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Social Organization, Population, and Land Use

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Social Organization, Population, and Land Use

ABSTRACT

We examine the population-environment relationship at the local community level by focusing on the impact of population changes on changes in land use. 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 impacts on land use. We use newly available longitudinal measures of local land use changes, local population dynamics, and community context from the Nepalese Himalayas to provide empirical estimates of our theoretical model. This empirical investigation reveals that variations in model specification yield different substantive conclusions and that multiple dimensions of population change impact land use. Local birth rates have a large effect on local land use changes that is not explained by changes in population size or structure. This intriguing finding is consistent with the hypothesis that fertility influences household consumption patterns which in turn impact land use changes at the local level.

INTRODUCTION

Because degradation of the natural environment is believed to have potentially broad consequences for humanity, ranging from global warming to depletion of key resources to reduced quality of life, it has become the subject of increasingly intense research over recent decades. This is just as true in the social sciences as in the natural, biological and physical sciences. The social sciences have been particularly concerned with the consequences of social organization and social actions on levels of environmental degradation – areas in which Sociology has a great deal to offer in terms of both theory and method. The central objective of this paper is to identify the areas in which Sociological theory and methods are likely to produce dramatic advances in research on the environment and illustrate this potential with a specific case study. Our illustration links together social organization of the local context, population dynamics, consumption behaviors, and land use/land cover dynamics.

Theoretically, five key principles now common place in many areas of Sociological reasoning are likely to prove particularly fruitful for research on the environment. These principles begin with a focus on the investigation of micro-level associations to inform our understanding of macro-level trends. Building on this principle, four other key principles can be used to guide reasoning regarding micro-level associations with environmental change. One of these is construction of context specific hypotheses regarding micro-level associations. A second is attention to the proximate determinants of specific environmental outcomes through which other more theoretically interesting or policy relevant factors affect these outcomes. A third is explicit consideration of reciprocal causation, in which an environmental factor of interest may influence the factors we also believe shape that dimension of the environment. And the fourth is direct attention to the social organization of human groups in addition to the simple size and affluence of those groups. Our theoretical aim is to combine these five principles into a framework for the study of land use change to illustrate their potential to advance research on the environment.

Methodologically, these theoretical principles motivate the application of four research tools to the study of the environment that are also now commonplace in many other areas of sociological research. The first tool is longitudinal research designs. Because of the great potential for reciprocal causal relationships among micro-level factors, measurement of change over time are needed to adjudicate the temporal ordering among associations (Axinn and Pearce 2006; Campbell and Stanley 1967). The second tool is multilevel research design and empirical models. Multilevel designs are necessary to establish the relationships across levels of analysis, such as the national level, the community level, the household level, or the individual level (Entwisle and Mason 1985; Raudenbush and Bryk 2002). The third tool is decomposition of categories into sub-categories. Decomposition into sub-categories can produce important new insights into the sources of change and variation in the overall subject under study. The fourth tool is mixed-method measurement to create the richest possible empirical description for the identification of potential causal pathways linking social factors to the environment (Axinn and Pearce 2006). Our methodological aim is to demonstrate that by combining these methodological tools scientists can build empirical evidence to match the theoretical principles outlined above.

We focus on one specific dimension of environmental quality: land use. Although many other dimensions of environmental quality are important, changes over time in the use of land, moving land out of forest cover and into agriculture or moving land out of agriculture and into buildings and infrastructure, have some of the broadest implications for global diversity of both flora and fauna species. In fact, scientific concern regarding the determinants of land use has generated numerous new studies of land use patterns around the world, in both contemporary and historical settings (Entwisle 2001; Gutmann 2001; Gutmann and Cunfer 1999; Moran 2001; Rosenzweig 2001; Fox, Rindfuss, Walsh and Mishra 2003; Simmons 1987; Wolman 1993). We join these new studies in focusing on micro-level relationships between the human population and land use, with particular attention to the effects of social organization and population processes on land use. The research we report here investigates the determinants of the transition from subsistence agricultural land use, which emphasized maintenance of a diverse ecology in the settled areas immediately surrounding households, to use of land for buildings and infrastructure.

We use longitudinal, multilevel, mixed-method measures from the foothills of Nepalese Himalayas to test the predictions from our theoretical model. Nepal is widely known as one of the world's most diverse ecological settings, but also as a setting on the brink of serious environmental degradation (Blaike and Brookfield 1987; Eckholm 1976). The fragile Himalayan environment is suffering rapid deforestation and soil erosion, which threaten both the vegetation and the fauna dimensions of the region's bio-diversity. Further, the combination of rapid population growth and rapid social and economic change make Nepal the ideal setting to test the effects of these two key factors on changes in land use. The study itself provides a unique combination of longitudinal measurement at two levels of analysis: local community level changes over time in social organization, land use, and population and household level changes over time in population and consumption patterns. Together these measures of social organization, population, consumption behavior, and land use provide an opportunity to test key hypotheses derived from our theoretical framework. The results give us valuable new insights into the local-level processes shaping land use change.

A THEORETICAL MODEL OF LAND USE CHANGE

In many ways understanding the macro-level trends is our ultimate goal in research on environmental change in general and land use specifically (Boserup 1981; Cohen 1995; Fox et al. 2003).

However, to achieve those goals we advocate beginning from the principle that detailed attention to micro-level associations is an important source of insight into the causes of macro-level trends. This approach has proved useful in many areas of Sociological research, spanning topics such as research on social stratification (Blau and Duncan 1967; Mouw 2002), professions (Abbott 1988; Xie and Shuaman 1998), religion (Smith and Denton 2005), families (Goldscheider and Waite 1985; Rindfuss, Morgan and Swicegood 1988), and segregation (Massey and Denton 1992; Wilson 1987). In research on the environment, macro-level theoretical reasoning has emphasized the combination population size, population affluence, and technology as the key factors combining to shape environmental quality (Hunter 2001; Stern et al. 1997). Fueled by that perspective, a number of recent macro-level studies continue to make contributions to our understanding of key factors related to environmental change and variation, including land use (Bongaarts 1996; Stern, Dietz, Ruttan, Socolow and Sweeney 1997; York, Rosa, and Dietz 2002). As a complement to such approaches, here we formulate a framework for the study of micro-level land use change and variation.

To accomplish this we draw on each of the other four principles of Sociological reasoning listed above. In order to construct a framework for studying micro-level land use change and variation we begin by identifying a specific context for our research, which allows us to construct context-specific hypotheses. These hypotheses use key proximate determinants of land use to identify likely causal pathways through which population size, affluence, and social organization ultimately shape land use. Our framework gives explicit attention to the importance of social organization as a dimension independent of population size or affluence and to the potential of reciprocal influences of land use patterns on factors which also affect land use.

Specific Land Use Transition

In the micro-level study of land use, specific types of land use transitions are likely to be shaped by different determinants. A micro-level model designed to predict the land use consequences of social, economic, or demographic change and variation must begin by identifying a specific land use transition. As in other areas of Sociology, we begin framing context specific hypothesis by defining the starting state of the process being studied, in this case land use (Axinn and Yabiku 2001; Thornton and Lin 1994). We focus on land use in settled areas in which land uses are characterized by subsistence agricultural production. This focus is quite different than an examination of changing land use in a forested area characterized by no human population that becomes settled for the first time. In a settled area characterized by subsistence agricultural production there is an existing pattern of consuming land, usually preserving a good deal of ecological diversity relative to areas characterized by market oriented production (Boserup 1965, 1981; Foster and Rosenzweig 2004; Mortimore 1993). This is because subsistence oriented households produce fruits and vegetables in addition to cereal crops, and also maintain common pasture or forest to provide fodder for animals, whereas market oriented producers generally specialize in a small number of agricultural products (Axinn and Axinn 1983; Geertz 1968; MaCalla 1997; Miracle 1968; Pingali 1997; Pingali and Rosegrant 1995). The model predicting land use we design begins with this settled, subsistence oriented land use pattern as the starting state.

Our model focuses on the effects of specific social, economic, and demographic changes on the percent of local land devoted to all uses resulting in vegetation in this type of setting. By vegetation we mean crops, plantations, pasture land, fallow land, and trees and plants in common land areas within settled local communities. This definition includes all land uses that might appear covered with vegetation from remote sensing images (Fox et al. 2003). So, we investigate the fraction of land area within a settled, subsistence oriented agricultural community that is devoted to vegetation. Our model focuses on the factors which are likely to change the fraction of land in the local community that is devoted to these uses. We also decompose the total land area devoted to vegetation into various sub-categories to provide more insight into potential mechanisms producing the observed changes over time.

Consumption Behavior as a Proximate Determinant of Land Use

The human population affects land use through behavior. The proximate determinants of land use patterns are the behaviors that affect use of the land. These include productive, recreational, and consumptive behaviors. For example, as human systems of production change, be they hunting and gathering, subsistence agriculture, or industrial production, patterns of consuming land change, and these changes alter the use of the land and the nature of the resulting land cover. From this perspective patterns of consuming land are a fundamental link between human behavior and land use or land cover. Although changing production, recreation, or consumption behavior may drive land consumption patterns, it is what people do with the land - the way they consume it - that determines land use and therefore land cover.

In a settled, subsistence agriculture oriented setting, two specific dimensions of patterns of consuming land are likely to have particularly important effects on the fraction of local land devoted to vegetation: consumption of plant life and construction of buildings and infrastructure. We argue that these two specific processes are key proximate determinants responsible for land use changes away from vegetation and toward the built environment at the local level in a settled, subsistence oriented setting. Although both the consumption of plants and construction will reduce the fraction of land devoted to vegetation in a settled area, it is important to differentiate between these two processes because some key determinants of changes in land use affect the two processes in opposite directions.

For example, increasing affluence is likely to promote construction of buildings and infrastructure thereby reducing the fraction of local land devoted to vegetation. But recent evidence from India indicates affluence reduces consumption of vegetation as families switch from fuel wood to alternative energy sources (Foster, Rosenzweig, and Behrman 2000; Rosenzweig 2001). At the local level this means more affluent communities may convert land out of vegetation at a higher rate because of construction activities, but they may also preserve vegetation at a higher rate because of declines in the use of fuel wood. The total effects of affluence on land devoted to vegetation, therefore, is determined by the relative magnitudes of these two opposing forces.

Technology is likely to have a similar relationship to changes in land use at the local level. In subsistence agricultural settings in most parts of the world, rural electrification represents a key source of change and variation in technology. Electrification provides an important fuel substitute likely to reduce consumption of vegetation (particularly fuel wood), but it may also stimulate construction, increasing the conversion of land out of vegetation. So, electrification is likely to increase the construction of buildings, thereby reducing the fraction of local land devoted to plant life, electrification is also likely to increase the fraction of land devoted to plant life by reducing consumption of plant life. The total effect of electrification on the fraction of land devoted to plant life will depend on the balance of the opposing effects via these two different proximate determinants.

Social Organization and Local Land Use

Economic and demographic studies of environment and land use generally emphasize factors such as affluence and population size, that influence the total volume of consumption, as key determinants of environmental conditions (Bongaarts 1992, 1996; Cohen 1995; Ehrlich, Ehrlich and Daily 1993; Evans and Moran 2002; Foster and Rosenzweig 2004). Clearly the total volume of consumption is a important determinant of environmental degradation in general and land use in particular (Fox et al 2003; Stern et al. 1997). However, in his path breaking theoretical work on Environmental Sociology, Foster (1999) identifies a key set of arguments from classical social theory that provide insight into changes in the *nature* of consumption as a potentially important determinant of environmental quality. These arguments point toward the social organization of daily life as a potentially critical determinant of the nature of consumption, and therefore environmental quality (Foster 1999). Our framework integrates consideration variations in the nature of consumption produced by variations in social organization into the formulation of hypotheses regarding environmental quality.

Many classical sociological treatments of social organization focus on the mode of *production*, and the implications of variations in the mode of production for social life (Durkheim 1984; Marx [1867] 1976;

[1863-65] 1981). Our conceptualization of social organization builds on this foundation by considering the relationship between macro-level organization and a broad array of micro-level social activities, including consumption, residence, recreation, protection, socialization, procreation along with production (Coleman 1990; Ogburn and Tibbits 1934). Historically, most social activities of daily living were organized within the family (Ogburn and Nimkoff [1955] 1976; Thornton and Fricke 1987). Changes in the technological and institutional context alter the extent to which these social activities are organized within family and kinship units versus outside of those units (Thornton and Fricke 1987; Thornton and Lin 1994). As new nonfamily organizations and services spread at the macro-level, the social activities of daily life are reorganized at the micro-level, increasingly taking place outside the family (Axinn and Yabiku 2001; Coleman 1990). The micro-level consequences of changes in the extent to which social activities are organized within families are both broad and dramatic (Coleman 1990; Durkheim 1984; Marx [1867] 1976, [1863-65] 1981; Thornton and Lin 1994). As we argue below, these include dramatic consequences for the nature of land consumption.

Nonfamily organizations and services, or what Coleman calls *corporate entities*, provide the means to organize consumption outside the family and thus stimulate widespread change in related social activities (Coleman 1990). One example is a shift from making clothes in the home to purchasing clothes in stores. Another is a shift from cooking in the home to eating in restaurants. There are many others (Coleman 1990; Ogburn and Tibbits 1934). We expect the proliferation of nonfamily organizations and services in communities to alter the social context so that more daily activities, including consumption, become organized away from the home and family. In the context of a setting characterized by subsistence agriculture, these consequences are likely to include a consumption shift from local land to more distant land.

These changes in daily life promote changes in patterns of consumption such that individuals are more likely to consume things they themselves did not produce. Marx describes this change as a *metabolic rift* - the creation of a gap between natural resources and the people consuming those resources, so that humans interact ever more indirectly with the natural resources they consume (Foster 1999; Marx [1867] 1976). Axinn, Barber and Biddlecom (2007) describe this change as a shift away from direct consumption of environmental resources toward indirect consumption of environmental resources. Greater access to nonfamily organizations and services at the community level gives local residents increasing opportunity to consume resources indirectly, thereby changing patterns of local land consumption (Axinn, Barber, and Biddlecom 2007).

Of course, many different nonfamily organizations and services may influence daily social life with consequences for consumption behavior (Axinn, Barber, and Biddlecom 2007). New nonfamily schools, health services, markets, wage employers and transportation services may all change social life to reduce direct consumption and increase indirect consumption. These changes will increase the effects of local consumers on land outside the local community, sometimes to affect land use very far away (Axinn, Barber, and Biddlecom 2007; Fox et al. 2003; Liu et al. 2005; Moran, Brondizio and VanWey 2005; Walsh et al. 2005). These changes in patterns of consuming land are likely to have important consequences for local land use and land cover.

In particular, in a setting of subsistence agriculture, increased access to nonfamily organizations is likely to promote a transition in local land use away from vegetation toward buildings and infrastructure. As social life become increasingly organized outside the family, particularly with regard to productive and consumption activities, households are less likely preserve local land area for diverse agricultural production and more likely to convert local land into buildings and infrastructure. This transition reflects a change in the type of consumption, rather than a change in the total volume of consumption. Therefore we expect these effects of access to nonfamily organizations to be independent of factors shaping the total volume of consumption.

Population Change and Local Land Use

Most theoretical perspectives on environmental change argue that at any given level of affluence and technology, population is the key determinant of natural resource consumption (Hunter 2001; Stern et al 1997). A number of different dimensions of population change may influence land use in general, and changes over time in the fraction of land devoted to plant life in a settled, subsistence oriented setting in particular. Population size changes, or changes in numbers of people, have probably received the greatest attention in previous research (Bilsborrow and DeLargy 1991; Bongaarts 1996; Cohen 1995; Ehrlich, Ehrlich, and Daily 1993; Heilig 1997; Myers 1991; Rees 1996). Most of this research focuses on macro-level associations. Greater numbers of people, and therefore population density in any one fixed area, reduces the fraction of land devoted to agricultural uses in that area by hastening the transition toward a built environment. Of course increased population size is also likely to promote agricultural extensification, through conversion of land in other locations into agricultural uses (Bongaarts 1996; Jolly and Torrey 1993; May 1995; Mortimore 1993; Schmidt-Vogt, 1994; Shapiro 1995; Thapa 1996; Tiwari 2000; Wolman 1993). However within a fixed local area the total effect of increasing numbers of people is predicted to be less land devoted to agricultural uses and vegetation. In a settled area characterized by subsistence production, the effect of population size is likely to be in the same direction for both of the two proximate determinants of land devoted to vegetation we identified above. Greater numbers of people should increase consumption of vegetation and increase construction of buildings and infrastructure. Thus more people is predicted to result in less land devoted to plant life.

Recent studies of micro-level connections between population change and land use, however, are beginning to indicate that numbers of households may be a more important predictor of land use patterns than numbers of people. For example, recent evidence from both Thailand and China indicates that the number of household units may be a more important determinant of land use than the number of people per se (Entwisle 2001; Liu et al. 2005; Walsh et al. 2005). This result seems plausible because the number of household units may drive the actual micro-level patters of consumption more closely than the number of people. To the extent households are they main consumers of vegetative resources, particularly in the form of fuel wood and fodder, greater numbers of households should result in decreased land devoted to vegetation. Thus at the local community level, change in the number of households may have a stronger influence on changes in land use than change in the number of people.

Population size, measured by either number of people or numbers of households, may not be the only dimension of population that shapes land use. Other dimensions of population, such as the age structure, or processes of fertility, mortality, and migration, may affect consumption of vegetation and construction of buildings and infrastructure. Dimensions of population that increase consumption of vegetation and construction of buildings are likely to reduce the local land area devoted to flora. Both population age structure and fertility are likely to have these effects.

Age structure may be an important determinant of changes in land use because younger age structures produce 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. The result will be changes in land use toward less land area devoted to vegetation. So an expansive age structure, with an increasing proportion of the population in young age groups, is likely to stimulate changes toward less land devoted to vegetation in any specific local area.

This prediction is quite consistent with recent findings from the Brazilian Amazon. In that setting, Moran and colleagues are finding strong associations 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 that increase the fraction of a population at specific ages characterized by life cycle changes such as marriage, childbearing, and household formation, therefore, are quite likely to impact land use. Although the Amazonian case addresses a much different phase of land use transition, from forested land to agriculture land rather than from agriculture land to built land, these important findings point toward the potential impact of changes in age structure on land use patterns.

Fertility processes are quite likely to have similar effects. Childbearing is a key step in the family building process likely to substantially increase household consumption. In a settled, subsistence agricultural setting childbearing is likely to result in both greater consumption of vegetation and higher levels of construction of buildings and infrastructure. Not only does childbearing increase demand for fuel wood and fodder, childbearing drives families to enlarge their existing home or build additional homes nearby. In areas where extended family co-residence is common, such as South Asia (Acharya and Bennett 1981; Fricke 1986), construction activity need not create what the families would identify as new households, they may simply create larger structures. Furthermore, for families in rural areas, common forest resources may be the main source of construction material. Thus the construction of new buildings not only takes up land formerly devoted to agriculture or common areas, it also increases the consumption of vegetation. Therefore we expect to find that communities with higher birth rates experience changes toward less land devoted to vegetation than communities with low birth rates.

In areas of existing rural settlement, beginning with land consumption patterns oriented toward subsistence agriculture, high rates of childbearing in the community may be one of the most important factors stimulating changes in land use toward less land area devoted to vegetation. The arrival of new children provides a unique stimulus to the construction of buildings and consumption of vegetation. These effects of childbearing may even be independent of the effects of age structure described above. Although high birth rates produce young age structures, if childbearing directly alters land consumption patterns to affect land use, empirical results should demonstrate an effect of birth rates independent of any estimated effects of age structure.

Thus, we have identified four conceptually distinct dimensions of population change that may effect land use: numbers of people, numbers of households, age structure, and birth rates. There are undoubtedly others. Our objective is not provide an exhaustive list, rather we identify these four dimensions of population change as a starting point. Our aim is to provide empirical test of this simple, but multi-dimensional, model of population effects on changes in land use at the local community level.

Linking Social Organization and Population

One issue that makes it difficult to assess the effect of population on local land use is the fact that the local context of social organization probably influences both population and land use. Research on key population parameters is consistent with the conclusion that the local context of family versus nonfamily organization shapes these parameters, at least in part. Contextual characteristics affect each of the key processes shaping population size, including fertility processes (Axinn and Yabiku 2001; Entwisle and Mason 1985; Entwisle, Casterline and Sayed 1989; Casterline 1985), migration processes (Massey and Espinosa 1997; Massey et al 2007) and mortality processes (Sastry 1996). Research on these topics has also shown that local-level contextual characteristics can be particularly important determinants of population parameters (Axinn and Fricke 1996; Entwisle, Casterline and Sayed 1989). Moreover, some of the same specific dimensions of local context we hypothesize will affect land use are also know to affect key population parameters (Axinn and Yabiku 2001; Massey and Espinoza 1997).

Thus, our understanding the effects of population on local land use may be mis-leading if local social organization is ignored. The relationships between population and land use are embedded within a common set of contextual level social organization determinants. As a result, precise specification of the relationship between population and land use at the micro-level requires a clear understanding of the influence of contextual social organization characteristics on both population processes and land use. That is, we will need multilevel models that include contextual aspects of social organization along with micro-level measures of variation in population.

Reciprocal Relationships between Population and Land Use

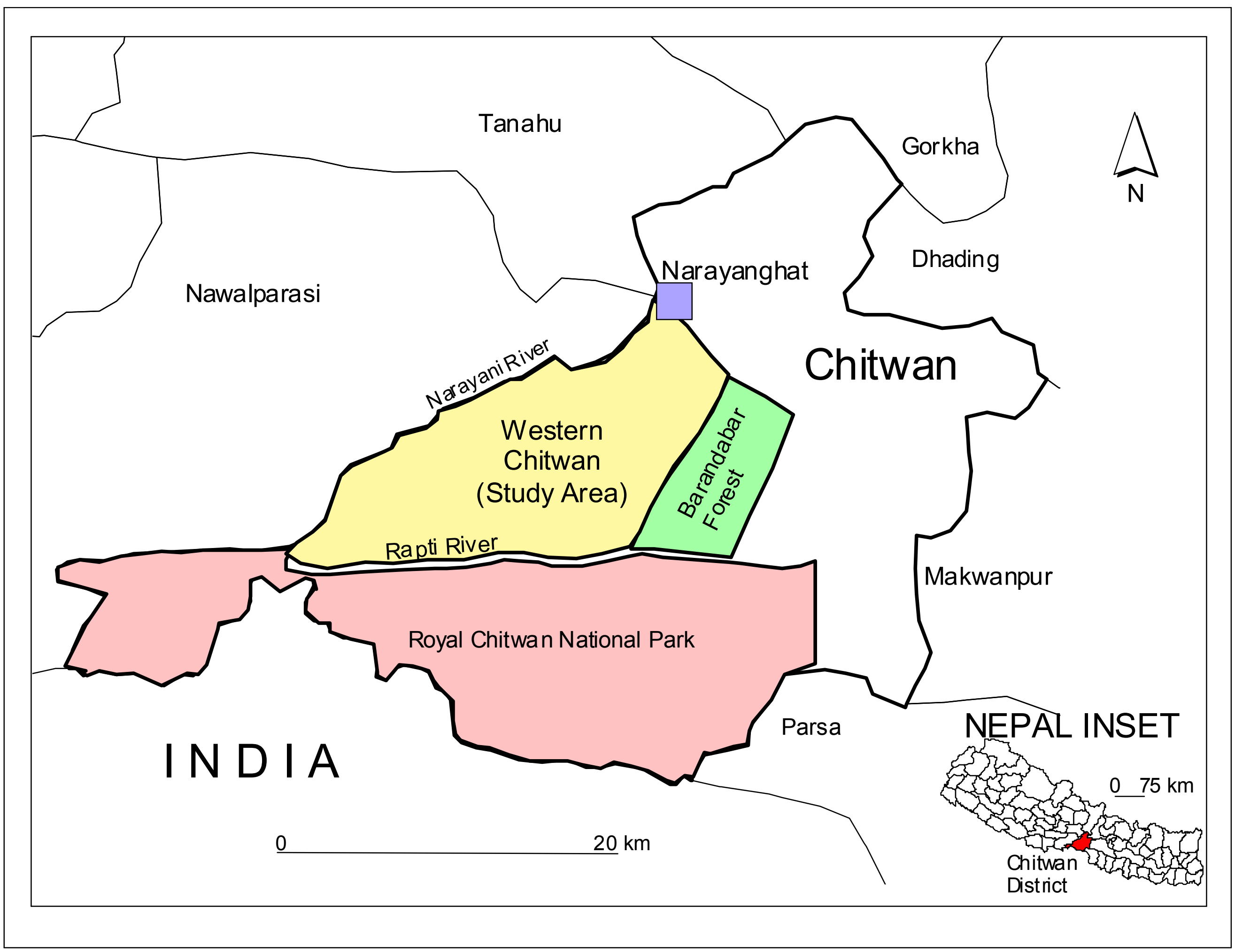
Finally, our micro-level investigations of factors shaping this land use transition must address the potential of land use to influence population as well as the effects of population on land use. Micro-level studies of causal associations in virtually every other area of Sociology point toward important reciprocal relationships between key factors. For example, variations in attitudes may shape subsequent behavior, but those same behaviors have important consequences for attitudes (Ajzen 1988). Across generations we have good reason to believe that educational attainment shapes income, but it also appears that income shapes educational attainment (Blua and Duncan 1967). Likewise, variation in religion and religiosity shape subsequent family behaviors, but family behaviors also shape religiosity (Stolzenberg, et al 1995; Thornton, Axinn and Hill 1992). The examples go on, but the point is clear. If we wish to investigate the relationship between micro-level variations in population and micro-level variations in land use, we must consider the possibility that not only may population affect land use, but land use may also affect population.

In fact recent empirical evidence is consistent with this expectation. Social scientists are increasingly sensitive to the idea that environmental quality may have an important effect on population processes. The consequences of environmental degradation on out-migration and mortality have received the most attention (Hamilton, Seyfrit, and Bellinger 1997; Hill 1990; Perz 1997). Research on the Nepalese setting indicates that environmental quality affects both subsequent migration behavior and subsequent fertility behavior (Biddlecom, Axinn and Barber 2005; Ghimire and Mohai 2005; Massey, Axinn and Ghimire 2007). These streams of research suggest an important reciprocal relationship, with environmental conditions such as land use potentially affecting subsequent population processes. Because of this possibility, estimation of the effects of population processes on changes in land use will require longitudinal measurement that can be used in models to control for the potential effects of land use on subsequent population processes.

SETTING, DATA, AND METHODS

The setting for this study is the Western Chitwan Valley located in South-Central Nepal. Chitwan is a wide flat valley nestled in the Himalayan foothills at approximately 450 feet above sea level. Until the early 1950s Chitwan was covered by virgin forests, infested with malaria carrying mosquitos, and home to many dangerous fauna, ranging from poisonous snakes to Bengal Tigers. Beginning in the mid-1950s, with assistance from the United States, the Nepalese government began a program of clearing the forest, eradicating malaria, and distributing land to settlers from the higher Himalayas. Approximately one-third of the original forest was preserved as Chitwan National Park, which remains home to several endangered species today. Our study examines land use patterns in a 92 square mile area of Western Chitwan that was cleared and settled (see Figure 1).

Figure 1 Map of Study Area : Chitwan Valley



Rich soils, flat terrain, and the promise of new opportunities drew many farmers into the area, but the valley remained a remote, isolated frontier until the late 1970s. The first all weather road into Chitwan was completed by 1979. This road linked Chitwan's largest town, Narayanghat, to the eastern portion of Nepal's East-West highway and, therefore, to cities in Eastern Nepal and India. Two other important roads followed. One west, linking Narayanghat to the western portion of Nepal's East-West highway. Another north, linking Narayanghat to Kathmandu, Nepal's capital city. Because of Narayanghat's central location, by the mid-1980s this once isolated town was transformed into the transportation hub of the country. This change produced a rapid proliferation of government services, business, and wage labor jobs in Narayanghat that spread through Chitwan in inverse proportion to distance from Narayanghat (Pokharel and Shivakoti 1986). These changes also continued to stimulate the government's investments in agriculture in the region, including heavy investments in irrigation, mechanization, improved seeds, pesticides, fertilizer, and new methods of production and marketing (Shivakoti and Pokharel 1989). The population of this valley continued to grow as well, with both in-migration and natural increase making significant contributions to this growth (His Majesty's Government 1987; Tuladhar 1989).

Together these forces dramatically altered the social and economic organization of Chitwan within the lifetimes of its residents. Bus service through the valley has given residents access to the wage labor opportunities and commerce of Narayanghat. Commercial enterprises, such as grain mills and new retail outlets, have scattered throughout Chitwan. A wide range of government services, from schools, to health posts, to police posts, have also sprung up. These changes constitute a significant transformation of the local context for the hundreds of small farming communities in Western Chitwan Valley.

Land use is a fundamental measure of how the environment is organized in this setting. Changes in land use are reflected in the relative magnitude of the land area devoted to agricultural and non-agricultural activities. The important categories of land use in this valley include land devoted to agriculture, land devoted to residences and other enterprises, and land devoted to public (common) forest and pasture. Over time, as the population has increased, the economy grown, and government infrastructure spread, land use in Chitwan has been transformed in many important ways, especially in the conversion of agricultural land to land for housing and other private (non-agricultural) enterprises and the reduction of public forest and grazing lands. Public lands are sometimes converted into land for agriculture, but more often converted directly into land for housing for the poor or new public services. This change is particularly important because public forest and grazing lands are a critical resource for farmers. Virtually every farmer in Chitwan has several animals (Axinn and Axinn 1983) and these common lands constitute the main source of fodder for farmers' animal herds. The conversion of common lands represents the degradation of the region's vegetative resources, which, over time, is also likely to have many negative consequences for the undomesticated populations of animals and birds which populate the region.

Data and Methods

The data to test our hypotheses come from a study of 138 neighborhoods scattered throughout Western Chitwan Valley.[1] For the purposes of this study a neighborhood was defined as a geographic cluster of five to fifteen households. These neighborhoods were chosen as an equal probability, systematic sample of neighborhoods in Western Chitwan and the characteristics of this sample closely resemble the characteristics of the entire Chitwan Valley (Barber, Shivakoti, Axinn, and Gajurel 1997). Boundaries of the land surrounding these neighborhoods bisect the areas between the selected neighborhoods and adjoining neighborhoods. This boundary procedure gives every unit of land in Chitwan one and only one chance of falling into our sample[2]. This procedure also means neighborhoods in more densely settled areas are characterized by smaller land areas than neighborhoods in more sparsely settled areas. Therefore we always take total land area into account when constructing our measures of land use.

To evaluate the influence of social organization and population on land use we focus our analyses at the neighborhood level. However, as a supplement to those neighborhood level analyses we also investigate household level relationships among social organization, population, and land use. Below we describe our measures and analytic strategy for the neighborhood level analyses in detail. Measures and methods for the household level analyses are described briefly when we turn to that investigation in our discussion of results.

Measures of Land Use

A team of field workers physically mapped every square foot of the land area of each neighborhood using compasses and tape measures. These measurements were computerized and used to calculate the land area of each neighborhood, by land use type. The neighborhoods themselves range from 46,762 square feet to 3,223,438 square feet, with a mean of 819,403.11 square feet and a standard deviation of 663,058.61 square feet. These measures were collected in exactly the same way, following exactly the same boundaries at two points in time - first in 1996 and then again in 2000. These two measurements, four years apart, provide longitudinal measures of change over time in land use at the local level.

This hands-on measurement strategy identified 17 distinct categories of land use. We combine these detailed categories into two broad groups: land covered by vegetation and land that is not covered by vegetation. Much of the research on land cover and land use relies on remotely sensed measures of land cover (Liverman, Moran, Rindfuss and Stern 1998; Fox, Rindfuss, Walsh and Mishra 2003). These broad categories of land covered by vegetation or not covered by vegetation are easily distinguished in remote

[1] Because our analysis focuses on changes in land use we eliminate ten neighborhoods entirely covered by buildings (no possible change in land use) and three neighborhoods completely flooded by rivers (no land use as a result of natural disasters). Thus we limited our analysis to land use change in 138 neighborhoods.

sensing images. Thus, our grouping of more detailed land cover categories into these two broad groups provides a measurement directly analogous to measurements easily available from remote sensing images.

We then further subdivide these broad groupings into more detailed categories of land use, based on the direct measurement of specific uses. We divide land covered by vegetation into agricultural uses and non-agricultural uses (top half of Table 1). Land used for agricultural includes irrigated low-land, unirrigated low-land, and up-land. Non-agricultural vegetation include private grass lands, public grass lands, private plantations and public plantations. We divide land that is not covered by vegetation into private buildings, public infrastructure, and other uses (bottom half of Table 1). This division is motivated by previous research that suggests contextual factors may have a particularly strong influence on land use through building of public infrastructure. Land used for private buildings includes the land area used for residential purposes, mills and other private businesses. Land under public infrastructure includes land used for schools, temples, roads and canals. Other uses includes land area under ponds, silted river banks, and public resting place. The first column of Table 1 displays the percentage of land area in each of these uses in 1996. The second column of Table 1 displays the percentage of land area in each of these uses in 2000.

The results presented in Table 1 clearly indicate that most land in Chitwan is devoted to agricultural uses. The same results also demonstrate that there is relatively little change in land use over the brief period from 1996 to 2000. There is a small and statistically insignificant drop in the percentage of land devoted to agricultural uses over this brief interval. However, there is a somewhat larger, and statistically significant, decline in land area devoted to non-agricultural vegetation over the same four years. The neighborhoods of Chitwan also experienced modest, but statistically significant growth in the fraction of land devoted to private buildings and public infrastructure during this brief four year interval. Note that in this part of the Himalayan watershed floods and changing river pathways that move land out of other uses and into river beds are quite common.

Although these changes in land use between 1996 and 2000 are modest, the small magnitude of these changes makes it that much more remarkable that population changes significantly alter land use over this brief period. We will demonstrate these important relationships to population parameters first by examining the broad categories of land covered by vegetation or not covered by vegetation and then by exploring change in the more detailed sub-categories presented in Table 1. Before turning to those analyses, we first describe the other measures that will ultimately be used in our multivariate models.

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[2] Note, however, that our sampling procedures produce a sample of the population of Western Chitwan and the land associated with the population sample. Our procedures are not designed to produce a representative sample of the land in Western Chitwan.

Table 1. Land use Over Time by Five Categories of Land (Fixed Land Area, N=138)

Land Use	1996		2000	
Flora				
Agricultural land	71. 88		71. 98	
Non-agricultural land	5. 81		3. 82	
Total Flora		77. 69		75. 80***
Non-flora				
Private building	12. 44		13. 83	
Public infrastructure	9. 74		10. 30	
Other uses	0. 13		0. 07	
Total Non-flora		22. 31		24. 20***
	100%		100%	

* $p < 0.05$ ** $P < 0.01$ *** $P < 0.001$ *Statistical significance of 1996 -2000 difference*

Measures of Population Change

Measures of population change come from prospective monthly demographic survey. Beginning 1996 key demographic events - migration, living arrangements, marriage, birth, death, and contraceptive use - were recorded monthly for every household in these 138 neighborhoods. Information collected during the 1996 to 2000 period are used to calculate the measures of population change between the measures of land use. As we explained above, change in number of people and in number of households may influence the proportion of land devoted to specific purposes differently. Our measures of change in number of people and number of households is the difference in number when demographic monitoring began in 1996 and the number at the beginning 2000, just before the 2000 measures of land use were collected.

Similarly, population age structure and fertility may have differential impacts on land use. We use the average birth rate as our measure of fertility. This measure is calculated by dividing the total number of births in a neighborhood during 1996 to 2000 by the average number of people in the neighborhood during the same period. We use the proportion of the neighborhood population under age 15 as our measure of the neighborhood age structure. This measure is constructed by dividing the number of people in the neighborhood aged 0-15 by the total number of people in the neighborhood, both in the year 2000. Higher proportions under age 15 indicate younger age structures. Descriptive statistics for each of these measures of population change are presented in Table 2.

Table 2. Descriptive Statistics of Variables Used in the Analyses of Land use (N=138)

Variables	Mean	SD.	Min.	Max.
Population Change 1996-2000				
Change in number of persons	2. 63	9. 86	-23	61. 00
Change in number of households	0. 68	2. 31	-4. 00	11. 00
Percent of people under age 15 (in 2000)	37. 30	7. 26	17. 50	55. 56
Crude birth rate (per 1000)	72. 61	44. 85	0. 00	202. 60
Community Context (in 1996)				
Average number of years non-family services within 30 minutes walk [a]	25. 21	7. 90	4. 00	41. 60
Other Controls (in 1996)				
Electrification (1= yes)	0. 37	0. 48	0. 00	1. 00
Proportion of households owned house plot	0. 65	0. 19	0. 0	1. 00
Proportion of households who rented out land	0. 11	0. 13	0. 00	0. 67
Proportion of households who owned any land	0. 61	0. 21	0. 08	1. 00
Total area in 100,000 square feet	819403. 11	663058. 61	46762	3223438

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

Measures of Local Social Organization

We use community access to new organizations and services that provide social connections outside of the family to operationalize measures of local social organization. This is the same strategy used in the most recent empirical research on community effects on fertility behavior (Axinn and Barber 2001; Axinn and Yabiku 2001) and consumption behavior (Axinn, Barber, and Biddlecom 2007). This strategy is also consistent with key findings from work on community effects on migration and mortality (Massey and Espinoza 1997; Sastry 1996). Our measures of community access to these organizations and services were gathered using the Neighborhood History Calendar (NHC) method. The specific techniques involved in this method are described in detail elsewhere, so we do not repeat those here (Axinn, Barber, and Ghimire 1997). The measure of proximity we use is the number of minutes neighborhood residents report they must walk to reach each of the services in question. We focus on five specific non-family organizations and services: schools, health services, bus services, employment center and market place. These NHC measures provide the travel times from homes in each of our 138 neighborhoods for each year in Chitwan's 50 year history of settlement. Although the NHC measures provide the flexibility to code many different types of variables, in order to capture each neighborhood's cumulative exposure to these non-family services we coded the number of years the neighborhood had each service within a 30 minute walk[3]. We then average the number of years across the five different services we examine. The final average number of years with services within a 30 minute walk is then included in multivariate models as our measure of community context. In these analyses we explore the impact of average number of years a neighborhood has schools, health services, bus services, employment center and market place within 30 minutes of walk on variations in land use. Descriptive statistics for this measure of community context are presented in Table 2.

Controls

The unique strength of our study is the longitudinal panel data for both our population measures and our land use measures. In addition to the population measures we also control for number of other factors that are likely to affect population change, land use or the relationship between the two. Those controls include electrification (technology), neighborhood size in terms of total land area, land use at the beginning of the period, and average neighborhood affluence. Our measure of electrification comes from the information we collected using NHC methods. If the neighborhood has electricity, we coded this measure as 1, otherwise we coded this measure 0. The size of neighborhood land area comes directly from the land use survey done in 1996. Here the area is reported in 100,000 square feet. Our measures of land use in 1996 are calculated in exactly the same way, following exactly the same neighborhood boundaries, as our measures of land use for 2000.

Because of much of the Nepalese economy is not monetized and the vast majority of households are primarily engaged in agriculture, our measures of affluence focus on home ownership and key inputs into agricultural production. Our measures of neighborhood affluence are constructed from the responses to household interviews conducted in 1996. In that interview a series of question were asked about different sources of household affluence, including whether the household owned the house plot or not, rented out any farm land or not, and owned any farm land or not. These measures are each coded as a dichotomy (1, 0). To create the neighborhood level measures we summed the household level measures and divided by the total number of households in that neighborhood. Descriptive statistics for the measures of electrification, affluence, and total land area also presented in Table 2.

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[3] Because the choice of a specific cut off value is arbitrary, we conducted extensive analyses of the sensitivity of estimates to the choice of this cut off. Although smaller cut off values create somewhat larger estimates of community effects, the conclusions based on these estimates are not altered by changing the length of the cut off. We also estimated models using several different measures of community access to services, including the average number of minutes to the nearest services in 1996 and the average number of services within a five minute walk in 1996. These alternatives also yield results similar to those presented here.

Analytic Strategy

We begin with simple models of change in land use using ordinary least squares regression. Models treat a 2000 measure of land use as the dependent variable while controlling for the same measure from 1996 in order to focus on change in land use. Our controls and measures of local social organization all come from 1996 and reflect the situation up to that time. Our measures of population change all reflect change during the period from 1996 to 2000.

In order to demonstrate the importance of longitudinal measurement of land use change, we begin by estimating an even more simple model that ignores land use measures from 1996. These models estimate the impact of population change and local social organization on land use in 2000 without controlling for land use in 1996. Because Chitwan was entirely covered by forest land prior to 1950, these models of variation in land use in 2000 provide insight into the factors correlated with land use change between 1950 and 2000.

These models are helpful for evaluating the overall impact of some factors on land use outcomes in 2000. A key example is the impact of local social organization. Models ignoring 1996 land use reveal the overall relationship between change in local social orgnaization (again Chitwan had none of the nonfamily organizations and services being measured prior to 1950) and change in land use. Once land use in 1996 is controlled, models only estimate the impact of local social organization in 1996 on land use *change* between 1996 and 2000.

Thus, to identify each of the important determinants of land use and to demonstrate the influence of alternative modeling strategies on results, we begin by estimating multivariate models of four dimensions of population change predicting the fraction of land covered by vegetation in 2000 without controlling for land cover in 1996. We then add out measure of community context to these models. Next we add controls for land cover in 1996. Comparisons across these three different types of models reveal much different relationships between population change and land use. Finally we turn to multivariate models of change in more detailed categories of land use to better understand the processes producing the relationship documented in previous models. Because the dependent variables in each of these models is expressed as a percentage, all multivariate models are estimated using Ordinary Least Squares regression.

RESULTS

Our investigation explicitly draws on the four specific research tools outlined in the introduction to this paper: longitudinal research design, multilevel research design, decomposition, and mixed method measurement. We begin by analyzing a community level measure of land use at a single point in time with a model that combines geographic measures of land use, ethnographic measures of community context, and survey measures of household characteristics, aggregated to the community level. These analyses focus on the percentage of land area covered by any vegetation in 2000. Table 3 presents the results from models estimating the relationship of the four population measures and our measures of community context on the percentage of land devoted to flora. The effect of each specific population measure is estimated in an independent model. In these models growing numbers of people, growing numbers of households, and younger age structures each reduce the percentage of land devoted to flora; however, only the change in the number of people is statistically significant at the $p<.05$ level.[4]

Our measure of community context has a strong and statistically significant negative effect on land area devoted to flora. Neighborhoods characterized by having more non-family services and organizations nearby for longer periods of time also experience a greater reduction in land area devoted to vegetation between 1950 and 2000 (not shown in tables). This result is not surprising because many of these new organizations and services may be located on land that was formerly covered by vegetation (Shivakoti et al. 1999). Likewise, these organizations and services also promote the construction of residences and businesses, thereby contributing to the conversion of land out of vegetation (Shivakoti et al. 1999). This measure of community context is important because other research indicates that these same dimensions of community context may have an important effects on fertility, mortality and migration (Axinn and Yabiku 2001; Massey and Espinoza 1997; Sastry 1996).

In these same models, electrification has a negative but not statistically significant relationship to the fraction of land devoted to flora. Neighborhood affluence also has a statistically significant impact on this dimension of land use. As one might expect, the proportion of households in the neighborhood who own some land is associated with a higher percent of land area devoted to flora. This is consistent with the hypothesis that more permanent assets (owned land) encourage land area devoted to flora. The total land area also has a strong positive impact on the fraction of land covered by flora. In this relatively rural agrarian setting it is not at all surprising that larger neighborhoods have a higher fraction of their land covered by flora, at least when 1996 land use is not controlled in the model.

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[4] Note that some may argue population size should be operationalized as static numbers of people or numbers of households rather than the change between 1996 and 2000. We also tested models using this specification to measure population size. The total number of households in 1996 has a significant negative effect on the percentage of land devoted to flora. Once 1996 land use patterns are controlled (as in Table 4 and all models

Table 3. OLS Regression Estimates of Neighborhood Level Models Predicting Percent of Land Area under Flora in 2000

Population change (1996-2000)				
Change in number of people	-0. 20* (1. 71)			
Change in number of households		-0. 56 (1. 06)		
Percent of people under 15 years of age (in 2000)			-0. 20 (1. 18)	
Crude birth rate				0. 01 (0. 32)
Community context (in 1996)				
Average number of years non-family services within 30 minutes walk~	-0. 37* (2. 08)	-0. 37* (2. 06)	-0. 40* (2. 27)	-0. 37* (2. 10)
Other controls (in 1996)				
Electrification	-1. 92 (0. 69)	-1. 88 (0. 67)	-2. 17 (0. 77)	-1. 81 (0. 64)
Proportion of households owned house plot	- 0. 53 (0. 06)	- 1. 13 (0. 11)	1. 10 (0. 11)	1. 10 (0. 11)
Proportion of households who rented out land	-6. 46 (0. 71)	-6. 03 (0. 66)	-4. 31 (0. 47)	-4. 88 (0. 53)
Proportion of households who owned any land	28. 41*** (3. 08)	28. 93*** (3. 09)	27. 31*** (2. 94)	28. 15*** (3. 00)
Total area in 100,000 square feet	1. 13*** (6. 09)	1. 13*** (6. 04)	1. 08*** (5. 59)	1. 13*** (6. 01)
R^2 –Adjusted	0. 44	0. 43	0. 43	0. 42
N (neighborhoods)	138	138	138	138

Note: † *P*<.1, * *P*<.05, ** *P*<.01; all probabilities are one-tailed. OLS regression estimates are reported on the first line, with t statistics in the parentheses on second line. All models estimated using multivariate OLS regression.

Longitudinal Design

Longitudinal research designs are now common place in many other areas of Sociological research because of the great potential for reciprocal causal relationships among micro-level factors (Axinn and Pearce 2006; Campbell and Stanley 1967). Measurements of change over time help to adjudicate the

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thereafter) this association disappears. The total number of people had no significant impact on percentage of land devoted to vegetation in any of these models.

temporal ordering among associations. In this case, because of the potential for land use patterns to influence subsequent population parameters we use the longitudinal design to control pre-existing land use in each community. That is, this strategy focuse on *change* between 1996 and 2000 by adding a measure of the land area devoted to vegetation in these neighborhoods in 1996 to the model (Table 4). The addition of this measure produces a dramatic change in the interpretation of these results. Because the models focus on the percentage of land in vegetation in 2000, the addition of this control for land devoted to vegetation in 1996 transforms other measures in the model to *predictors of change* in land devoted to vegetation between 1996 and 2000. Moreover, because 1996 to 2000 is a relatively brief interval, the percentage of land in vegetation in 1996 explains a great deal of variation in land under vegetation in 2000 (see Table 4). Thus the effect of the control for land use in 1996 is quite large and resulting model explains approximately ninety percent of the variance in 2000 land use. The close correspondence between the 1996 measure of land use and the 2000 measure of land use dramatically reduces the effects of many other measures in the model, rendering them statistically insignificant. This is not surprising given that the other controls reflect 1996 conditions that are also reflected in 1996 land use patterns. However, the high stability in land use patterns between 1996 and 2000 serves to dramatize the fact that population changes during this brief interval *are* related to changes in land use patterns.

In models of change in land use between 1996 and 2000 the effects of change in numbers of people and households are near zero. In contrast, the effect of both age structure and birth rates are statistically significant and important. In fact, our new estimate of the effect of age structure indicates that younger age structures significantly reduce land area devoted to flora, which is consistent with findings from studies of deforestation in the Brazilian Amazon (Moran et al. 2003), in spite of the fact that the Brazilian transition in land use is from virgin forests to cultivation and this Nepalese transition in land use is from cultivation to a built environment. Higher birth rates between 1996 and 2000 also reduce the fraction of land devoted to vegetation between 1996 and 2000, and this negative effect of birth rates is statistically significant. Having new babies in the household is likely to encourage both consumption of vegetation and construction of new buildings in this agrarian setting. The result is less land area devoted to flora. Younger age structures have a similar effect, and the reasons may be similar. Because high birth rates produce younger age structures (Shryock and Siegal 1976), it is important to test the independence of these two effects. We turn to that analysis next.

Table 4. OLS Regression Estimates of Neighborhood Level Models Predicting Percent of Land Area under Flora in 2000

Population change (1996-2000)				
Change in number of people	-0. 06 (1. 11)			
Change in number of households		-0. 26 (1. 05)		
Percent of people under 15 years of age (in 2000)			- 0. 17* (2. 12)	
Crude birth rate				-0. 04** (3. 11)
Land use in 1996				
% Land area under Flora	0. 92** (21. 45)	0. 91** (21. 63)	0. 92** (21. 95)	0. 95** (22. 62)
Community context (in 1996)				
Average number of years non-family services within 30 minutes walk~	0. 02 (0. 30)	0. 03 (0. 34)	0. 001 (0. 01)	0. 02 (0. 26)
Other controls (in 1996)				
Electrification	-0. 74 (0. 57)	-0. 72 (0. 55)	-0. 95 (0. 74)	-1. 16 (0. 91)
Proportion of households owned house plot	4. 42 (0. 97)	3. 84 (0. 82)	4. 75 (1. 07)	6. 74 (1. 53)
Proportion of households who rented out land	3. 08 (0. 72)	3. 10 (0. 72)	4. 20 (0. 99)	2. 59 (0. 62)
Proportion of households who owned any land	3. 20 (0. 71)	3. 45 (0. 76)	2. 50 (0. 56)	0. 79 (0. 18)
Total area in 100,000 square feet	0. 21** (2. 13)	0. 20* (2. 10)	0. 16† (1. 62)	0. 16* (1. 71)
R^2 –Adjusted	0. 87	0. 87	0. 88	0. 88
N (neighborhoods)	138	138	138	138

Note: † *P*<.1, * *P*<.05, ** *P*<.01; all probabilities are one-tailed. OLS regression estimates are reported on the first line, with t statistics in the parentheses on second line. All models estimated using multivariate OLS regression.

Decomposing Land Use Change

The next step in our analysis is to decompose this model of land use change for different types of land uses to learn more about the factors producing this change in land devoted to flora. We begin by re-estimating our model of land area devoted to vegetation to test for the independence of the various population effects presented in Table 4. These new results are presented in the first column of Table 5.

The new estimates in the first column of Table 5 include our measures of numbers of households, age structure, and birth rates all in the same model.[5] Even with all three population parameters in the same model, the results are remarkably similar to those presented in Table 4. Both younger age structures and higher birth rates significantly reduce the fraction of land devoted to vegetation. Moreover, this combined model demonstrates that the influences of age structure and birth rates are independent of each other and independent of the number of households in the community.

Increasing the number of households on a fixed area of land undoubtedly alters land consumption patters to affect land use in the long run. We fail to observe this effect as statistically significant in the brief four year period examined here, but it is quite likely that such an effect will be observed over a longer period of investigation. That important non-result highlights the importance of the two statically significant and independent results observed over this brief four year period. Young age structures and high birth rates change household patterns of consuming land in a way that reduces the land devoted to vegetation and increases land devoted to buildings and infrastructure. As Moran and his colleagues argue for Brazil (2003), younger age structures increase the household supply of labor and change the nature of household consumption by creating a higher fraction of household members in a high consumption period of life. Likewise, we argue that childbearing per se is a demographic event likely to stimulate both higher consumption of vegetation and higher construction of household living space. Thus, on a fixed area of land both young age structures and high birth rates are likely to contribute to the transition of land out of vegetation and into built uses in a settled agrarian setting. And, these two important population effects on land use are independent of each other in spite of being positively related. Their independence from the number of households suggests that the construction-related effects of changes in age structure and birth rates take the form of additions to existing homes or construction of new businesses, *not* the construction of additional households.

In the next column of Table 5 we examine the fraction of land devoted to one specific type of vegetation – agriculture. Applying our model of population effects, we find that age structure and birth rates have significant negative effects on the fraction of land devoted to agriculture. So, the effects of age structure and birth rates on the fraction of land devoted to vegetation is mainly a consequence of conversion of land out of agriculture. This result is not surprising given that the vast majority of land covered by vegetation in this setting is in agricultural uses.

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[5] Note that the number of people and the number of household are highly colinear, so we do not include both measures in the same model. Alternative models using numbers of people instead of numbers of households yield the same results as those presented in Table 5.

Table 5. OLS Regression Estimates of Neighborhood-level Models Predicting Percent of Land Area in Each Use in 2000

Model	Flora (Agriculture and non-agriculture)	Agricultural Land	Private Buildings	Public infrastructure
Population Change (1996-2000)				
Change in number of households	-0. 17 (0. 71)	-0. 28 (0. 85)	0. 23 (0. 92)	-0. 03 (0. 26)
Percent of people under 15 years of age (in 2000)	-0. 15* (1. 89)	-0. 19* (1. 85)	0. 18** (2 31)	-0. 06 (1. 45)
Crude birth rate	-0. 03** (2. 74)	-0. 03* (1. 69)	0. 03* (2. 10)	0. 01 (1. 64)
Land Use in 1996				
% Land area in the same use in 1996	0. 94** (22. 56)	0. 73** (15. 68)	1. 002** (17. 47)	0. 92** (27. 33)
Community Context (in 1996)				
Average number of years non-family services within 30 minutes walk	0. 03 (0. 03)	-0. 06 (0. 55)	0. 02 (0. 26)	-0. 05 (1. 21)
Other Controls (in 1996)				
Electrification	- 1. 29 (1. 02)	-1. 15 (0. 66)	0. 51 (0. 39)	0. 65 (1. 22)
Proportion of households owned house plot	5. 50 (1. 21)	3. 91 (0. 63)	2. 63 (0. 56)	-8. 75 (3. 96)
Proportion of households who rented out land	2. 99 (0. 72)	-2. 35 (0. 42)	-4. 11 (0. 96)	1. 27 (0. 63)
Proportion of households who owned any land	1. 07 (0. 24)	5. 94 (1. 01)	-7. 31 (1. 62)	7. 01 (3. 34)
Total area in 100,000 square feet	0. 13 (1. 38)	0. 26 (2. 00)	0. 01 (0. 10)	-0. 08 (2. 00)
R^2 –Adjusted	0. 88	0. 80	0. 81	0. 87
N	138	138	138	138

Note: † *P*<.1, * *P*<.05, ** *P*<.01; all probabilities are one-tailed. OLS regression estimates are reported on the first line, with t statistics in the parentheses on second line. All models estimated using multivariate OLS regression.

In the final two columns of Table 5 we examine two types of land that are *not* covered in vegetation – land covered in private buildings (residences and other businesses) and land covered in public infrastructure. Private buildings and public infrastructure each represent a similar fraction of the built environment in this setting. Again, applying our model of population effects we find that younger age structures and higher birth rates significantly increase the fraction of land covered in private buildings, but not the fraction of land devoted to public infrastructure. Indeed, younger age structure slightly reduces the land area devoted to public infrastructure. Thus even in this relatively brief period, age structure and birth rates substantially increase land devoted to private buildings at the expense of land devoted to flora.

This decomposition of land use provides insight into the mechanisms linking population change to land use change that are not likely to be available from remote sensing images. Although the ability of remote sensing to detect and measure land cover is extremely advanced (Liverman, Moran, Rindfuss and Stern 1998), remote sensing can tell us little about the ownership and uses of the buildings replacing vegetation in settled agrarian settings such as this valley in Nepal. Clearly however, population change may affect the construction of some types of buildings more closely than others, and these specific types of buildings may be responsible for the overall effect of population change on land area devoted to flora. In this setting, the construction of private buildings appears to be a key link between population parameters and land area devoted to flora.

Social Organization, Population, and Common Land Use at the Household Level

Finally, we take advantage of the multilevel research design and mixed method data collection embedded in this longitudinal study to investigate the household-level dynamics corresponding to these community-level findings. To do this we investigate the use of common land by the households in these communities. This analysis is confined to the 1007 households who owned at least one animal in both 1996 and 2000. Among these households we examine the use of common land for grazing or collection of fodder in 1996 and 2000. Our models treat common land use in 2000 as the outcome of interest and control for common land use in 1996, therefore modeling household level <u>change</u> in common land use between 1996 and 2000. We construct a series of household-level measures of social organization, population, and controls analogous to the community-level measures used in our preview analyses. These household-level measures are explained in detail in Appendix A. The presentation of results in Table 6 focuses on population influences, though the estimates come from models that include 1996 measures of common land use, community context, affluence, electrification and ethnicity.

Table 6. Household Level Flora Consumption: Odd Multiplier Coefficients from Logistic Regression Estimates of Common Land use in 2000 (Asymptotic z-ratios in parentheses)

Population measures	
Number of people (1996)	0.93 (1.56)
Change in number of people in household	0.86 (2.70)
Percent of people under 15 years of age (in 2000)	1.01** (2.95)
Crude birth rate	1.53** (2.82)
Community context (in 1996)	
Average number of years non-family services within 30 minutes walk	0.20** (3.20)
Common land use (in 1996)	
Percent Household used common land (1996)	8.41** (11.81)
Other household controls (in 1996)	
Electrification	1.42 (1.65)
Owns house plot	0.92 (0.21)
Renting out land	0.70 (1.30)
Owns farm land	1.04 (0.10)
Household ethnicity (High caste Hindu as reference group)	
Lower caste Hindu	1.75 (1.79)
Newar	1.15 (0.31)
Terai Tibeto-Burmese	1.26 (0.90)
Hill Tibeto-Burmese	1.56 (1.70)
-2 Log Likelihood	815
N (Households)	1012

Investigation of household-level changes in common land use reveals results that add insight into our community level results. A younger household age structure and more births in the household each significantly increase the use of common land for grazing animals and collecting fodder between 1996 and 2000 (see Table 6). Moreover these effects are independent of each other. This finding reveals an important mechanism through which younger age structures and higher birth rates shape land use. In this setting younger age structures and higher birth rates intensify use of common land to support animal husbandry. This household-level dynamic contributes to vegetation consumption at the neighborhood level. Higher vegetation consumption in neighborhoods with young age structures and high birth rates help to reduce the fraction of land devoted to vegetation over time.

Note that, as expected, in this household-level model of common land use access to more nonfamily organizations and services in the local community significantly reduce the likelihood of using common land. Contextual changes that promote social organization outside the family also promote indirect consumption of resources from distant land areas and reduce direct consumption of resources from nearby land (Axinn, Barber and Biddlecom 2007; Foster 1999). As a result, greater nonfamily organization reduces use of local common land for grazing and fodder collection, even among those who continue to own animals. This same dimension of community context reduces land devoted to vegetation (see Table 3), but clearly not because of its influence on common land use. This interesting result provides evidence that community context influences land use in opposing directions via alternative proximate determinants.

The effects of age structure and birth rates, however, are independent of these consequences of community context, and independent of the other factors included in our model. New babies and young children in the household drive up the demand for milk, eggs, and meat in rural households in Chitwan. Increasing household consumption of these animal products increases demand for fodder from nearby common land areas. The results of our previous analysis decomposing land use at the community level were consistent with construction mechanisms affecting land use. The results of this household level analysis are consistent with fodder consumption mechanisms affecting land use. By taking advantage of the longitudinal measurements at both community and household levels we provide evidence that both key proximate determinants of land use are likely to connect young age structures and high birth rates to changes over time in land use.

CONCLUSION

Research on social influences on environmental quality has begun an important transition toward more micro-level studies (Fox et al. 2003; NRC 2005). This transition opens many new arenas for the application of social science theory to the advancement of environmental research. Just as at the macro-level, patterns of consumption and production remain essential mechanisms linking humans to their environment in micro-level research. But micro-level investigation of these mechanisms demands broader use of theoretical tools from the social sciences. At the micro-level, economics continues to provide leadership in our understanding of the links among wealth, consumption, and the environment (Foster 2005). Sociology, however, has great potential to advance our theoretical understanding of the links among social organization, social actions, consumption, and the environment (Foster 1999). We illustrate this potential with the case study of Nepal reported above.

Following reasoning commonly applied in other areas of Sociology, we construct a theoretical framework for micro-level studies of land use from a sociological perspective. This framework begins by identifying a specific land use transition – from settled subsistence agriculture to buildings and infrastructure – in order to construct context and outcome specific hypotheses regarding micro-level associations. Next the framework identifies consumption patterns as key proximate determinants of this transition through which social organization and population influence local land uses. The framework highlights the social organization of human groups, in addition to the simple size and affluence of those groups, and identifies dimensions of social organization likely to produce a key transition in consumption behavior, from consumption of the products of nearby land to the consumption of products of far away land. The framework then considers population effects, moving beyond simple conceptualizations of the population size to population parameters likely to shape the nature of local consumption patterns. The framework explicitly links social organization to population parameters because of known associations between social organization and key population parameters. Finally, the framework includes explicit consideration of reciprocal causation, in which land uses at an early time point may influence the same dimensions of population change we also believe shape land use at a later time. Although this framework is explicitly designed to understand the transition from settled, subsistence agricultural land use toward land use for buildings and infrastructure, many of the key principles of this framework are applicable to the more general study of social organization, population, and land use dynamics.

The empirical evidence we present is consistent with the key dimensions of this framework. Perhaps most interesting and important is the conclusion that multiple dimensions of population change affect land use. Our analyses focus on a broad transition in land use and a very narrow window of time, from 1996 to 2000. Nevertheless, our results demonstrate that both young age structures and high birth rates significantly accelerate the conversion of land out of vegetation cover and into buildings and infrastructure in an agricultural setting. Moreover, the effects of age structure and birth rates are independent of each other, and independent of changes in the total number of households on these fixed land areas.

We argue that young age structure and high birth rates alter the nature of consumption patterns, in particular increasing the construction of private residences and private businesses. By decomposing land uses into more detailed categories, available from direct physical inspection of the land, we provide evidence that is consistent with this argument. We also use longitudinal data at the household level to show that young age structures and high birth rates increase the use of common land to graze animals and collect fodder. This increasing consumption of vegetation is also likely to contribute to land use changes away from land covered by flora. Thus our analyses point toward both vegetation consumption and building construction as mechanisms linking population parameters to land use.

These results highlight the importance of consumption behavior as a link among social organization, population and land use, as well as the utility of considering multiple dimensions of population change. New research focusing on the specific links between population parameters and household consumption behavior will undoubtedly advance our understanding of these complex processes. Clearly such research will profit by considering multiple dimensions of population change, including parameters such as age structure and birth rates along with more commonly studied factors such as numbers of people and numbers of households. In fact, in rural agrarian settings similar to the Nepalese site studied here, the effects of age structure and birth rates may be more important than the effects of sheer numbers of people and numbers of households. Although this result may strike some as surprising, it is consistent with the hypothesis that the nature of land consumption may have as much effect on land use and land cover as the sheer volume of consumption, at least within some volume thresholds.

The results we present also demonstrate that model specification does matter, and changes in model specification can produce substantial differences in substantive conclusions about the relationships between population change and land use change. As predicted, taking full advantage of the longitudinal measurement to specify precise models of land use change alters our results in important ways. Although all of Chitwan was covered by vegetation in 1950, so that models of the percent of land covered by vegetation in 2000 reflect change between 1950 and 2000, failure to control for more recent land use patterns produces much different conclusions about the effects of recent local population changes. Without controlling for land use in 1996, our models of land use in 2000 demonstrate little effect of population parameters pertaining to the 1996-2000 period. However, once land use in 1996 is added to these models as a control, we find strong evidence that 1996-2000 population parameters do affect land use *change* over the same period. Time one land use, and other unobserved factors associated with time one land use, undoubtedly affect subsequent population change. Without controlling for this important source of reciprocal causation, models of time two land use that do not control land use at time one may produce misleading results. This finding points to the high priority for detailed longitudinal measurement of land use change in investigations of the relationship between population and land use change.

So, even as the transition toward micro-level of investigation of the human-environment connections prompts broader use of social science theory, it also motivates use of a broader set of social science methodological tools. In the case study we report we use longitudinal design, multilevel design, decomposition, and mixed-method measurement. The combination of these tools yields important insights into the processes linking population change to land use pattern, but it the result is a beginning point for such investigations, *not* the final product. In this relatively young field, a great deal more research is needed to arrive at conclusive models of these connections. We argue that the theoretical and methodological tools highlighted here will prove at least useful, and at most essential, in this long term endeavor.

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Appendix A

Description of Measures Used in the Household Level Analyses of Common Land Use

Household use of common land

In our household level analyses we model the use of common land for grazing or collecting fodder for animals in 2000, controlling for common land use in 1996. Our measures of common land use come from responses to a series of question in the household survey, first conducted in 1996 and repeated in 2000. The responses to the survey questions were coded as 1 if the household used common land either for grazing animals or for collection fodder and 0 other wise. Thus, this analyses is confined to 1007 households from the same 138 neighborhoods who have animals both in 1996 and 2000. Because our outcome of interest here is whether or not a household used common land or not we used logistic regression to model the impact of household level population change on use of common land, controlling for other household and community level characteristics.

Population measures

Our measures of population change come from prospective monthly demographic survey. Beginning 1996 key demographic events - migration, living arrangements, marriage, birth, death, and contraceptive use - were recorded monthly for every household in these 138 neighborhoods. Information collected during the 1996 to 2000 period are used to calculate the measures of population change between the measures of land use. As we explained above, the number of people in a household come from the monthly household registry of households in the 138 neighborhood at the beginning, change in number of people and number of households is the difference in number when demographic monitoring began in 1996 and the number at the beginning 2000, just before the 2000 measures of land use were collected.

Similarly, population age structure and birth rate also come from the household registry. Birth rate is calculated by dividing the total number of births in a household during 1996 to 2000 by the average number of people in the household during the same period. We use the proportion of the household member under age 15 as our measure of the household age structure. This measure is constructed by dividing the number of household members aged 0-15 by the total number of household members in the household, both in the year 2000. Higher proportions under age 15 indicate younger age structures. Descriptive statistics for each of these measures of population change are presented in Table below.

Wealth

Because of much of the Nepalese economy is not monetized and the vast majority of households are primarily engaged in agriculture, our measures of wealth focus on home ownership and key inputs into agricultural production. Our measures of household wealth are constructed from the responses to household interviews conducted in 1996. In that interview a series of question were asked about different sources of household wealth, including whether the household owned the house plot or not, rented out any farm land or not, and owned any farm land or not. These measures are coded as a dichotomy (1, 0).

Household Ethnicity

Previous research in Chitwan also suggests a strong association between household ethnicity and occupation and land use. Nepalese society consists of many ethnic and linguistic subgroups (Bista 1972; Dahal 1993; Gurung 1980, 1998). Although ethnicity in Nepal is complex, scholars have often categorized ethnicity into five major groups for analytical purposes: High Caste Hindus, Low Caste Hindus, Newar, Hill Tibeto-burmese, and Terai Tibeto-burmese (Axinn and Yabiku 2001; Blaikie et al. 1980;). We have adopted these categories for this analysis. For more information about these ethnic groups see Bista (1972), Gurung (1980), and Fricke (1988). We coded individuals "1" if they are members of a specific category and "0" if not, using High Caste Hindus as a reference group for comparison.

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