Population and biodiversity in a natural resources-dependent community *

Dirgha J. Ghimire

William G. Axinn

The University of Michigan

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Abstract

This article examines the influence of population on local terrestrial biodiversity, with a special focus on species diversity. We construct a theoretical framework for the study of micro-level population-environment relationships that guides the appropriate specification of empirical models and emphasizes the multidimensional nature of population influence on flora diversity. We use newly available longitudinal measures of vegetation counts, local population dynamics, and measures of local community context from the foothills of Nepalese Himalayas to provide empirical estimates of our theoretical model. This empirical investigation reveals that multiple dimensions of population influence floral diversity in their surrounding. Multiple dimensions of population-size, age structure, birth and household size - each have a large negative effect on local flora diversity, however, these effects are greatly varies by the property right/management regimes of the local resource. This intriguing finding is consistent with the hypothesis that human influence on environment, particularly local biodiversity, is greatly mediated by the property right/management regimes of the local resource.

Introduction

Last century has witnessed dramatic changes in Earth landscape leading to environmental change and degradation, specifically deforestation, including the loss of both the vegetation abundance and species diversity. Even though all 191 Members States of United Nations have shown strong commitment to protect biodiversity the planet continues to lose species and genetic diversity at all levels- locally, nationally and globally, at alarming rates. With the extraction of marine resources now or already past its pick, the terrestrial ecosystem have the most of the burden to feed, clothe, and shelter growing population, particularly in the poor countries in the tropics with the most diverse ecosystems and expanding population and consumption behavior. Making the study of loss of species diversity a ubiquitous element of population and environment dynamics and a common object of social and ecological research.

This paper examines the relationship between population dynamics, property right/management regimes of the local resource and local terrestrial biodiversity, with a special focus on species diversity. Changes in vegetation specifically, the loss of terrestrial biodiversity, are contributed by two major factors: conversion of forest into other uses, into agriculture, particularly for food production, and degradation of existing forest and public common land. As the possibility of conversion of forest into agricultural land is almost exhausted in most poorer parts of world, we focus on loss of biodiversity from forest and public common land areas in a natural resource-dependent community in the foothill of Nepalese Himalayas.

Research literature on conservation biology has identified human actions as major driving force behind loss of vegetation and species diversity, yet very few empirical studies have been done on how human actions affect local species diversity. Moreover, the theoretical models, empirical research to explain the loss of vegetation and species diversity and program polices designed to protect vegetation and species diversity, to date, are mostly directed towards macro-level associations between population growth and loss of vegetation and species diversity though deforestation. Thus, the efforts to understand the interrelationship between human actions and loss of vegetation and species diversity and the program designed to steward (recovery or maintenance) the current vegetation (cover and biomass) and species diversity are severely suffered from lack of information at appropriate level , including information on the diversity, distribution of species, social and ecological processes, and magnitude and intensity of human interactions with the vegetation and species diversity–over and inappropriate use such as disruption of biochemical and reproductive cycle, technology use, introduction of invasive species, changes in life style, and mechanization (Cameron, 1996; Novacek and Cleland, 2001).

In the last century alone a great number of plant species are believed to be permanently disappeared from the planet and many more are in the process of becoming extinct. The rapid loss in terrestrial vegetation and species diversity is found to be strongly associated with conversion of forested land into agricultural land (Wolman 1993) mainly for food production (Bongaarts 1996). This conversion of forested land into mono-cropping agricultural land has tremendous impact on the loss of local biodiversity. Moreover, conversion of the forest into agriculture not only change the biodiversity of the forested area converted into agriculture land but also draw large number of people around the remaining forest and common land area and continue to have greater impact on vegetation and species diversity for longer period. In this study we developed a theoretical framework that focuses on micro-level link between local population and species diversity in a natural resource dependent community. Additionally, our theoretical framework also recognizes the important role of the natural resource property right/management regimes and community context on the link between population dynamics and species diversity.

The task of establishing a causal relation between factors such as population dynamics and species diversity that are likely to be reciprocally related puts high demand on measurement including appropriate level and with appropriate temporal order. However, most previous studies used cross-sectional data, making it almost impossible to establish the temporal order. And, also do not have precisely matching data both on the changes in species diversity and population measures over time from the same level or geographic region. Pichon (1993) argues that although new data collection techniques such as remote sensing have considerably enhanced our ability to map the changes in land use and natural resources depletion, these techniques have underscore the impact of local agro-ecological forces and socioeconomic factors on vegetation and species diversity.

Using time series data with uniquely detail hand counted measures of vegetation, monthly registration of population size and structure, and periodic measures of household consumption and community context from the Chitwan Valley Family Study, specifically designed to study the reciprocal relationship between population and environment, this study addresses several important limitations of previous studies.

We examine the changes in species diversity in three different property-right systems: 1) national reserve guarded by National Army (National Park), 2) Community protected forest, and 3) common public land with no protection. A comparison between three different management systems (some scholars often called it property-right systems) provides a unique opportunity to test much debated but less rigorously tested theoretical perspective, *the tragedy of commons,* to understand human impact on vegetation and species diversity.

Second, unlike any other studies that we know of, our measures of environmental change come from hand counted botanical counts of plants. The hand counting and identification of each and every single plant provides uniquely detail measures of vegetation species diversity. In addition, the hand counting was repeated in 2000 and 2004, after four years following the same procedure by the same group of botanists as in 1996. This recounting of the plant provides precise measures of change in species diversity over eight-year period. Because of the time series data, it allows us to control for vegetation species diversity in time-three (2004) and precisely examine the impact of change in population process between time-one and time-two (1996-2000) on species diversity, later in time-three.

Third, the household survey data first collected in 1996 and repeated in 2000 provides important information on changes in individuals' livelihood and consumption patterns crucial to the understanding of the relationship between population and species diversity. This survey data collected information pertaining to farming, technology use, land ownership, livestock ownership and grazing, household assets, and energy use. In addition, because geographic position of each neighborhood from where the population measures come from and the geographic position of each the vegetation plots are recorded it allows us to link the household consumption patterns to vegetation abundance and species diversity.

Finally, measures of population structure and population size are particularly unique in two important ways. First, these measures come not only from the same geographical area as the vegetation measures but also come from a population that is the major user the vegetation in this setting. Second, because the population measures are collected using a prospective monthly household registration system which provides uniquely detail measures of changes in population structure and population size.

Theoretical framework

Human interventions have greatly changed the patterns of land use, natural resources use, and the biodiversity over the past centuries (Jenkins 2003; Novacek and Cleland, 2001; Simmons 1987; Wolman 1993). Indeed, there is now unanimous conscious among the scientific communities that the current massive degradation of habitat and extinction of species is unprecedented. Despite the commitment made to protect biodiversity by all UN members we continue to lose species and genetic diversity at alarming rates (Grime 1997; Living Planet Report [LPR], 2004; Meffe and Carroll 1994; Primack 1994; Wilson 1988; 1998). As a result, this issue has received great attention and prompted a great number of research, particularly, in the later half of the past century. For the most part, these research have predominantly emphasized population growth, changes in the land use and land cover (deforestation), pollution, and climate change at macro-level. Most important here have been the dramatic restructuring of earth landscape through deforestation, industrialization, and urbanization.

Although the changes in forest resources, both in terms of abundance and diversity, could be both the cause and the consequence of population change, the impact of population growth and population re-distribution on natural environment, particularly on biodiversity, has been major concern of the researcher and probably received the greatest attention (Ehrlich 1988; Shivakoti et al., 1999; Wilson 1988; Vitousek et al. 1997). Ecologists have offered a wide range of general models of human ecological system (Consortium of International Earth Science Information Network 1992; Costanza and Daily 1992; Ojima et al. 1994). Their model focuses on human population growth, resources consumption and efficiency of resource use as driving force of environmental change in general and biodiversity in particular. In the similar vein, Hardin (1968), in his seminal paper, suggested two human factors that drive environmental change. The first factor is the increasing demand for natural resources and environmental services rising from the ever growing human population and per capita resource consumption. The second factor is the way in which human beings organize themselves to extract resources from the environment which is well known as *“the tragedy of commons”*.

Even though previous studies are quite useful in identifying the linkages at aggregate level these studies are less useful in explaining the mechanisms at local level through which human actions lead to changes in natural environment –vegetation abundance and species diversity. Moreover recent literature on human-environment relationship have emphasized the failure of such models to explain the mechanisms of environmental changes and have called for the inclusion of micro-level human behaviors, particularly changes in consumption both pattern of consumption and per capita consumption, as part of the explanation (Axinn & Ghimire 2007; Liu et al. 1999; Liu et al. 2003).

By no means, we claim that the macro-level factors such as acid rain, air pollution, global warming, or other changes in atmospheric climate are not important. Our purpose in this paper is not to choose between macro and micro explanations for environmental change and degradation. In fact, we believe that both are important and the larger and more appropriate task is to demonstrate how the micro-level population-environment relationship informs our understanding of the macro level global environmental change and degradation.

Although we endorse the need for this larger task, because our research is confined to a single valley and by design control for macro-level variations, our agenda in this paper is much more humble—and that is to demonstrate how human interventions at local level: both the property-right systems and consumption patterns affect the local vegetation abundance and species diversity. Additionally, as discussed above, we also investigate the influence of local community context on population and environment relationship.

Property-right systems and vegetation abundance and species diversity

We begin with Hardin's second thesis, *"the tragedy of commons"*. Hardin (1968) assumes that resources are common to all and as a "rational" user of the commons, individual makes demand on a resource, until the expected benefits of his or her action equals the expected cost. Because each individual only cares about his or her cost and ignores others, in the absence of direct cost, individuals are inclined to cumulate as much resources as they can (i.e. acting with out restrain to maximize personal short-term gains), leading to overuse and potential destruction of the environment. He argued that users of the commons are caught in an inevitable process that leads to destruction of the resources their livelihood depends on. To avert the imminent destruction of the commons Hardin offers two alternatives socialization or privatization of the commons and over looks the possibility of self-organized management of common resources, ordinary people have practicing for centuries (Blaikie and Brookfiled 1987; Ciriacy-Wantrup and Bishop 1975; Wade 1988; Ostrom 1990).

The research literature that emerged out of "*the tragedy of commons*" discredits Harding's simplistic assumption of *"resources are common to all"* and, suggests that variations in individuals' right to access the resources is what drives the resources, which has been labeled as common-pool resource (CPR), use leading to environmental change (De Young 1999; Ostrom 1990; Ostrom et al.1999). This literature has identified four types of, what is called, property-rights systems used to regulate the common-pool resource: (1) Open access, (2) Group property, (3) Individual property, and (4) Government property. These property-rights systems characterized with access the resources from open access to all to access to only an individual or firm, who own the resource. If the assumption of "rational actor" is true than one would expect that the common-pool resources under open access to all property-right systems are likely to deteriorate most, leading to environmental change and degradation. Whereas the common-pool resources under individual or group property are likely to be used more carefully and likely deteriorate least, leading to a more sustainable environment.

Population processes and species diversity

Hardin (1968) also sees that the increasing demand for natural resources and environmental services steaming from the growing human population and per capita resource consumption as another major driver of environmental change. Numerous studies have demonstrated important links between population size, population structure, migration, and environmental changes (Bilsborrow and DeLargy 1991; Bongaarts 1996; Cohen 1995; Ehrlich, Ehrlich, and Daily 1993; Heilig 1997; Myers 1991; Rees 1996). In general greater numbers of people, and therefore population density in any one fixed area, increases the pressure on local biodiversity for food and other basic needs. Increased population size is also likely to promote agricultural extensification, through conversion of forested land into agricultural uses (Axinn and Axinn 1983; Pokharel and Shivakoti 1986; Shivakoti, Khan, Axinn, and Axinn 1977; Shivakoti and Pokharel 1989) and intensification, through use of improved irrigation, fertilizer, pesticides, new technology and improved varieties (Bongaarts 1996; Jolly and Torrey 1993; May 1995; Mortimore 1993; Schmidt-Vogt, 1994; Shapiro 1995; Thapa 1996; Tiwari 2000; Wolman 1993). However in settled areas, such as Chitwan, where conservation of forested land into agriculture is very much limited and strongly regulated, the total effect of increasing numbers of people is predicted to be high pressure on exiting forested area and common areas resulting in loss of biodiversity and productivity. In a settled area characterized by subsistence production, the impact of greater numbers of people should increase extraction of natural resources consumption of plant and increase construction of buildings and infrastructure. Thus, greater number of people in a fixed area would be predicted to result in loss of vegetation abundance and species diversity.

Recent studies on population and environmental change, particularly energy use, however, are beginning to indicate that household, as unit of both the production and consumption, may be a more important predictor of environmental degradation than simple numbers of people. For example, recent evidence indicates that in addition to the number of household units, household size may be a more important determinant of energy use than the number of people per se (Liu, Daily, Ehrlich, & Luck 2003; Liu et al. 2005; Walsh et al. 2005). This result seems plausible because cooking a meal for two people cost less than cooking two separate meals, thus in addition to the number of household units, household size in fact may drive the actual micro-level patterns of consumption more closely than the number of people or number of household per se. To the extent households are the main consumers of natural resources, particularly in the form of fuel wood, fodder and construction materials, greater numbers of households should result in loss of vegetation abundance and species diversity. Thus at the local community level, household consumption patterns may have been a stronger influence on local vegetation than individual behavior, per se.

Number of people or household size, may not be the only dimension of population that link to environmental change and degradation. Other dimensions, such as the age structure, or processes of fertility, mortality, and migration, may affect consumption of vegetation and construction of buildings and infrastructure. In particular, a young age structure and high fertility are likely to increase both the consumption of vegetation for fuel, fodder and housing, and thereby reduce the vegetation abundance and species diversity. Younger age structures influence plant use because they result in expansive populations, with ever larger cohorts entering ages of high consumption. What Rindfuss (1991) describes as the most "demographically dense" period of life, roughly age 15-30, is also a period of high consumption. Marriages, childbearing, migration, and changes in living arrangements all stimulate consumption. At the community level, in a subsistence agricultural setting, this consumption is quite likely to translate into higher consumption of vegetation and more construction of buildings and infrastructure. So an expansive age structure, with an increasing proportion of the population in young age groups, is likely to stimulate changes toward less vegetation in any specific local area.

This prediction is quite consistent with recent findings from the Brazilian Amazon. In that setting, strong associations were found between age-graded life cycle changes and conversion of forest land into agricultural land (Moran 2001; Moran, Brondizio and VanWey 2005). Changes in population age structure toward an increasing fraction of the population at ages characterized by life events such as marriage, childbearing, and household formation, therefore, are quite likely to effect vegetation in the surrounding areas.

Thus, we have identified four conceptually distinct dimensions of population change that may affect land use: numbers of people, age structure, fertility and household size. There are undoubtedly others. Our objective is not to provide an exhaustive list, but to identify these three dimensions of population change as a starting point. Our aim is to provide empirical tests of this simple, but multi-dimensional, model of population effects on environmental change and degradation: species diversity.

Thus, although our main interest is in the impact of population change on the local environment: species diversity. However, a model designed to predict the consequences of social, economic, or demographic changes on biodiversity must begin by identifying a specific starting state of biological resource consumption patterns, before moving on to identify the likely consequences of specific changes. For example, as human systems of resource consumption change, be they hunting and gathering, subsistence agriculture, or industrial production, patterns of organization of daily social activities, and these changes alter the use of the local resources and the patterns of consumption of local vegetation.

Setting

Chitwan Valley, which lies in the south central part of Nepal, is the study area for this research. Nepal is widely known as one of the ecologically diverse and at the same time seriously at the brink of environmental degradation. Nepal, the poorest country in the Himalayan region, is one of the richest countries in terms of biodiversity and ranks 31st in world's biodiversity position. It houses 118 different ecosystems, 75 vegetation types and 35 forest types (NBS, 2002). Although Nepal occupies less than 0.1 percent of the earth's land mass, it supports about 8% of all birds, 4% of all mammals, 6% of all bryophytes, 3% of all pteridophytes and 1.53 % of all reptiles (NBS, 2002). It is estimated that Nepal contains more than 5891 species of flowering plants, 383 pteridophytes, 853 bryophytes, 471 lichens, 1822 fungal species, and 687 algal species (Shrestha, 2001).

However during the 20th century Nepal's landscape has changed dramatically, particularly the conversion of forested land area into agricultural land. The area under forest decreased from 43.9% in 1965 to 25.43 % in 2005. As early as the 1970s, Erik Eckholm, in his treatise *Losing Ground,* vividly (although some think overly exaggerated) presented the condition of deteriorating mountain environments and outlined the consequences of excessive human intervention on the fragile mountain ecosystem. He mentioned "There is no better place to begin an examination of deteriorating mountain environment than Nepal" (p.76). He further insists that once the possibility for deforestation for cultivation is exhausted and the hill slopes become nonproductive the farmers from hills will become ecological refugees who will then move to the foothills and the piedmont plains.

Because more than 85 percent Nepalese still live in rural areas, fuel wood is still major source of energy, earn their livelihood from substance farming, and heavily dependent on forest resource for their diverse economic and non-economic needs, biodiversity plays very important in their daily life and social well-being (Paudel 2004). This is particularly true for forest dwellers, herders, and peasants who rely on the biological diversities to fulfill their needs (Bhatia et al., 1998). However, the diversity in ecosystems, species and genetic resources is being gradually lost due to over population, poverty, unsustainable utilization and faulty land use. It is estimated that 26 mammals, 9 birds and 3 reptiles are either endangered, vulnerable or threatened (Tiwari, 1998). Among the flowering species, 246 species are endemic and 8 species are suspected to be extinct (Shrestha and Joshi, 1996).

The study area is boarded by the East-West highway in the North East, the Narayani River in Northwest, Royal Chitwan National Park and Rapti River in South with a land area of 91 square miles. Until early the 1950s, this valley was completely covered with dense forest and was a habitat of many wild animals including the Bengal tiger, one-horned Rhinos, and many other wild animals. Around the mid-1950s, in order to lessen the impact of rapid population growth in the rather fragile mountain environment, the Nepalese government opened this valley for human settlement as buffer zone for rapidly increasing population. People from neighboring hills and mountains were brought for settlement. The flat terrain with its highly fertile soil and warm climate offered promising opportunities for people who were struggling with the steep mountain slopes to support their survival. Since then, the valley has undergone rapid changes both in term of physical and socioeconomic conditions (Shivakoti et al. 1999). As a result, the dense forest turned into a populated agriculture based settlement area.

In late the 1970s the valley was connected by a national highway that runs from the east to west of the country. A few years later another roads connected the valley with Kathmandu, the nation's capital. There has been massive expansion of schools, health services, markets, bus stops, and employment centers within the study area. Although the expansion of these services is pervasive, the level of physical development is still in a very primitive stage. Except the national highway, which runs along the northern border of the study area, most of the roads within the study area are still seasonal and unpaved. Despite the massive transformation, this valley remains predominantly an agriculture-based society. 83 percent of the respondent of the study analyzed here reported that they were growing crops at the time of our survey.

The population of the valley continues to grow both through the continuing flow of in migration from the hills, as well as by natural increase. The population in Chitwan is growing at slightly faster then in rest of the country. Population of Chitwan grew form 259,571 to 354, 488 between tow census 1981 and 1991. The annual growth of 3.66 percent was one of the highest among the different districts of Nepal (Pearce 1999).

With respect to fertility, although Nepal has undergone a steady decline in fertility since the 1970s fertility rate is still quite above replacement level. The slow pace of fertility decline and continuous flow of migrants from the hills has kept the growth rate in terai (low land) quite high. Most recent estimate suggests an annual growth rate of 2.37 per annum. However, recent survey revels that women desire relatively small families: the mean ideal number of children is

2.9. (Pradhan, et al. 1997: 96-98). In deed, only one-quarter women would ideally prefer a family with four or more children.

In one hand, the high population growth has increased the pressure on limited land allowed for settlement and other natural resources. On the other hand, massive expansion of the social institutions, infrastructure (school, health services, transportation services), and commercialization in agriculture sector has lead to diversification of vegetation use. The high population growth in combination with proliferation of the social institutions, infrastructure and diversification in agriculture has produce dramatic changes within the lifetime of Chitwan residents. Which gives us a unique setting to study the long debated question: impact of population on local vegetation, particularly species diversity. In paragraphs below, we outline the likely impact of population on local species diversity.

Data and Methods

The information to test our hypotheses comes from multiple data sets from a panel study of 259 flora plots and 151 neighborhoods. Measures of vegetation, and household agriculture practices and consumptions were collected in three waves first in 1996 and repeated in 2000 and 2004, whereas the population measures are collected through a monthly household registry system that was started in 1997.

Measures of species diversity

Our measures of vegetation come from hand counted botanical counts of plants from 258 sample plots from the surrounding national reserve (Royal National Chitwan Park), community managed forest and common public land, first counted in 1996 and repeated in 2000 and 2004 following the same procedure by the same group of botanists as in 1996. To count number and kind of plant species we use three types of sampling units (quadrats) (a)10 x 10 m^2 plots for trees and woody climbers (b) 3 x 3 m^2 plots for shrubs, saplings of trees and herbaceous climbers and (c) 1 x 1 m^2 plots for herbs and seedlings of trees, shrubs and climbers. The hand counting of each and every single plant in two points in time (1996 and 2000) provides uniquely detail measures of change in vegetation, over a period.

The species diversity refers to composition of species in a sampled area. Thus diversity index is the ratio between the numbers plants of each species. Although there are a number of diversity indices, we use Shannon diversity index for simplicity, which essentially suggests that higher number in the diversity index more equally different species are distributed in the sample plot.

In addition, the GPS coordinates (latitude and longitude) of flora plots and neighborhoods provides greatest measurement flexibility and allow us to link flora and neighborhood data. Although, one could argue that changes in population in the nearest neighborhood should have the greatest impact on local vegetation nearby, because people use flora for many different economic and non–economic purposes (fuel wood, fodder, pasture, medicine, and religious purposes), the assumption of nearest have greatest impact seems to be too simplistic to us. In stead we argue that, people may not limit to just to the nearest flora plot but may use their immediate surrounding to meet their multiple needs. Therefore, for the purpose of this paper, our measures of species diversity is average of all the flora sample plots within 5 kilometer radii from a sample neighborhood[1]. Thus our measure of species diversity is the average of all the flora plots within 5 kilometer radii from a specific neighborhood in question. In addition, as we

[1] Although how far people would travel to collect fodder, fuel wood, or take their animal to graze could greatly vary by specific context and one could even argue about this, here we choose 5 kilometers for three reasons. First, in our house hold survey less then 5 percent respondents reported spending more than 100 minutes to travel to the place where fodder is collect it and bring it home. Because, 75 minutes essentially means walking 5 kilometer one way with a load, we think using 5 KM radii, we believe, captures all flora use. Second, 5 KM radii also ascertain that all a good number of neighborhoods has at least one or more flora plots within 5 KM. Finally, we also used a 10KM

describe above, because different population and community factors may influence vegetation through different mechanisms we identified three distinct categories of vegetation by type of management: national reserve, community managed forest and common public land. Table 1 provides the descriptive statistics of these measures.

(Table 1 about here)

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Analytical Strategy

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Results

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Conclusion:

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radii and re run these analyses which substantially reduced the number of sample neighborhoods that has one or ore sample flora plots but did not change the result substantively.

Reference

Barber, J., G. Shivakoti, W. G. Axinn, K. Gajurel. 1997. "Sampling Strategies for Rural Settings: A Detailed Example from the Chitwan Valley Family Study Nepal." Nepal Population Journal 6(5):193-203.

Baral, H. S. and G. Uppadhaya. 1998. Birds of Royal Chitwan National Park

Banskota, K. B. Sharma, U. R. Sharma and A. Rijal 1998. Royal Chitwan national Park after twenty years: An assessment of values, threats and opportunities, KMTNC, Kathmandu.

Binswanger, H., and Pingali, P. 1989. " Population growth and technological change in agriculture" In K Davis, M. Bernstam, and H. Selletrs (Eds) Population and Resources in a changing world. Stanford: Morrison Institute for Population and Resource Studies

Bilsborrow, R. 1987. "Population Pressure and Agricultural Development in Developing Countries: A Conceptual Framework and Recent Evidence" World Development. 15 (2) pp 183-203

Bilsborrow, Richard F. & DeLargy, Pamela F. 1991. Land use, Migration, and Natural Resource Deterioration: The Experience of Guatemala and the Sudan. In K. Davis and M. Bernstam (Eds.). Resources, Environment, and Population. Oxford: Oxford University Press.

Blaike, P. and H. Brookfield. 1987. Land Degradation and Society. New York: Methuer.

Blaike, Piers, John Cameron, and David Seddon. 1980. Nepal in Crisis: Growth and Stagnation at the Periphery. Oxford University Press Delhi.

Bongaarts, J. 1992. "Population Growth and Global Warming" Population and Development Review 18 (2)

Bongaarts, J. 1996. "Population Pressure and Food Supply System in the Developing World." Population and Development Review 22 (3): 483-503.

Boserup, E. 1965. The Conditions of agricultural growth : The economics of agrarian change under Population pressure. Chicago: Aldine Press

Boserup, E. 1981. Population and Technological Change: A Study of Long-term Trends. Chicago: The University of Chicago Press.

Cameron M.M. 1996. " Biodiversity and Medicinal Plants in Nepal: Involving Untouchables in Conservation and development" *Human Organization* 55(1):

Ciriacy-Wantrup, S. V. and R. Bishop. 1975. "Common Property as a Concept in Natural Resources Policy." *Natural Resources Journal* 15(10): 713-727.

Ehrlich, P. R. and Anne H. Ehrlich and Gretchen C. Daily. 1993. "Food Security, Population, and Environment." *Population and Development Review* 19 (1)

Edds, D. R. 1989. Multivariate analysis of fish assemblage composition and environmental correlates in a Himalayan river –Nepal's kali Gandaki/Narayani. Unpublished Ph.D. dissertation, Oklahoma State University, Stillwater.

Forester, Deborah J. and Gary E. Machlis. 1996. "Modeling Human factors That affect the Loss of Biodiversity." *Conservation Biology* 10(4): 1253-1263.

Jolly, C. L. 1994. "Four Theories of Population Change and the Environment." Population and Environment: *A Journal of Interdisciplinary Studies*. 16(1)

Jolly, C. L. and B.B. Torrey. 1993. Population and Land Use in Developing Countries. National Academy Press. Washington D.C.

Kumar, S. and D. Hotchkiss. 1988. "Consequences of Deforestation for Women's Time Allocation, Agricultural Production, and Nutrition in Hill Areas of Nepal." International Food Policy Institute Research Report *69*. Washington, D.C.

Liu, Jianguo, Zhiyun Ouyang, Yingchun Tan, Jian Yang and Heming Zhang. 1999. "Changes in Human Population Structure: Implication for Biodiversity Conservation." *Population and Environment* 21(1):45-58.

Liu,J., G. C. Daily, P. R. Ehrlich, and G. W. Luck. 2003. "Effects of household dynamics on resource consumption and biodiversity." Nature 421(6922):530-533 Jan 30 2003; Nature Cover JAN 30 2003; News and Views; Supplementary Information

Liu, J., Li An, S.S. Bate, R.E. Groop, Z. Laing, M. A. Linderman, A.G. Mertig, Z.Ouyang, and J. Qi. 2003. "Human Impacts on Land Cover and Panda Habitat in Wolong Nature Reserve: Linking Ecological, Socioeconomic, Demographic and Behavioral Data." In J. Fox, R.R Rindfuss, S.J. Walsh and V. Mishra edited *People and the Environment: Approaches for Linking Household and Community Survey to Remote Sensing and GIS*. Kluwer Academic Publisher.

Malthus, T. R. 1798. An Essay on the Principle of Population. Reprinted, pp. 15-139 in P. Appleman, Ed., An Essay on the Principle of Population. New Work: W. W. Norton.

Matthews, S. A., Ganesh P. Shivakoti and Netra Chhetri. 2000. "Population Forces and Environmental Change: Observation from Western Chitwan, Nepal." *Society and Natural Resources* 13: 763-775.

May, J.F. 1995. "Policies on Population, Land Use, and Environment in Rwanda." *Population and Environment: A Journal of Interdisciplinary Studies* 16 (4)

Millette, T. L., A. R. Tuladhar, R. E. Kasperson, and B.L. Turner II. 1995. "The use and limits of remote sensing for analyzing environmental and social change in Himalayas Middle Mountains of Nepal." *Global Environmental Change* 5 (4) pp. 367-380

Mortimore, M. 1993." Land Transformation under Agricultural Intensification." In C. L. Jolly and B. B. Torry Eds *Population and Land Use in Developing Countries*. National Academy Press. Washington D.C.

National Research Council. 1986. *Population growth and economic development: policy questions*. Washington, D.C: National Academy Press.

Ostrom, E. 1990. *Governing the Commons: the Evaluation of Institutions for Collective Action.* Cambridge, UK: Cambridge University Press

Ostrom, E., Joanna Burger, Christopher B. Field, Richard B. Norgaard, and David Policansky. 1999. "Revisiting the Commons: Local Lessons, Global Challenges." *Science* 284 (4):278-282.

Pandit, B. H and G. B. Thapa. 2003. "A Tragedy of Non-timber Forest Resources in the Mountain of Commons of Nepal." *Environmental Conservation* 30(3): 283-292.

Pichon, F.J. 1997. "Settler Household and Land-Use Patterns in Amazon Frontier: Farm-Level Evidence from Ecuador" World Development. 25 (1):

Rijal, A. 1999. "Biodiversity conservation in and around Chitwan National Park." *Unicorn* 1(1): 29- 38.

Shapiro, D. 1995. "Population Growth, Changing Agricultural Practices, and Environmental Degradation in Zaire." *Population and Environment*: A Journal of Interdisciplinary Studies. 16 (3)

Shivakoti, G., W. G. Axinn, P. Bhandari, and N. Chhetri. 1999. "The impact of Community Context on Land Use in an Agriculture Society" *Population and Environment*. 20:3 191-213

Shreatha, Vinod P. 1999. "Forest resources of Nepal: destruction and environmental implications." *Contributions to Nepalese Studies* 26,2:295-307.

Shrestha, G. L. 2001. Wild edible plants of Nepal. pp. 40-50. Uncultivated foods and biodiversity: proceedings of the workshop held in Kathmandu, Nepal September 24-26, 2001. USC Canada Nepal, Baluwatar, Nepal.

Tiwari, N. R. 1998. Biodiversity conservation in Nepal. Pp 83-104 in Report on the International Meeting on Himalaya Ecoregional Co-operation: Ecoregional Co-operation for Biodiversity Conservation in the Himalayas. The United Nations Development Programme in co-operation with WWF and with the assistance of ICIMOD. February 16-

18, 1998. Kathmandu, Nepal

Tiwari, P. C. 2000. "Land use changes in the Himalaya and their impact on the plains ecosystem: need for sustainable land use ." *Land Use Policy* 17: 101-111.

Vitousek, P.M., H. A. Mooney, J. Lubchenco and J. M. Melillo. 1997. "Human Domination of Earth's Ecosystems." *Science* 277:494-499.

Wade, R. 1988. *Village Republics: Economic Conditions fro Collective Action in South India.* Okland, USA, ICS press

Wilson, E. O. (Ed). 1988. *Biodiversity.* Washington DC: national Academy of Science Press

Wolman, M.G. 1993. "Population, Land Use, and Environment: A Long History." In C. L. Jolly and B. B. Torry (Eds) Population and Land Use in Developing Countries. National Academy Press. Washington D.C.

Table 1. Descriptive Statistics of Dependent Variable: Shannon Diversity Index at Time-3 (2004)

	N	Time-3 (2004)				Paired T-test between T1 & T3
		Mean	Std Dev	Min	Max	T ratio
Study area						
Shannon Diversity Index	259 plots	165	0.70	0	3.21	1.08
Nearest plot from the Neighborhood						
Shannon Diversity Index	151 NBH	1.57	0.72	0.16	2.78	1.11
Average of plots within 5 KM by Plot Type						
Shannon Diversity Index						
Chitwan National Park	92 NBH	1.09	0.11	0.87	1.82	-10.89
Community Managed Forest	76 NBH	1.15	0.21	0.71	1.69	-13.72
Public Common Land	151 NBH	0.96	0.11	0.70	1.21	-46.28

* $p < 0.05$ ** $P < 0.01$ *** $P < 0.001$ *Statistical significance of 1996 -2004 difference*

Table 2. Descriptive Statistics for measures of flora diversity, population, community context, and neighborhood attributes

		Time-1 (1996)				Time-2 (2000)			
	N	**Mean**	**Std Dev**	**Min**	**Max**	**Mean**	**Std Dev**	**Min**	**Max**
Population									
Number of persons	151 NBH	57.23	22.93	12.00	127.00	54.08	24.29	7.00	125.00
Number of people under age 15	151 NBH	20.80	10.64	4.00	61.00	19.90	10.82	3.00	65.00
Annual number of birth	151 NBH	1.77	1.54	0.00	7.00	1.35	1.29	0.00	6.00
Household size	151 NBH	5.57	1.19	3.50	10.87	4.85	1.23	1.80	10.25
Community context									
Average number of years non-family services within 15 minutes walk [a]	151 NBH	17.74	9.95	0.00	41.60	21.39	10.49	0.80	45.60
Flora diversity : Shannon diversity index									
Study area	259 PLOTS	1.61	0.58	0.00	2.73				
Nearest plot	151 NBH	1.51	0.61	0.01	2.42	1.61	0.56	0.27	2.89
Community managed forest	76 NBH	1.73	0.32	1.22	2.53	1.94	0.41	1.31	2.79
Chitwan national park	92 NBH	1.49	0.42	0.52	2.10	1.77	0.44	0.69	2.41
Public common land	151 NBH	1.52	0.17	1.11	1.99	1.52	0.27	0.85	1.95
Neighborhood attributes									
Proportion of household has electricity	151NBH	0.36	0.42	0.00	1.00	0.83	0.18	0.00	1.00
Proportion of household collect firewood	151 NBH	0.45	0.27	0.00	1.00	0.47	0.25	0.00	1.00
Proportion of household collect fodder	151 NBH	0.35	0.25	0.00	1.00	0.36	0.20	0.00	1.00
Proportion of household graze their animals	151 NBH	0.15	0.14	0.00	1.00	0.11	0.08	0.00	1.00
Livestock unit owned per household	151 NBH	2.07	1,14	0.00	6.34	1.83	0.93	0.00	5.55
Total Neighborhood area in 100,000 square feet	151 NBH	7.84	6.80	0.04	32.23				

[a].Non-family services include school, health service, bus stop, employment center and market.

Table 3. OLS regression estimates of flora diversity in nearest plot from the neighborhood (t- ratio in parentheses)

	Dependent Variable: Change in Flora Diversity between 2000 and 2004			
Change in population between 1996-2000				
Number of people	-0. 04 (1. 41)			
Number of people under 15 years of age		- 0. 00 (0. 67)		
Annual number of birth			-0. 04 (0. 17)	
Household size				-0. 04 (1.08)
Flora diversity				
Shannon diversity index in 2000	0. 69** (9. 23)	0. 70** (9. 30)	0. 70** (9. 34)	0. 69** (9. 22)
Community Context				
Average number of years non-family services within 15 minutes walk˜	0. 1 0* (2. 18)	0. 10* (2. 08)	0. 10* (2. 12)	0. 10* (2. 19)
Other Controls				
Proportion of household has electricity	-0. 56** (5. 10)	-0. 57** (5. 04)	-0. 56** (5. 00)	-0. 54** (4. 70)
Proportion of household collect firewood	0. 09 (0. 53)	-0. 07 (0. 40)	0. 06 (0. 35)	0. 07 (0. 42)
Proportion of household collect fodder	- 0. 45** (2. 43)	-0. 43** (2. 32)	0. 44** (2. 35)	0. 43** (2. 33)
Proportion of household graze their animals	0. 44 (1. 36)	0. 44 (1. 36)	0. 44 (1. 36)	0. 46 (1. 41)
Livestock unit owned per household	0. 02 (0. 36)	0. 02 (0. 34)	0. 02 (0. 35)	0. 04 (0. 58)
Total area in 100,000 square feet	-0. 01 (0. 64)	-0. 01 (0. 67)	-0. 01 (0. 70)	-0. 01 (0. 47)
Intercept	0. 44	0. 44	0. 43	0. 39
R^2 –Adjusted	0. 60	0. 59	0. 59	0. 59
N	151	151	151	151

- p < .05 one-tail ** P< .01 one-tail

Table 4. OLS regression estimates of flora diversity in Community managed forest plot within five kilometer from the neighborhood (t- ratio in parentheses)

	Dependent Variable: Change in Flora Diversity between 2000 and 2004			
Change in population between 1996-2000				
Number of people	**-0. 003**** **(2. 04)**			
Number of people under 15 years of age		**- 0. 007*** **(2. 15)**		
Annual number of birth			**-0. 03*** **(1. 91)**	
Household size				**-0. 05**** **(2. 87)**
Flora diversity in 2000				
Shannon diversity index	**0. 26**** **(4. 24)**	**0. 27**** **(4. 49)**	**0. 24**** **(3. 79)**	**0. 28**** **(4. 80)**
Change in community Context between 1996-2000				
Average number of years non-family services within 15 minutes walk˜	**0. 04** **(1. 16)**	**0. 03** **(0. 90)**	**0. 04** **(1. 16)**	**0. 05** **(1. 55)**
Change in other neighborhood attributes between 1996-2000				
Proportion of household has electricity	**-0. 15*** **(1. 79)**	**-0. 16*** **(1. 95)**	**-0. 14*** **(1. 71)**	**-0. 11** **(1. 35)**
Proportion of household collect firewood	**0. 01** **(0. 13)**	**0. 03** **(0. 27)**	**0. 00** **(0. 00)**	**0. 009** **(0. 09)**
Proportion of household collect fodder	**- 0. 06** **(0. 50)**	**0. 10** **(0. 84)**	**0. 04** **(0. 32)**	**0. 08** **(0. 69)**
Proportion of household graze their animals	**0. 11** **(0. 58)**	**0. 14** **(0. 74)**	**0. 16** **(0. 78)**	**0. 11** **(0. 60)**
Livestock unit owned per household	**0. 03** **(0. 79)**	**0. 03** **(0. 75)**	**0. 05** **(1. 37)**	**0. 05** **(1. 29)**
Total area in 100,000 square feet	**-0. 004** **(1. 09)**	**-0. 004** **(1. 10)**	**-0. 003** **(0. 71)**	**-0. 002** **(0. 55)**
Intercept	**0. 57**	**0. 58**	**0. 60**	**0. 42**
R^2 –Adjusted	**0. 23**	**0. 24**	**0. 23**	**0. 28**
N	**76**	**76**	**76**	**76**

< .05 one-tail ** P< .01 one-tail

Table 5. OLS regression estimates of flora diversity in Chitwan national park plot within five kilometer from the neighborhood (t- ratio in parentheses)

	Dependent Variable: Change in Flora Diversity between 2000 and 2004			
Change in population between 1996-2000				
Number of people	**0. 001 (1. 31)**			
Number of people under 15 years of age		**0. 0001 (0. 04)**		
Annual number of birth			**0. 001 (0. 26)**	
Household size				**0. 001 (0. 12)**
Flora diversity in 2000				
Shannon diversity index	**0. 18** (8. 39)**	**0. 18** (8. 25)**	**0. 18** (8. 26)**	**0. 18** (8. 25)**
Change in community context between 1996-2000				
Average number of years non-family services within 30 minutes walk˜	**-0. 01 (0. 58)**	**-0. 004 (0. 41)**	**-0. 004 (0. 43)**	**-0. 004 (0. 42)**
Change in other neighborhood attributes between 1996-2000				
Proportion of household has electricity	**0. 04 (1. 37)**	**0. 04 (1. 38)**	**0. 04 (1. 28)**	**0. 04 (1. 25)**
Proportion of household collect firewood	**0. 01 (0. 07)**	**0. 002 (0. 05)**	**0. 001 (0. 04)**	**0. 002 (0. 06)**
Proportion of household collect fodder	**- 0. 02 (0. 42)**	**- 0. 02 (0. 57)**	**- 0. 02 (0. 50)**	**- 0. 02 (0. 58)**
Proportion of household graze their animals	**-0. 001 (0. 01)**	**0. 003 (0. 05)**	**0. 004 (0. 07)**	**0. 003 (0. 05)**
Livestock unit owned per household	**0. 01 (0. 88)**	**0. 01 (0. 99)**	**0. 01 (0. 93)**	**0. 01 (0. 90)**
Total area in 100,000 square feet	**0. 002 (1. 94)**	**0. 002 (2. 04)**	**0. 002 (2. 05)**	**0. 002 (1. 99)**
Intercept	**0. 74**	**0. 73**	**0. 74**	**0. 74**
R^2 –Adjusted	**0. 47**	**0. 46**	**0. 46**	**0. 46**
N	**92**	**92**	**92**	**92**

< .05 one-tail ** P< .01 one-tail

Table 6. OLS regression estimates of flora diversity in Public common land plot within five kilometer from the neighborhood (t- ratio in parentheses)

	Dependent Variable: Change in Flora Diversity between 2000 and 2004			
Change in population between 1996-2000				
Number of people	- 0. 0003 (1. 39)			
Number of people under 15 years of age		-0. 001** (2. 61)		
Annual number of birth			-0. 002 (1. 12)	
Household size				-0. 007** (2. 55)
Flora diversity				
Shannon diversity index in 2000	0. 38** (30. 22)	0. 38** (30. 69)	0. 38** (30. 22)	0. 38** (30. 46)
Change in community context between 1996-2000				
Average number of years non-family services within 30 minutes walk˜	0. 002 (0. 59)	0. 001 (0. 43)	0. 002 (0. 63)	0. 003 (0. 75)
Change in other neighborhood attributes between 1996-2000				
Proportion of household has electricity	-0. 01 (1. 84)	-0. 02 (1. 95)	-0. 01 (1. 78)	-0. 01 (1. 29)
Proportion of household collect firewood	0. 02 (1. 33)	0. 01 (1. 29)	0. 02 (1. 45)	0. 02 (1. 37)
Proportion of household collect fodder	0. 01 (0. 60)	0. 01 (0. 80)	0. 01 (0. 45)	0. 01 (0. 74)
Proportion of household graze their animals	-0. 002 (0. 11)	-0. 002 (0. 10)	-0. 002 (0. 11)	-0. 002 (0. 11)
Livestock unit owned per household	-0. 0003 (0. 07)	- 0. 0001 (0. 02)	0. 0002 (0. 05)	0. 0001 (0. 03)
Total area in 100,000 square feet	-0. 0002 (0. 58)	- 0. 0002 (0. 58)	-0. 0003 (0. 68)	0. 0001 (0. 13)
Intercept	0. 38	0. 38	0. 38	0. 37
R^2 –Adjusted	0. 91	0. 91	0. 91	0. 91
N	151	151	151	151

< .05 one-tail ** P< .01 one-tail