted. Date of next review: by _____. Degree of Risk: _____
____ Approved pending modifications. Date of next review: by _____. Degree of Risk: _____
     Modifications accepted (date): _____.
____ Not approved. (See attached statement.)
____ Judged not research with human subjects

     Date: 3/7/14    Chair's Signature:  Cynthia A. Erdley              6/12

Figure A.1. University Of Maine Institutional Review Board decision letter (Application #2014-02-14).

THE UNIVERSITY OF MAINE

Survey of Local Views Toward Community Forestry and Conservation Initiatives
Jared R. Stapp, University of Maine

**Please indicate your level of agreement with the following statements on a scale of
1 (strongly agree) to 5 (strongly disagree).**

| | १ पूर्ण सहमत | २ सहमत | ३ तटस्थ | ४ असहमत | ५ पूर्ण असहमत |
|---|---|---|---|---|---|
| (1) १ मेरो घर दाउराको लागि नजिकैको स्थानिय वनमा निर्भर छ। | ☐ | ☐ | ☐ | ☐ | ☐ |
| (2) २ मेरो घर घाँसको लागि स्थानिय वनमा निर्भर छ। | ☐ | ☐ | ☐ | ☐ | ☐ |
| (3) ३ मरो समुदायमा बनको अवस्थामा तत्कालिन समयमा सुधार आएको देखिन्छ। | ☐ | ☐ | ☐ | ☐ | ☐ |
| (4) ४ म मेरो समुदायमा रहेको वर्तमान अवस्थाप्रति सन्तुष्ट छु | ☐ | ☐ | ☐ | ☐ | ☐ |
| (5) ५ म मेरो ठाँउको सामुदायिक बन उपभोक्ता संचालन तथा प्रभावकारितामा सक्रिय रुपले सहभागि छु। | ☐ | ☐ | ☐ | ☐ | ☐ |
| (6) ६ सामाजिक सहकार्यले मेरो समुदायको बनको अवस्थामा सुधार भएको छ। | ☐ | ☐ | ☐ | ☐ | ☐ |
| (7) ७ सामुदायिक बन उपभोक्ता प्रयासले मेरो समुदायको वनको अवस्थामा सुधार भएको छ। | ☐ | ☐ | ☐ | ☐ | ☐ |
| (8) ८ सबै समुदायका सदस्यहरुले सामुदायिक बन व्यवस्थापन अनुरुपको समान फाइदा पाउनुपर्छ भन्ने कुरा महत्वपूर्ण छ। | ☐ | ☐ | ☐ | ☐ | ☐ |
| (9) ९ मलाइ लाग्छ पुन बृक्षारोपणमा जोड दिने NGO हरुको सहयोगले हाम्रो समुदायको वनको अवस्थामा सुधार भएको छ। | ☐ | ☐ | ☐ | ☐ | ☐ |
| (10) १० म NGO हरु संग काम गर्ने र सहयोग पाउने आशा राख्दछु जसले मेरो सामुदायिक बनको अवस्थामा सुधार गर्छ। | ☐ | ☐ | ☐ | ☐ | ☐ |
| (11) ११ म तत्कालिन बन नियमहरु प्रति सन्तुष्ट छु। | ☐ | ☐ | ☐ | ☐ | ☐ |
| (12) १२ म जिल्ला बन कार्यालयका कर्मचारीप्रति सन्तुष्ट छु। | ☐ | ☐ | ☐ | ☐ | ☐ |
| (13) १३ नेपालको तत्कालिन राजनैतिक वातावरणले दिगो बन व्यवस्थापनमा प्रोत्साहन गरेको छ। | ☐ | ☐ | ☐ | ☐ | ☐ |
| (14) १४ बनको दिगोपनाको लागि बचाउन राम्रो र सुधारिएका चुल्होको महत्वपूर्ण भूमिका छ। | | | | | |
| (15) १५ बनको दिगोपनाको लागि मेरो समुदायमा गोबरग्यासको महत्वपूर्ण भूमिका छ। | ☐ | ☐ | ☐ | ☐ | ☐ |
| (16) १६ यदि कुनै पनि आर्थिक कारण छैन भने म अपनाउन सक्छु। | | | | | |
| (a) सुधारिएको चुल्हो — पहिल्यै प्रयोग गरिसकेको ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| (b) घरेलु बायोग्यास — पहिल्यै प्रयोग गरिसकेको ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

Figure B.1. Survey in Nepali (side 1).

(17)१७ तपाइको वनको सहयोगको लागि कुन सरकारी नियम परिवर्तन गरिनुपर्दछ जस्तो लाग्छ?

(18)१८ तपाइ बसेको ठाउमा सामुदायिक साझेदारी मार्फत सामुदायिक वन व्यवस्थापन गर्दा आइपर्ने कठिनाई हरु के के हुन्?

| (19) लिङ | पुरुष ☐ | महिला ☐ | | | |
|---|---|---|---|---|---|
| (20) सामुदायिक वनको सदस्य | छ ☐ | छैन ☐ | | | |
| (21) शिक्षा | निराक्षर ☐ | प्रारमिक ☐ | निम्नमाधायमिक ☐ | माध्यमिक ☐ | उचमाध्यमिक ☐ |
| (22) स्थानिय कि अन्य क्षेत्र वाट आउनु भएको | कृपाय क्षेत्र लेखनुहोस | | | | |
| (23) जात | कृपाय जात लेखनुहोस | | | | |
| (24) थर | कृपाय थर लेखनुहोस | | | | |
| (25) उमेर | कृपाय उमेर लेखनुहोस | | | | |
| (26) पेशा | कृपाय पेशा लेखनुहोस | | | | |
| (27) परिवार सदस्य संख्या | कृपाय संख्या लेखनुहोस | पुरुष | महिला | | |
| (28) जग्गा हेक्टर | कृपाय हेक्टर लेखनुहोस | | | | |
| (29) बस्तु | भैसि | वाख्रा | गाई | ,सुगुर | _____ |
| (30) आफनुे पेशाले घरको खर्च धान्न सक्नु भएको छ? | छैन ☐ | कहिलकाहि ☐ | छ ☐ | | |

| Date and time: | |
|---|---|
| Surveyors: | |
| VDC: | |
| Village: | |
| GPS Coord. | |

Figure B.2. Survey in Nepali (side 2).

166

# APPENDIX C: SURVEY CONDUCTED IN NEPAL (IN ENGLISH)

THE UNIVERSITY OF MAINE

**Survey of Local Views Toward Community Forestry and Conservation Initiatives**
**Jared R. Stapp, University of Maine**

**Please indicate your level of agreement with the following statements on a scale of 1 (strongly agree) to 5 (strongly disagree).**

| | 1 Strongly Agree | 2 Agree | 3 Neutral | 4 Disagree | 5 Strongly Disagree |
|---|---|---|---|---|---|
| 1. My household relies on local forests for fuelwood | ❑ | ❑ | ❑ | ❑ | ❑ |
| 2. My household relies on local forests for fodder for livestock | ❑ | ❑ | ❑ | ❑ | ❑ |
| 3. Forests in my community have improved in recent years | ❑ | ❑ | ❑ | ❑ | ❑ |
| 4. I am satisfied with the current condition of forests in my community | ❑ | ❑ | ❑ | ❑ | ❑ |
| 5. I am actively involved in the operation and effectiveness of the Community Forest User Group (CFUG) in my area | ❑ | ❑ | ❑ | ❑ | ❑ |
| 6. Efforts by our CFUG have improved the condition of forests in my community | ❑ | ❑ | ❑ | ❑ | ❑ |
| 7. Forest condition in my community has improved because of community-wide cooperation | ❑ | ❑ | ❑ | ❑ | ❑ |
| 8. It is important that all community members receive benefits from the way that forests are managed in my community | ❑ | ❑ | ❑ | ❑ | ❑ |
| 9. Non-governmental organizations (NGOs) that promote reforestation efforts have improved forests in my community | ❑ | ❑ | ❑ | ❑ | ❑ |
| 10. I am willing to work with and receive help from NGOs to improve forest conditions in my community | ❑ | ❑ | ❑ | ❑ | ❑ |
| 11. I am satisfied with current forest policies in Nepal | ❑ | ❑ | ❑ | ❑ | ❑ |
| 12. I am satisfied with my District's Forest Officers | ❑ | ❑ | ❑ | ❑ | ❑ |
| 13. Nepal's political climate today supports sustainable forest management | ❑ | ❑ | ❑ | ❑ | ❑ |
| 14. Fuel-efficient stoves are important in sustaining forests in my community | | | | | |
| 15. Household biogas is important in sustaining forests in my community | ❑ | ❑ | ❑ | ❑ | ❑ |
| 16. If there were no economic constraints, I would be willing to adopt: | | | | | |
| a. Fuel-efficient stove — *Already use* ❑ | ❑ | ❑ | ❑ | ❑ | ❑ |
| b. Household biogas — *Already use* ❑ | ❑ | ❑ | ❑ | ❑ | ❑ |

Figure C.1. Survey in English (side 1).

17. What governmental/policy changes do you think need to be made to support forests in your community?




18. What barriers limit community-wide cooperation in managing community forests where you live?




| 19. Gender | Male ☐ | Female ☐ | | | |
|---|---|---|---|---|---|
| 20. I am a member of a CFUG | Yes ☐ | No ☐ | | | |
| 21. Education | None ☐ | Primary ☐ | Lower Secondary ☐ | Secondary ☐ | University ☐ |
| 22. Region of origin | Please Write: | | | | |
| 23. Ethnicity | Please Write: | | | | |
| 24. Caste | Please Write: | | | | |
| 25. Age | Please Write: | | | | |
| 26. Occupation | Please Write: | | | | |
| 27. Number of persons in your household | Please Write: | | | | |
| 28. How many hectares of land do you own? | Please Write: | | | | |
| 29. How many of each type of livestock do you own? | Buffaloes | Goats | Cattle | Pigs | _____ |
| 30. With your occupation, are you able to meet your household's everyday needs? | No ☐ | Sometimes ☐ | Yes ☐ | | |


| Date and time: | |
|---|---|
| Surveyors: | |
| VDC: | |
| Village: | |
| GPS Coord. | |

Figure C.2. Survey in English (side 2).

**APPENDIX D: FULL, DOCUMENTED AGENT-BASED MODEL CODE**

Table D.1. Full, documented code for agent-based model presented in Chapter 3.

**<u>Global, Spatial, and Village Variables; Extensions; Breeds</u>**

globals

[

bachauli-dataset          ;GIS raster layer

grow-f                    ;Stores the number of forest patches to change

grow-a                    ;Stores the number of agriculture patches to change

forest-percent           ;% of forest patches in the world compared to % at Setup

]


patches-own

[

bachauli                  ;LULCC GIS data assigned to patches

agriculture              ;Patch type is agriculture

forest                    ;Patch type is forest

shrub                     ;Patch type is shrub

river                     ;Patch type is river

]


breed

[

villages                ;All five villages

village                 ;Each individual village


villages-own

[

forestneed              ;Household need for forests and perception of forest trends

cacf                    ;Willingness to support collective action and community forestry

policy                  ;Supportive of forest-related institutions and policies in place

name                    ;Name of each village to be displayed as a label

population              ;Current population of each village

pop-original            ;Original population of each village

village-score           ;Combined, mean score from all three input attitude variables

support-f?              ;Describes whether or not the village supports forests

pop-patches             ;Number of patches a village is able to convert to either forest or ag.

]


extensions

[ gis ]                 NetLogo GIS Extension for using GIS data in the model


## Setup Procedures


to setup

clear-all                                              ;Clear world, reset all variables

```
set bachauli-dataset gis:load-dataset "bachauli.asc"        ;Load GIS extension data

gis:apply-raster bachauli-dataset bachauli                  ;Apply GIS characteristic

gis:set-world-envelope gis:envelope-of bachauli-dataset     ;Set envelope to GIS layer

resize-world -204 204 -137 137                              ;Resize to 1/4 of GIS layer


ask patches

[

if bachauli = 1 [ set shrub True ]                          ;Set shrub patches

if bachauli = 2 [ set agriculture True ]                    ;Set agriculture patches

if bachauli = 3 [ set forest True ]                         ;Set forest patches

if bachauli = 4 [ set river True ]                          ;Set river patches

]


update-patch-color                                          ;Update color after LULCC type is assigned


set-default-shape villages "house"                          ;Set village shape to house

create-villages 5                                           ;Create 5 villages

[

set size 10                                                 ;Make them size 5

set color 33                                                ;Make the villages brown

set forestneed random-normal 3.18 0.94                      ;Set initial forestneed based on survey

set cacf random-normal 3.35 0.81                            ;Set initial cacf based on survey
```

171

```
set policy random-normal 2.19 1.23        ;Set initial policy based on survey

]


ask village 0

[

set name "Sauraha"                        ;Set/name Village 0 as Sauraha

setxy -83 31                              ;Set Sauraha location

set population 4495                       ;Set Sauraha current population

set pop-original 4495                     ;Set Sauraha original population

set pop-patches ( round ( population / 1000 ) )    ;Set Sauraha pop-patches as pop /1,000

]


ask village 1

[

set name "Bachauli"                       ;Set/name Village 1 as Bachauli

setxy -6 48                               ;Set Bachauli location

set population 1740                       ;Set Bachauli current population

set pop-original 1740                     ;Set Bachauli original population

set pop-patches ( round ( population / 1000 ) )    ;Set Bachauli pop-patches as pop /1,000

]


ask village 2

[
```

172

```
set name "Jankauli"                                  ;Set/name Village 2 as Jankauli

setxy -29 22                                         ;Set Jankauli location

set population 1510                                  ;Set Jankauli current population

set pop-original 1510                                ;Set Jankauli original population

set pop-patches ( round ( population / 1000 ) )      ;Set Jankauli pop-patches as pop /1,000

]


ask village 3

[

set name "Jhuwani"                                   ;Set/name Village 3 as Jhuwani

setxy 79 81                                          ;Set Jhuwani location

set population 2560                                  ;Set Jhuwani current population

set pop-original 2560                                ;Set Jhuwani original population

set pop-patches ( round ( population / 1000 ) )      ;Set Jhuwani pop-patches as pop /1,000


ask village 4

[

set name "Tarauli"                                   ;Set/name Village 3 as Tarauli

setxy 113 83                                         ;Set Tarauli location

set population 600                                   ;Set Tarauli current population

set pop-original 600                                 ;Set Tarauli original population

set pop-patches ( round ( population / 1000 ) )      ;Set Tarauli pop-patches as pop /1,000
```

```
ask villages

[ set label name set label-color white ]                ;Label name, set color white


if gov-policy = True                                    ;If gov-policy is True:

[

ask villages

[ if random-float 1 > .5                                ;There is a 50% probability of:

[ set policy ( policy * 1 + random-float 0.05 ) ] ]     ;Increase policy by # between 0 - 5%

]


if equal-rights-policy = True                           ;If equal-rights-policy is True:

[

ask villages

[ if random-float 1 > .5                                ;There is a 50% probability of:

[ set cacf ( cacf * 1 + random-float 0.05 ) ] ]         ;Increase cacf by # between 0 - 5%

]


ask villages

[

set village-score                                       ;Set base village score by:

( ( ( forestneed + cacf + policy ) / 3 ) / 5 )          ;Mean of 3 scores, /5

]
```

```
set mimic-neighbors mimic-neighbors          ;Set to value slider is set to


set forest-percent precision (((count patches    ;Set base value for forest-percent as:
with

[ forest = True ] ) / 44777 ) * 100 ) 2          ;% of forest relative to amount at Setup


reset-ticks                                  ;Reset ticks

end
```

## **Go Procedures**

```
to go

if ticks = 300 [ stop ]        ;After 300 months (25 years) have passed, stop the

                               model

calculate-village-score        ;Change 3 scores, calculate mean from 3 input variables

calculate-support-for-forests  ;Determine whether or not each village supports forests

calculate-patches-conversions  ;Calculate # patches will be converted to ag. & forest

convert-patches                ;Convert randomly selected patches to forest and ag.

grow-population                ;Increase population by value of population-growth-rate

update-patch-color             ;Update patch colors after patch conversions

tick                           ;Add one tick (equals one month)

end
```

## Calculate-Village-Score

```
to calculate-village-score
if gov-policy = True                                    ;If gov-policy is True:
[
ask villages
[ ifelse village-score >= 582                           ;If village's village-score is >= 0.582:
[ if random-float 1 > .9                                ;There is a 10% probability of:
[ set policy (policy * 1 + random-float 0.01 ) ] ]      ;Increasing policy by # btwn. 0 - 1%
[ if random-float 1 > .5                                ;Otherwise, a 50% probability of:
[ set policy (policy * 1 + random-float 0.05 ) ] ] ]    ;Increasing policy by # btwn. 0 - 5%
]


if equal-rights-policy = True                           ;if equal-rights-policy is True:
[
ask villages
[ ifelse village-score >= 582                           ;If village's village-score is >= 0.582:
[ if random-float 1 > .9                                ;There is a 10% probability of:
[ set cacf ( cacf * 1 + random-float 0.01 ) ] ]         ;Increasing policy by # btwn. 0 - 1%
[ if random-float 1 > .5                                ;Otherwise, a 50% probability of:
[ set policy ( policy * 1 + random-float 0.05 ) ] ] ]   ;Increasing policy by # btwn. 0 - 5%
]
```

```
set forest-percent ( ( ( count patches with          ;Set forest-percent as:

[ forest = True ] ) / 8997 ) * 100 )                 ;% of forest relative to % at Setup

if random-float 100 > forest-percent                 ;# btwn. 0 - 100 is > forest-percent:

[

ask villages

[ set forestneed                                     ;Increase forestneed # btwn. 0-25%

( forestneed * 1 + random-float 0.25 ) ]

]


ask villages

[

if random-float 100 <                                ;If # between 0 - 100 is less than:

( ( ( population - pop-original )                    ;% of population growth

/ pop-original ) * 100 )

[ set forestneed forestneed * .75 +                  ;Decrease forestneed # btwn. 0 - 25%

random-float 0.25 ]

]


ask villages

[

let nearest-neighbors other villages                 ;Nearest-neighbors as other villages

let their-fn-scores                                  ;Set their-fn-scores as:

( mean [ forestneed ] of nearest-neighbors )         ;Mean forestneed of neighbors
```

```
ifelse their-fn-scores > forestneed                ;If their-fn-scores > forestneed:

[ let fn-difference ( their-fn-scores – forestneed )  ;Diff: their-fn-scores & forestneed

if random-float .5 < mimic-neighbors              ;If # btwn. 0-0.5 < mimic-neighbors:

[ set forestneed forestneed +                     ;Set forestneed forestneed +:

random-float fn-difference ] ]                    ;# btwn. 0-fn-difference


[ let fn-difference ( forestneed - their-fn-scores )  ;Diff: their-fn-scores & forestneed

if random-float .5 < mimic-neighbors              ;If # btwn. 0-0.5 < mimic-neighbors:

[ set forestneed forestneed -                     ;Set forestneed forestneed minus:

random-float fn-difference ] ]                    ;# btwn. 0-fn-difference

]


ask villages

[

let nearest-cacf-neighbors other villages         ;Nearest-cacf-neighbors other villages

let their-cacf-scores                             ;Set their-cacf-scores as:

( mean [ cacf ] of nearest-cacf-neighbors )       ;Mean cacf of neighbors


ifelse their-cacf-scores > cacf                   ;If their-cacf-scores > cacf:

[ let cacf-difference (their-cacf-scores – cacf ) ;Find diff: their-cacf-scores & cacf

if random-float .5 < mimic-neighbors              ;If # between 0 - 0.5 < mimic-neighbors:

[ set cacf cacf +                                 ;Set cacf to own cacf plus:
```

```
random-float cacf-difference ] ]                    ;# btwn. 0-cacf-difference


[ let cacf-difference ( cacf - their-cacf-scores )   ;Find diff: their-cacf-scores & cacf

if random-float .5 < mimic-neighbors                 ;If # between 0 - 0.5 < mimic-neighbors:

[ set cacf cacf -                                    ;Set cacf to own cacf minus:

random-float cacf-difference ] ]                    ;# btwn. 0-cacf-difference

]


ask villages

[

let nearest-policy-neighbors other villages          ;Set as other villages

let their-policy-scores                              ;Set their-policy-scores as:

( mean [ policy ] of nearest-policy-neighbors )      ;Mean policy of neighbors


ifelse their-policy-scores > policy                  ;If their-policy-scores > policy:

[ let policy-difference ( their-policy-scores – policy )   ;Diff: their-policy-scores & policy

if random-float .5 < mimic-neighbors                 ;# btwn. 0-0.5 < mimic-neighbors:

[ set policy policy +                                ;Set policy to own policy plus:

random-float policy-difference ] ]                  ;# btwn. 0-policy-difference


[ let policy-difference ( policy - their-policy-scores )   ;Diff: their-policy-scores & policy

if random-float .5 < mimic-neighbors                 ;# btwn. 0-0.5 < mimic-neighbors:

[ set policy policy -                                ;Set policy to own policy minus:
```

random-float policy-difference ] ]                              ;# btwn. 0-policy-difference

]


ask villages

[

set village-score                              ;Recalculate village-score

( ( ( forestneed + cacf + policy ) / 3 ) / 5 )         ;Mean of 3 scores /5

]


ask villages

[

if village-score > 1                              ;If village-score >1 (on 0-1 scale):

[ set village-score 1 ]                          ;Change back to the max. value (1)

]

end


**<u>Calculate-Support-For-Forests</u>**


to calculate-support-for-forests

ask villages

[

ifelse village-score >= .582                     ;If village-score is >= 0.582:

[ set support-f? True set color blue ]           ;Set support-f? true, change color to blue

```
[ set support-f? False set color red ]          ;Set support-f? false, change color to red

]

end
```

## Calculate-Patches-Conversions

```
to calculate-patches-conversions

set grow-a 0                          ;Reset local variable grow-a to zero

set grow-f 0                          ;Reset local variable grow-f to zero


ask village 0                         ;Ask Sauraha (Village 0):

[

ifelse support-f? = True              ;If suport-f? = true, than:

[ set grow-f ( grow-f + pop-patches ) ]   ;Set grow-f to grow-f plus pop-patches

[ set grow-a ( grow-a + pop-patches ) ]   ;Otherwise, grow-a to grow-a + pop-patches

]


ask village 1                         ;Ask Bachauli (Village 1):

[

ifelse support-f? = True              ;If suport-f? = true, than:

[ set grow-f ( grow-f + pop-patches ) ]   ;Set grow-f to grow-f plus pop-patches

[ set grow-a ( grow-a + pop-patches ) ]   ;Otherwise, grow-a to grow-a + pop-patches

]
```

```
ask village 2                           ;Ask Jankauli (Village 2):

[

ifelse support-f? = True                ;If suport-f? = true, than:

[ set grow-f ( grow-f + pop-patches ) ] ;Set grow-f to grow-f plus pop-patches

[ set grow-a ( grow-a + pop-patches ) ] ;Otherwise, grow-a to grow-a + pop-patches

]


ask village 3                           ;Ask Jhuwani (Village 3):

[

ifelse support-f? = True                ;If suport-f? = true, than:

[ set grow-f ( grow-f + pop-patches ) ] ;Set grow-f to grow-f plus pop-patches

[ set grow-a ( grow-a + pop-patches ) ] ;Otherwise, grow-a to grow-a + pop-patches

]


ask village 4                           ;Ask Tarauli (Village 4):

[

ifelse support-f? = True                ;If suport-f? = true, than:

[ set grow-f ( grow-f + pop-patches ) ] ;Set grow-f to grow-f plus pop-patches

[ set grow-a ( grow-a + pop-patches ) ] ;Otherwise, grow-a to grow-a + pop-patches

]

end
```

### Convert-Patches

```
to convert-patches

let random-grow-f-patches n-of ( grow-f )        ;Random patches = to grow-f

patches with [ shrub = True                      ;Patches are shrub patches

and count neighbors with [ forest = True ] > 0 ] ;Patches border >= 1 forest patch


ask random-grow-f-patches                        ;Ask these shrub patches:

[

set forest True                                  ;Set forest to true

set shrub False                                  ;Set shrub to false

]


let random-grow-a-patches n-of ( grow-a )        ;Random patches = to grow-a

patches with [ shrub = True or forest = True     ;Patches are either shrub or forest

and count neighbors with [ agriculture = True ] > ;Patches border >= 1 agriculture

0 ]                                              patch


ask random-grow-a-patches                        ;Ask these shrub or forest patches:

[

set agriculture True                             ;Set agriculture to true

set shrub False                                  ;Set shrub to false

set forest False                                 ;Set forest to false
```

]

end


**<u>Grow-Population</u>**


```
to grow-population
ask villages                          ;Ask each village:
[
set population ( ( population ) *     ;Set population as current population, plus:
( 1 + ( population-growth-rate / 100 ) ) )    ;Population growth rate from slider
set pop-patches ( round ( population / 1000   ;Set pop-patches as population /1,000
) )
]
end
```


**<u>Update-Patch-Color</u>**


```
to update-patch-color
ask patches with [ forest = True ]        ;If forest equals true (LULCC type is forest):
[ set pcolor 61 ]                         ;Change patch color to dark green
ask patches with [ agriculture = True ]   ;If agriculture equals true (LULCC type is ag.):
[ set pcolor 55 ]                         ;Change patch color to light green
ask patches with [ shrub = True ]         ;If shrub equals true (LULCC type is shrub):
```

```
[ set pcolor 34 ]                          ;Change patch color to brown

ask patches with [ river = True ]          ;If river equals true (LULCC type is river):

[ set pcolor 95 ]                          ;Change patch color to light blue

end
```

**BIOGRAPHY OF THE AUTHOR**

Jared R. Stapp grew up in a small agricultural town in northern Utah, and because of that, has always had an intimate connection with the natural world. The nearest metropolitan hub was 80 miles away, so he spent his youth exploring the seemingly unlimited trails in the neighboring mountains, canyons, and deserts. Today, Jared finds a similar sense of exploration, inquisitiveness, and fulfillment from his academic pursuits. While in his undergraduate at Utah State University (USU), Jared was a laboratory technician for three years at the USDA Forage and Range Research Laboratory, a restoration ecology technician in USU's College of Natural Resources, completed an NSF-funded Research Experience for Undergraduates internship with the Smithsonian Environmental Research Center in Edgewater, Maryland, and was a research intern for five months with the Institute for Tropical Ecosystem Studies at the University of Puerto Rico. After completing his B.S. degree in Environmental Studies with a minor in Sustainable Systems in December, 2012, Jared migrated to Orono, Maine in the fall of 2013, where he had developed a great connection with his adviser Dr. Robert Lilieholm, who gave him the freedom to design his thesis work and expressed his interest in beginning a project in Nepal. Upon completion of his M.S. in the summer of 2015, Jared will leave New England to return to the West and begin a Ph.D. in Environmental Science, Policy, and Management at the University of California, Berkeley with the long-term goal of being a university professor, researcher, and mentor to students. He is a candidate for the Master of Science in Ecology and Environmental Science degree from the University of Maine in August 2015.