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Social Organization, Population, and Land Use*

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Abstract

We present a new approach to the investigation of human influences on environmental change that explicitly adds consideration of social organization. This approach identifies social organization as an influence on the environment that is independent of population size, affluence, and technology. The framework we present also identifies population events, such as births, that are likely to influence environmental outcomes beyond the consequences of population size. The theoretical framework we construct explains that explicit attention to social organization is necessary for micro-level investigation of the population-environment relationship because social organization influences both. We use newly available longitudinal, multilevel, mixed-method measures of local land use changes, local population dynamics, and social organization from the Nepalese Himalayas to provide empirical tests of this new framework. These tests reveal that measures of change in social organization are strongly associated with measures of change in land use, and that the association is independent of common measures of population size, affluence, and technology. Also, local birth events shape local land use changes and key proximate determinants of land use change. Together the empirical results demonstrate key new scientific opportunities arising from the approach we present.

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 (Foster 1999; Stern, Dietz, Ruttan, Socolow and Sweeney 1997; York, Rosa, and Dietz 2002)¹. The central objective of this paper is to identify the areas in which sociological theories and methods are likely to produce 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 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 the

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¹In fact there is a substantial and growing sub-field of sociology devoted to studies of environmental issues (Bell 2008; Buttel 1996; Cohen 2006; Derksen and Gartrell 1993; Dickens 2004; Dunlap and Catton Jr 1979; Hawlwy 1984 and Irwin 2001).

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 the explicit consideration of reciprocal causation, in which an environmental outcome of interest may also influence the factors (such as population) that we believe shape that environmental outcome. The last principle 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 specific research tools to the study of the environment that are also now common 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, measures 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 the 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—such as moving land out of forest cover into agriculture or moving land out of agriculture 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 studies in focusing on micro-level relationships between 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 the use of land for buildings and infrastructure.

By applying the five principles of theoretical reasoning described above to the study of land use, we formulate a new framework for the study of this land use transition that goes beyond current approaches in two fundamental ways. Current reasoning focuses on population size, affluence, and technology as the key forces that shape land use (Cohen 1995; Hunter 2001; Stern et al. 1997). First, we argue that specific population events likely shape land use patterns independent of population size, affluence, and technology because the events themselves have important consequences for consumption behaviors. We focus on birth events as a fundamental example of this relationship, arguing that birth events alter the consumption behavior of parents, with important implications for land use in settled subsistence agricultural settings. Second, we argue that in addition to the forces shaping the sheer quantity of consumption, changes in social organization at the community level

promote changes in the nature of consumption, with potentially important consequences for land use patterns especially in a setting of settled subsistence agriculture. The integration of social organization into our theoretical and empirical models of environmental changes, such as land use, provides a more comprehensive picture of change over time. Because these same dimensions of social organization also influence population parameters, direct integration of social organization enhances our understanding of the relations between population parameters and environmental changes as well.

We use longitudinal, multilevel, mixed-method measures from the foothills of the 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 (Blaikie, Cameron and Seddon 1980; Blaike and Brookfield 1987; Eckholm 1976; Gurung 1998). 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. This paper demonstrates how these exceptionally rich measures can be used to provide direct description of relationships predicted by theoretical reasoning. The results offer valuable new insights into the local-level processes shaping land use change.

A Theoretical Model of Land Use Change

In many ways, understanding 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 these 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 population size, population affluence, and technology as the key factors combining to shape environmental quality (Cohen 1995; 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, population events, affluence, technology or social organization ultimately shape land use. Our framework gives explicit attention to the importance of social organization as a dimension independent of population, technology, or affluence, and to the potential of reciprocal influences of land use patterns on factors which also affect land use.

A 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 hypotheses 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; Gurung 1998; McCalla 1997; Miracle 1968; Pingali 1997; Pingali and Rosegrant 1995). The model we design for predicting land use 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). With this definition in mind, 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 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 the use of land 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: (1) consumption of plant life and (2) 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 that 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 that 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 effect 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. In other words, electrification is likely to increase the construction of buildings, thereby reducing the fraction of local land devoted to plant life, but 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.

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; Gurung 1998; 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 are 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, 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 (Entwistle 2001; Liu et al. 2005; Walsh et al. 2005). This result seems plausible because the number of household units may

drive the actual microlevel patterns of consumption more closely than the number of people. To the extent that households are the 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 number 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 marriage, fertility, mortality, and migration, may also affect consumption of vegetation and construction of buildings and infrastructure. Population events that increase consumption of vegetation and construction of buildings will change land use. We focus here on fertility, or birth events, as a particularly important example.

Independent of the number of people or number of households in a fixed area, childbearing events are likely to alter consumption practices in ways that change land use. First, 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. In such settings birth events typically increase demand for fuel wood and fodder, as new parents heat their homes with fuel wood more than they would otherwise, and feed their animals more in order to increase their supply of milk and meat. Fuel wood and fodder consumption are by far the largest volume consumption of nearby land cover by rural subsistence agricultural households (Axinn and Axinn 1983) and birth events are likely to increase both.

Likewise childbearing drives families and their neighbors to build public infrastructure nearby. The most universal examples are schools and health care. Even when these are both available elsewhere, birth events often increase the demand to have facilities nearby. Childbearing is also likely to motivate other kinds of infrastructure construction, including recreational facilities, religious centers, markets, employers, electrification, or water systems. In settings with existing infrastructure, childbearing may simply motivate residential moves to be closer to that infrastructure (McAuley and Nutty 1982). But in settings of very little infrastructure, residents are motivated to build new infrastructure and to build it nearby. 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 more births experience changes toward less land devoted to vegetation than communities with fewer births.

Second, even among those most motivated to preserve local resources, such as subsistence farmers, the immediate time and resource demands associated with a new baby are likely to reduce devotion to environmental conservation (Castro et al. 2009; Diekmann and Preisendorfer 1998). As an example, consider an analogy more common in rich industrialized settings such as the United States – cloth diapers. In the U.S. many environmentally-conscious parents-to-be make plans to use cloth diapers for their newborn because of their devotion to the conservation of natural resources. However, shortly after the birth event, the extraordinary demands of caring for the new baby lead many such parents to abandon this plan in favor of more expedient disposable diapers. The literature on parenthood demonstrates that parents are likely to hold more positive attitudes toward environmental conservation than nonparents (Dupont 2004; Hamilton 1985; Huastein and Hunecke 2007; Teal and Loomis 2000), but the immediate demands of caring for a new

infant are likely to produce behavioral choices less favorable to resource conservation. In a subsistence agricultural setting, these consumption consequences are most likely to affect the land cover of nearby land parcels.

Thus, in areas of existing rural settlement, beginning with land consumption patterns oriented toward subsistence agriculture, childbearing events 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 are likely to be independent of the effects of numbers of people or households as described above. Although high birth rates produce more people, and may also produce more households, if childbearing directly alters land consumption patterns to affect land use, empirical results should demonstrate an effect of birth events independent of any estimated effects of population size per se.

Other population events may also shape land consumption in ways that create independent influences on land use. Our objective is not to provide an exhaustive list. Rather we identify birth events as an important contrast to a typical approach to the influence of population on the environment. Our aim is to provide empirical tests of this simple, but multi-dimensional, model of population effects on changes in land use at the local community level. We argue that the results of these tests should motivate the investigation of a much broader range of population events.

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). Above, we add to this literature by arguing specific population events are also likely to shape the volume of consumption of environmental resources independent of population size or affluence. Clearly the total volume of consumption is an 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 the consideration of 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, and procreation along with production (Coleman 1990; Ogburn and Tibbitts 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). These concepts have received substantial attention in the recent social science literature on environmental change (Burkett 1999; Clark 2003; Clausen and Clark 2005; Dickens 2004; Fischer-Kowalski and Haberl 1988; Foster and Burkett 2000; Foster and Clark 2003; Moore 2000; Moore 2003; York, Rosa and Dietz 2003a, 2003b). Axinn, Barber and Biddlecom (2010) 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 2010).

Of course, many different nonfamily organizations and services may influence daily social life with consequences for consumption behavior (Axinn, Barber, and Biddlecom 2010). 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 2010; 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. The metabolic rift Marx describes is so powerful because it can influence human decision making across the full breadth of human behaviors so that these behaviors become less and less grounded in motivation to preserve and nurture the natural environment. In a subsistence agricultural setting this growing rift means less motivation to preserve agriculturally productive lands and more tolerance for behaviors that convert those lands out of agriculture into alternative uses such as buildings or roads. As social life becomes increasingly organized outside the family, subsistence agricultural households are less likely to 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 (such as affluence and population size).

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. 2010) 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 known to affect key population parameters (Axinn and Yabiku 2001; Massey and Espinoza 1997).

Thus, our understanding of the effects of population on local land use may be misleading 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.

Reciprocal Relationships between Population and Land Use

Finally, our micro-level investigation 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 (Blau 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 the environmental quality and perceptions about the local environment affect both subsequent migration behavior and subsequent fertility behavior (Biddlecom, Axinn and Barber 2005; Ghimire and Mohai 2005; Ghimire and Hoelter 2007; Ghimire and Axinn 2010; Massey, Axinn and Ghimire 2010). 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 mosquitoes, 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 (Conway and Shrestha 1981; Elder et al. 1976; Gurung 1998; Shrestha 1989, 1990). 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.

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, located in the northwest corner of the study area, 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, and 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, businesses, and wage labor jobs in Narayanghat that spread through Chitwan in inverse proportion to distance from Narayanghat (Müller-Böker 2001; Pokharel and Shivakoti 1986; Shrestha 1989, 1990). 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 (Conway and Shrestha 1981; Shivakoti and Pokharel 1989; Shrestha 1989.). The population of this valley continued to grow as well, with both immigration and natural increase making significant contributions to this growth (His Majesty's Government 1987; Tuladhar 1989; CBS 2002).

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, such as schools, health posts, and 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, as the economy has grown, and as government infrastructure has 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

agriculture, but more often converted directly into housing for the landless 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 136 neighborhoods scattered throughout Western Chitwan Valley¹. 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 sample². This procedure also means that 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 population and social organization 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 828,216.04 square feet and a standard deviation of 663,689.15 square feet. These measures were collected in exactly the same way, following exactly the same boundaries at two points in time: first in 1995 and then again in 2005. These two measurements, ten 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 sensing images. Thus, our grouping of more detailed land cover categories into these two broad groups

¹Because our analysis focuses on changes in land use we eliminate ten neighborhoods entirely covered by buildings (no possible change in land use) and five neighborhoods completely flooded by rivers (no land use as a result of natural disasters). Thus we limited our analysis to land use change in 136 neighborhoods.

²Note, 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.

provides a measurement directly analogous to measurements easily available from remote sensing images.

We also decompose these general land use categories into more specific categories to investigate potential mechanisms of change over time. Specifically, we divide land that is not covered by vegetation into private buildings, public infrastructure, and other uses. This division is motivated by previous research that suggests contextual factors may have a particularly strong influence on land use through the 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. The first column of Table 1 displays the percentage of land area in each of these uses in 1995, the second column displays the percentage of land area in each of these uses in 2005 and finally the third column presents results from a paired t-test of the significance of change between 1995 and 2005.

The results presented in Table 1 clearly indicate that most land in Chitwan is devoted to vegetation. The same results also demonstrate that there is relatively little change over time, but there is a statistically significant reduction in neighborhood land under vegetation over the period from 1995 to 2005. 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 ten year interval.

Although these changes in land use between 1995 and 2005 are modest, the small magnitude of these changes makes it much more remarkable that population changes significantly altered land use over this 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.

Measures of Population Change

Measures of population change come from a prospective monthly demographic survey. Between the measures of land use key demographic events—migration, living arrangements, marriage, birth, death, and contraceptive use—were recorded monthly for every household in these 136 neighborhoods. This information is used to calculate measures of population change between the measures of land use. Our measures of change in number of people and number of households is the difference in number just after the land use measure in 1995 and the number just before the 2005 measures of land use. We use the total number of births between the land use measures as our measure of childbearing events. Descriptive statistics for each of these measures of population change are presented in Table 2.

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 2010; Macht, Axinn and Ghimire 2007). This strategy is also consistent with key findings from work on community effects on migration and mortality (Massey and Espinoza 1997; Massey, Williams, Axinn and Ghimire 2010; 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 that neighborhood residents report they must walk to reach each of the services in question. We focus on six specific non-family organizations and services: schools, health services, bus services, employment centers, market places and agricultural co-operatives. The NHC measures provide the travel times from homes in each of our 136 neighborhoods for each year in Chitwan's 45-year history of settlement. Although the NHC measures provide the flexibility to code many different types of variables, in order to capture the change over time in each neighborhood's exposure to these non-family services we coded the mean number of minutes to walk to each of these services for 1950, 1995, and 2005³. We then use those measures to construct two different variables describing change over time. The first uses the difference between 1950 and 1995 to measure change in the average walking time over the 45 years *before* our first land use measure. The second uses the difference between 1995 and 2005 to measure change in the average walking time *between* our two land use measures. In 1950 all services were 12 hours or more in walking time from all neighborhoods in Chitwan, so the baseline for these comparisons is a minimum of 720 minutes average walking time in 1950. Larger numbers for the difference between 1950 and 1995 mean that mean walking times have dropped more, or services are more accessible than in neighborhoods with smaller differences between 1950 and 1995 (see Table 2 for the mean, standard deviation, minimum and maximum of this difference). Similarly, large numbers for the difference between 1995 and 2005 mean that services have grown more accessible between our two land use measures. Note that a key hypothesis is that greater access to these services increases conversion of land out of vegetation, so that we expect these specific measures to have a negative influence on land area devoted to vegetation.

Controls

The unique strength of our study is in the longitudinal panel data for our population measures, our measures of local social organization, and our land use measures. Because our main aim is to evaluate the influence of social organization and population parameters on land use independent from known consequences of affluence and technology, our multivariate models of land use include measures of affluence and technology. 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.

Because 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 household assets, ownership of key agricultural inputs, and income. Our measures of neighborhood affluence include three specific measures: wealth, income, and proportion of households that rented out land.

Our measures of wealth come from household interviews conducted at the beginning of the study in 1996. In that household interview a series of questions were asked about different sources of household wealth, including whether the household owned the house plot or not, owned any farm land or not, the number of farm animals owned, the number of pieces of farm and household equipment owned, and housing quality. We use these measures to construct an index summarizing household wealth. Because the scale of the response to each of the questions varies, we standardized the values in each of these domains into Z scores, with mean of 0 and standard deviation of 1, and summed them all to construct a composite

³Because we could choose many different variables to operationalize changes in access to nonfamily services, we conducted extensive analyses of the sensitivity of estimates to the choice of this variable. Although some alternatives create somewhat larger estimates of community effects, the conclusions based on these estimates are not altered by the choice of operationalization.

index of household wealth. This household level wealth index was then averaged to create a neighborhood-level measure of wealth.

The measure of income comes from responses to household interviews conducted in 2000. In that interview respondents were asked: Thinking about your total household income from all sources, including wages, salaries, pensions, income selling crops, animals, or goods, income from renting out house, land or equipment, business, income from gift or other payments, since (month) last year, would you say that the total income you received all sources was 50,000 rupees or less or more than 50,000 rupees?

Depending on the response (less or more) the respondent was then asked appropriate follow up questions to estimate their household income. The responses to these follow up questions resulted into eight income categories: (1) no income, (2) less than 10,000, (3) 10,000–25,000, (4) 25,001–50,000, (5) 50,001–100,000, (6) 100,001–250,000, 250,001–500,000 and (8) more than 5,000,000. These household income categories were then averaged to create the neighborhood-level income.

The third measure of affluence is the proportion of households that rented out any farm land. In the 1996 household interview, respondents were asked whether or not they rented out any farm land. These household-level yes/no responses were then summed across households to create the neighborhood level measure.

Finally, to adjust for heterogeneity in the land area being analyzed, we also control for the size of neighborhood land area comes directly from the land use survey done in 1995. Here the area is reported in 100,000 square feet. Measure of distance to Narayanghat is measured in miles. Descriptive statistics for the measures of electrification, affluence, distance to the city and total land area are also presented in Table 2.

Analytic Strategy

To be comprehensive in our investigation we use all the methodological tools described in the introduction. This approach leads us to divide our analysis into four steps. In step one we evaluate the extent of potential reciprocal relationship between land use and key population parameters. To do this we use previously published results estimating the effects of land use on key determinants of population size, including marriage, birth timing and migration. In step two we switch to our main objective – models of land use change – and begin with models of the percentage of land devoted to vegetation of any type. In step three we decompose land uses by type and investigate models of specific types of land uses to examine consequences of birth events for a key proximate determinant of this land use transition: the construction of buildings. Finally in step four we change the level of analysis to focus on households and household consumption practices to examine the extent to which birth events shape consumption of vegetation, the other key proximate determinant of this land use transition. Below we outline our specific analytic strategy for each of these steps.

Step One – Land use predicting population parameters—Though the main objective of our analysis is to assess the potential influence of social organization and population on changes in land use, we begin by investigating the potential for reciprocal relationships among these measures. That is, we investigate models of the influence of land use on subsequent population parameters. To accomplish this as parsimoniously as possible, rather than present new analyses we report from previously published work investigating these same population parameters. This strategy is possible because dozens of previous studies focusing on population outcomes using measures from this same longitudinal panel study of Chitwan Valley have already been completed. These previous studies include more than a half dozen articles on marriage (Barber 2004; Ghimire et al 2006; Hoelter, Axinn and

Ghimire 2004; Yabiku 2004, 2005, 2006a, 2006b), a dozen articles on fertility (Axinn and Barber 2001; Axinn and Yabiku 2001; Barber and Axinn 2004; Barber et al. 2000; Barber et al. 2002; Biddlecom, Axinn and Barber 2005; Brauner-Otto, Axinn and Ghimire 2007; Ghimire and Axinn 2006, 2010; Ghimire and Hoelter 2007; Ghimire and Mohai 2005; Maples, Murphy and Axinn 2002) and nearly a dozen articles on migration (Bhandari 2004; Bohra-Mishra and Massey 2009, 2010, Forthcoming; Massey, Axinn and Ghimire 2010; Massey et al. 2010; Piotroski 2010; Shrestha and Bhandari 2007; Williams 2009). The majority of this work is focused on estimating the consequences of community-level changes in access to non-family services and organizations on marriage, childbearing and migration. The results provide clear and comprehensive information about those relationships. Although less of this previous work investigates land use, previously published work includes documentation of the influence of land use on marriage, childbearing and migration, each within the context of a comprehensive model of other known determinants of these population processes. Thus results from these previous studies provide strong evidence regarding the potential for reciprocal influences of land use on population.

Step Two – Population and social organization predicting change in land use

—The next step of our analysis switches to neighborhood-level models of land use. These models borrow analytic strategy from the attitude-behavior literature – a domain of inquiry in which both theory and empirical evidence indicate reciprocal relationships are commonplace (Ajzen 1988). In that literature models of attitude change are most often estimated by treating attitudes measured at time 2 as the dependent variable, attitudes measured at time 1 as a key control variable, and measures of other events occurring between time 1 and time 2 as potential predictors of the change in attitudes between time 1 and time 2. Following that strategy, we will treat community-level measures of land use in 2005 as our dependent variable, community-level measures of land use in 1995 as a key control variable, and measures of population and social organization events occurring between 1995 and 2005 as potential predictors of land use change between 1995 and 2005. We begin with simple models of change in land use using ordinary least squares (OLS) regression.

Step Three – Decomposing land use types to investigate proximate determinants

—Next we turn to models of change in more detailed categories of land use to better understand the processes producing the relationship documented in previous models. Using the unique fieldwork-based measures of specific land use types these analyses allow us to distinguish among specific types of vegetation, such as crops versus community forest or grazing, and among specific types of buildings, such as private residences versus community infrastructure (schools, health posts, water systems, etc.). Thus these fieldwork-based measures provide a level of detail in land use that is not possible from remote-sensing—based land use measures (Fox et al. 2003). We exploit that detail to learn more about the relationships among social organization, birth events, and specific proximate determinants of land use, such as construction of buildings. Because the dependent variables in each of these models are expressed as a percentage, all models are estimated using OLS regression.

Step Four – Household-level investigation of consumption behavior—Finally, to investigate the other key proximate determinant of land use in this setting—consumption of vegetation—we switch to household level analyses of consumption behaviors. Here as an example we examine changes between 1996 and 2005 in the likelihood of using common land areas nearby the household for collection of fodder. Consumption of fodder from nearby land is the highest volume impact of these subsistence agricultural households on

land nearby in this setting (Axinn and Axinn 1983). Moreover, fodder consumption is closely tied to animal husbandry in this setting (Axinn and Axinn 1983) and birth events are quite likely to increase animal husbandry because of increased demand for meat and milk. Thus this household-level analysis provides an important window into the relationship between birth events and another important proximate determinant of land use, consumption of vegetation.

The analysis itself follows exactly the same strategy as our analyses of change over time in land use, though now at the household level. Household measures of common land use in 2005 are treated as our dependent variable, household measures of common land use in 1996 as a key control variable, and measures of population and social organization events occurring between 1996 and 2005 as potential predictors of common land use change between 1996 and 2005. Our measures of population events – changes in numbers of people and birth events – are both measured at the household level for this analysis, but the measures of social organization remain at the community level, just as in previous models. Thus, this portion of the analysis uses multilevel models with social organization at the community level predicting common land use at the household level. Because use of common land is treated as a dichotomy—coded 1 if it occurred and 0 if it did not—we use logistic regression to estimate these models, and adjust for the multilevel properties of the model.

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 reporting the consequences of community level measures of land use in 1995 for marriage, childbearing and migration after 1996. Both the longitudinal and the multilevel research design are needed to estimate these relationships. Once we have established the extent to which land use shapes population events, we move on to investigate the consequences of population events between 1996–2005 for changes in land use and the proximate determinants of land use.

Land use predicting population parameters

As described above, to document the potential for reciprocal causation in the population-environment relationship as parsimoniously as possible we report on previously published results that use these same data. This strategy is possible because dozens of previous studies focusing on population outcomes using measures from this same longitudinal panel study of Chitwan Valley have already been completed. For example, the strong effects of community-level change and variation in social organization on population outcomes are well-documented. The spread of new non-family services and organizations at the community level: (a) significantly reduces the hazard of marriage delaying marriage (Yabiku 2004, 2006); (b) significantly reduces the hazard of first births delaying the initiation of childbearing (Ghimire and Axinn Forthcoming; Ghimire and Hoelter 2007); (c) significantly increases the hazard of contraceptive use limiting childbearing (Axinn and Barber 2001; Axinn and Yabiku 2001; Barber and Axinn 2004; Barber, Pearce, Chaudary and Gurung 2002; Brauner-Otto, Axinn and Ghimire 2007); and (d) significantly reduces the hazard of out-migration keeping people in the local community (Bohra-Mishra and Massey 2009; Massey, Williams, Axinn and Ghimire 2010; Williams 2009). Together these results mean that in the specific setting we study and in the specific data we use the spread of non-family services and organizations shapes the population parameters which determine change in number of people, change in number of households and number of births. So, if these same changes in social organization also influence land use they likely condition the population-environment relationship in a fundamental way.

The published literature provides less documentation of environmental effects on these same population outcomes. But this literature does provide three specific results that show land use at one time can have strong, statistically significant consequences for key population parameters, even when controlling for the full array of factors known to shape those population parameters. First, Yabiku demonstrated in 2006 that higher fractions of land devoted to agriculture produced higher subsequent rates of marriage even controlling for other known predictors of marriage timing (Yabiku 2006). Second, Ghimire and Hoelter demonstrated in 2007 that higher fractions of land devoted to agriculture produced higher subsequent rates of first births even controlling for other known predictors of birth timing (Ghimire and Hoelter 2007). Both of these results are consistent with the hypothesis that having more land in agriculture motivates households to add labor through marriage and childbearing. Third, Massey and colleagues demonstrated in 2010 that higher fractions of land devoted to vegetation produced lower subsequent rates of out-migration even when controlling for other known predictors of out-migration (Massey, Axinn and Ghimire Forthcoming). This result too is consistent with the expectation that more land cover in agriculture, forest or grazing motivates need for labor so people stay rather than move.

Together these results mean that land use at one point in time can influence subsequent population processes in statistically significant and substantively important ways. In fact, this evidence demonstrates that land use can shape the specific processes that determine the subsequent number of people, number of households or number of births in any fixed area. Therefore, any effort to estimate the effects of those same population parameters on change in land use will be biased if it does not use measures of land use before population change to control for the confounding effects of this reciprocal influence of land use on population. Because that is exactly what we aim to do in the next step of our analysis, when we investigate the effects of population change between 1996 and 2005 on land use in 2005 we control for land use in 1995.

Population and social organization predicting change in land use

The next step of our analysis switches to neighborhood-level models of land use. As described above, we treat community-level measures of land use in 2005 as our dependent variable, community-level measures of land use in 1995 as a key control variable, and measures of population and social organization events between 1995 and 2005 as predictors of land use change between 1995 and 2005. Also, as described above, in evaluating the long term consequences of changes in social organization at the community level, we investigate both the 45-year change between 1950 and 1995 and the 10-year change between 1995 and 2005. We begin with simple models of change in land use estimated using OLS regression.

Social Organization—We begin by investigating the relationship between social organization at the community level and the land area devoted to vegetation. This measure of land under vegetation has the advantage of being exactly analogous to measures from satellite imagery used in other research on environmental change over time (Fox et al. 2003; Liverman, Moran, Rindfuss and Stern 1998). Our first model estimates the association between community change from 1950–1995 and the variation in percent of land under vegetation in 2005 (see column 1, of Table 3). Our measure of community context has a strong and statistically significant negative effect on land area devoted to vegetation. Larger changes toward lower walking times (more non-family services and organizations nearby) are associated with lower fractions of land devoted to vegetation. Because 100% of these land areas were devoted to vegetation in 1950, this result means those neighborhoods experiencing less growth in non family organizations and services (smaller reductions walking times to get to such things) also experience less conversion of land out of vegetation. 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).

Now we investigate this same association using the full rigor of our longitudinal panel study design. The next model introduces a control for land area devoted to vegetation in 1995 (column 2 of Table 3). Adding this measure of land use to the model changes the focus from variation in 2005 (or change from 1950–2005), to change in land use from 1995–2005. Because our initial measure of social organization at the community level captures changes occurring *before* 1995, it is reasonable to expect relatively little association in this model. However, we find that our measure of community context continues to have a statistically significant negative effect on land area devoted to vegetation. That is, increased access to non-family services and organizations from 1950–1995 are significantly associated with ongoing changes toward less land devoted to vegetation from 1995–2005. Note, however, that focus on change over this much smaller time period (1995–2005 rather than 1950–2005) produces much smaller estimates of the effect of community context on land use (approximately 3.5 times smaller in column 2 than in column 1 of Table 3).

Finally, building directly on the model displayed in column 2, we add a measure of change in social organization at the community level between 1995 and 2005 (column 3 of Table 3). This model reveals that both community changes in social organization from 1950–1995 and changes from 1995–2005 have independent influences on conversion of land out of vegetation, and both are in the same direction. So, change in community context shapes change in land area devoted to vegetation, and these influences are strong enough that *both* community context *before* the period of land use change being examined *and* community context *during* the period being examined affect the transition toward a built environment. These results not only highlight a crucial factor shaping changes over time in land use, but they are also fundamental to our understanding of the connection between population change and land use change. This is because other research indicates that these same dimensions of community context have important effects on fertility, mortality and migration (Axinn and Yabiku 2001; Massey and Espinoza 1997; Sastry 1996).

In these same models, electrification has virtually no relationship to the fraction of land devoted to flora. Our other measures of neighborhood affluence also have little influence on change in this dimension of land use. Only our neighborhood-level income measure has an association with change in land devoted to vegetation, and that relationship is relatively modest (column 3 of Table 3). As one might expect, higher income is associated with higher proportions of land devoted to vegetation. This is consistent with the hypothesis that more wealth encourages the devotion of land to vegetation (Foster 2005; Rosensweig 2001). The total land area also has a strong positive association with the fraction of land covered by vegetation in 2005 before we control for land area devoted to vegetation in 1995 and focus on the change from 1995–2005 (column 1 of Table 3). In this relatively rural agrarian setting it is not surprising that larger neighborhoods have a higher fraction of their land covered by vegetation, at least when 1995 land use is not controlled in the model.

Population—Our next set of models in Table 4 take the final model of social organization at the community level (column 3 of Table 3) and add measures of population change from 1996–2005. These models are designed to estimate the association between population change between 1996 and 2005 and land use change between 1995 and 2005, controlling for community-level social organization and other factors. The results demonstrate that changes in number of people, number of households, and number of births each reduce the land area devoted to vegetation, at least when estimated separately. The negative coefficients

displayed in columns 1, 2, and 3 of Table 4 mean that increases in each specific population measure are associated with reductions in the area of land devoted to vegetation. The direction of these associations is just as predicted; in a fixed area of land, we expect more people or more households to reduce land under vegetation. Likewise, having new babies in the household is likely to encourage both consumption of vegetation and construction of new buildings in this agrarian setting, also leading to less land area devoted to vegetation.

One argument in the theoretical framework we advance is that failure to consider the conditioning effects of social organization at the community level will produce biased estimates of the influence of population parameters on land use change that overestimate the magnitude of this relationship. As we describe in the first step of our analysis, other studies document the strong effects of community-level social organization on population parameters. In columns 4, 5 and 6 of Table 4 we provide empirical evidence of the consequence for models of land use. The results presented in these three columns come from models re-estimating the population effects, but this time omitting measures of social organization at the community level from the model. In each case the direction of the estimate is the same, but the magnitude of the estimate is larger. Though none of these differences are substantively large, the comparison reveals all the differences go in one direction: larger estimates of the influence of population on land use change. Social organization influences both population processes and land use change. Models that do not adjust for change or variation in social organization have the potential to produce misleading estimates of the relationship between population change and land use change.

Not shown in the tables, these three population effects on land use are not independent of one and other. In addition to the analyses shown in Table 4, we also estimated a model including all three population change measures. Though the sign of all three remains negative, none have a statistically significant influence on land use change independent of the others. This result is not surprising given the positive correlation among number of people, number of households, and number of births. Nevertheless, our theoretical framework predicts that births will influence mechanisms of land use change independent of the number of people or households per se. To investigate this prediction directly, we now switch to a decomposition of land uses that would not be possible with remote sensing measurement.

Decomposing land use types to investigate proximate determinants

The next step in our analysis is to decompose this model of change in land use for different types of land use in order to learn more about the factors producing this change over time in land devoted to vegetation. Our fieldwork-based measures allow us to distinguish among specific types of vegetation or buildings. For parsimony, we focus on results that most clearly illustrate how different dimensions of population change may influence change in land use through separate mechanisms. These results come from models decomposing the land area not covered in vegetation into specific alternatives to vegetation: private buildings (residences, businesses, etc.) versus public infrastructure (schools, health posts, water systems, etc.). Because the dependent variables in each of these models are expressed as a percentage, these multivariate models are also estimated using OLS regression.

These new models are organized to highlight the contrast between measures of change in number of people and measures of the number of births. The first column of Table 5 displays results from a model of change in land devoted to private buildings. In this model number of births have no significant independent associations with change in land devoted to private buildings, but the number of people increases land area devoted to private buildings⁵. Note that number of households produce the same result (not shown in tables), but this finding is virtually tautological; more households are positively associated with

more land devoted to private residences. The result for number of people is not far off. If the number of people in a fixed land area grows over time, the percentage of land devoted to private buildings (including residences) also grows (column 1 of Table 5). In fact, the self-evident logic of this result is a key reason population growth is always identified as a key factor in theories of land use change over time. This virtually self-explanatory result, however, only serves to highlight the extremely interesting results in the second column of Table 5.

Next we examine change in the land area devoted to public infrastructure such as schools, water systems, or other government services to contrast to private buildings. Here we see that when controlling for the change in number of people per se, births have a statistically significant independent association with change in land devoted to public infrastructure. More births are associated with more land area devoted to these public services. We argue that childbearing per se is a demographic event likely to stimulate higher construction of public services and infrastructure. Thus, on a fixed area of land, high birth rates are likely to contribute to the transition of land out of vegetation and into built uses in a settled agrarian setting. The independence of this effect from the number of people suggests that the construction-related effects of births stimulate a different mechanism of demand for public infrastructure than the mechanisms associated with the numbers of people per se.

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 (Fox et al. 2003; 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, with independent consequences for land use change over time. In this setting, the construction of private buildings appears to respond to changes in number of people as theory predicts, but number of births also has an independent influence on the construction of public infrastructure.

Household level investigation of consumption behavior

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 1242 households from the 136 neighborhoods we study. Among these households we examine the use of common land for grazing or collection of fodder in 1996 and 2005. Our models treat common land use in 2005 as the outcome of interest and controls for common land use in 1996, therefore modeling household level *change* in common land use between 1996 and 2005. We construct a series of household-level measures of population and controls analogous to the community-level measures used in our preview analyses and we control for community-level measures of social organization using multilevel models. The descriptive statistics of these household-level measures are presented and explained in Appendix A.

Our comparison of population influences on common land use investigates the occurrence of a birth in the household between 1996 and 2005 and the change in the number of people in the household from 1996–2005, controlling for the number of people in the household in

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

1996. The top panel of Table 6 displays these results. In column 1 the occurrence of a birth in the household significantly increases the odds of using common land for grazing and fodder collection. Column 2 demonstrates that increasing numbers of people also increase the odds of using common land, but that the positive effect of birth events is independent of this effect of numbers of people per se. The consumption-related consequences of these two important dimensions of population both work in the same direction, but they also influence common land consumption independently. Thus for each of the two key proximate determinants of land use we identify—construction of buildings and infrastructure and consumption of vegetation birth events have an important influence that is independent of changes in the total number of people. Birth events increase construction of public infrastructure and also increase the consumption of vegetation from common land, both leading to less vegetation in nearby land cover.

Next, panel 2 of Table 6 displays our estimates of the influence of neighborhood-level access to nonfamily services on common land use. As expected, in this household-level model increased access to nonfamily organizations and services in the local community is associated with a change toward a significantly lower likelihood of using common land (row 3 of Table 6). This result means those neighborhoods experiencing more growth in nonfamily organizations and services (bigger reduction in walking times to get to such things) also experience less use of common land to graze or gather fodder. 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 2010; 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.

Finally, this household-level investigation also reveal that while long term changes in community context (1950–1995) continue to shape changes in common land use (1996–2005), more recent changes in community context (1996–2005) do not. Though surprising, in this setting the changes in community context from 1950–1995 were considerably more dramatic than the changes from 1996–2005, which may explain our findings. The long term change from 1950–1995 included the first construction of roads and canals and the widespread proliferation of schools, health services and markets (Axinn and Barber 2001; Axinn and Yabiku 2001). These dramatic changes continue to influence the ways households interact with the land around them, reducing use of common lands for grazing and fodder collection in the long run.

The effects of births are also independent of these consequences of community context, and independent of the other factors included in our model. New babies in the household drive up the demand for milk, eggs and meat. 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 birth events 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 also considers population effects, moving beyond simple conceptualizations of 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 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. First and foremost, we show community-level measures of changes in social organization are significantly associated with changes in land use. The majority of previous theories of environmental change focuses on factors shaping the volume of consumption rather than the social organization of consumption. The empirical evidence we provide supports the conclusion that explicit consideration of social organization can provide a more comprehensive understanding of the consumption forces shaping environmental outcomes (Axinn et al 2010; Foster 1999). New research attention to the important relationship between social organization and environmental outcomes is likely to both advance our understanding of environmental change and open new doors for research into the links between humans and their environment.

Another key conclusion is that multiple dimensions of population change affect land use. Our analyses focus on a broad transition in land use and a relatively narrow window of time, from 1996 to 2005. Nevertheless, our results demonstrate that birth events significantly accelerate the construction of public infrastructure and significantly increase consumption of vegetation from common land independent of changes in the numbers of people.

We argue that births alter the nature of consumption patterns, in particular increasing the construction of public infrastructure and consumption of vegetation. 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 birth events 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 public infrastructure 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 birth rates, marriage rates, in-migration, out-migration and mortality along with more commonly studied factors such as numbers of people and numbers of households.

The results we present also demonstrate that model specification does matter and changes in model specification can produce differences in substantive conclusions about the relationships between population change and land use change. As predicted, taking full advantage of the multilevel, longitudinal, mixed method measurement to specify precise models of land use change alters our results in systematic ways. Specifically, because community context shapes both population parameters and environmental outcomes, failure to control for community-level factors produces a systematic over-estimate of the relationship between population and environment. Likewise, substantial evidence is consistent with the conclusion that environmental conditions influence population outcomes, so that failure to explicitly incorporate reciprocal influences is also likely to produce biased estimates of the population-environment relationship. The transition in environmental research from a macro-level focus to a micro-level focus exposes scientists to these risks of misunderstanding the relationships we study. The tools to address these issues that have been pioneered in other substantive areas of social research including multilevel, longitudinal research designs and detailed, mixed-method measurement provide a powerful means to address these risks.

These strategic issues are important because there is little chance the new focus on microlevel models of environmental change will reverse. Not only does the micro-level focus open new, more theoretically broad research questions, but it is also fundamental to the formulation of public policies and programs aimed at reducing environmental degradation. Human beings are the agents affecting the quality and quantity of the natural environment. To affect human behaviors, policies and programs will have to address the micro-level causes of those behaviors. However, the scientific study of micro-level causes of human behavior remains one of the most complex and illusive goals of the social sciences (Abbott 1998; Axinn and Pearce 2006; Freedman 1991; Heckman 1978, 2000; Marini and Singer 1988; Marsden 1992; Moffitt 2003, 2005; Raftery 1988; Rubin 1974; Winship and Morgan 1999). Progress on micro-level models of the causes of environmental degradation will demand that scientists use the best micro-level theoretical and methodological tools available. The case study we present here demonstrates those tools have some promise for advancing this crucial area of social research.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

References

- Abbott, Andrew. *The System of Professions: An Essay on the Division of Expert Labor*. Chicago: University of Chicago Press; 1988.
- Ajzen, Icek. *Attitudes, Personality and Behavior*. Chicago: Dorsey Press; 1988.
- Axinn, Nancy W.; Axinn, George H. *Small Farmers in Nepal: A Farming Systems Approach to Description*. Kathmandu: Rural Life Associates; 1983.
- Axinn, William G.; Barber, Jennifer S. Mass Education and Fertility Transition. *American Sociological Review*. 2001; 66(4):481–505.
- Axinn, William G.; Barber, Jennifer S.; Biddlecom, Ann E. Social Organization and the Transition from Direct to Indirect Consumption. *Social Science Research*. 2010; 39(3):357–368. [PubMed: 20514347]
- Axinn, William G.; Barber, Jennifer S.; Ghimire, Dirgha J. The Neighborhood History Calendar: a Data Collection Method Designed for Dynamic Multilevel Modeling. *Sociological Methodology*. 1997; 27(1):355–392. [PubMed: 12348199]
- Axinn, William G.; Fricke, Thomas. Community Context, Women's Natal Kin Ties, and Demand for Children: Macro-micro Linkages in Social Demography. *Rural Sociology*. 1996; 61(2):249–271.
- Axinn, William G.; Pearce, Lisa D. *Mixed Method Data Collection Strategies*. Cambridge: Cambridge University Press; 2006.
- Axinn, William G.; Yabiku, Scott T. Social Change, the Social Organization of Families, and Fertility Limitation. *American Journal of Sociology*. 2001; 106(5):1219–1261.
- Barber, Jennifer S. Community Social Context and Individualistic Attitudes Toward Marriage. *Social Psychology Quarterly*. 2004; 67(3):236–256.
- Barber, Jennifer S.; Axinn, William G. New Ideas and Fertility Limitation: The Role of Mass Media. *Journal of Marriage and Family*. 2004; 66(5):1180–1200.
- Barber, Jennifer S.; Murphy, Susan; Axinn, William G.; Maples, Jerry. Discrete-Time Multilevel Hazard Analysis. *Sociological Methodology*. 2000; 30(1):201–235.
- Barber, Jennifer S.; Pearce, Lisa D.; Chaudhury, Indra; Gurung, Susan. Voluntary Associations and Fertility Limitation. *Social Forces*. 2002; 80(4):1369–1401.
- Barber, Jennifer S.; Shivakoti, Ganesh P.; Axinn, William G.; Gajurel, Kishor. Sampling Strategies for Rural Settings: a Detailed Example from the Chitwan Valley Family Study, Nepal. *Population Journal of Nepal*. 1997; 6:193–203.
- Bhandari, Prem. Relative Deprivation and Migration in an Agricultural Setting of Nepal. *Population and Environment*. 2004; 25(5):475–499.
- Biddlecom, Ann E.; Axinn, William G.; Barber, Jennifer S. Environmental Effects on Family Size Preferences and Subsequent Reproductive Behavior in Nepal. *Population and Environment*. 2005; 26(3):183–206.
- Bilsborrow, Richard F.; Delargy, Pamela F. Land Use, Migration, and Natural Resource Deterioration: The Experience of Guatemala and the Sudan. In: Davis, Kingsley; Bernstam, Mikhail S., editors. *Resources, Environment, and Population: Present Knowledge, Future Options*. New York: Oxford University Press; 1991.
- Bista, Dor Bahadur. *People of Nepal*. Kathmandu: Ratna Pustak Bhandar; 1972.
- Blaikie, Piers; Brookfield, Harold, editors. *Land Degradation and Society*. New York: Methuen; 1987.
- Blaikie, Piers; Cameron, John; Seddon, David. *Nepal in crisis: Growth and stagnation at the periphery*. New York: Oxford University Press; 1980.
- Blau, Peter; Duncan, Otis D. *The American Occupational Structure*. New York: Wiley; 1967.
- Bohra-Mishra, Pratikshya; Massey, Douglas S. Environmental Degradation and Out-Migration: New Evidence from Nepal. In: Piguet, Etienne; Pécoud, Antoine; de Guchteneire, Paul, editors. *Migration, Environment and Climate Change*. UNESCO Book; 2010.

- Bohra-Mishra, Pratikshya; Massey, Douglas S. Processes of Internal and International Migration from Chitwan, Nepal. *International Migration Review*. 2009; 43(3):621–651. [PubMed: 21423821]
- Bongaarts, John. Population Growth and Global Warming. *Population and Development Review*. 1992; 18(2):299–319.
- Bongaarts, John. Population Pressure and the Food Supply System in the Developing World. *Population and Development Review*. 1996; 22(3):483–503.
- Boserup, Ester. *The Conditions of Agricultural Growth: The Economics of Agrarian Change Under Population Pressure*. Chicago: Aldine Press; 1965.
- Boserup, Ester. *Population and technological change: A study of long term trends*. Chicago: University of Chicago Press; 1981.
- Brauner-Otto, Sarah R.; Axinn, William G.; Ghimire, Dirgha J. The Spread of Health Services and Fertility Transition. *Demography*. 2007; 44(4):747–770. [PubMed: 18232209]
- Burkett, Paul. *Marx and nature: A red and green perspective*. New York: St. Martin's; 1999.
- Campbell, Donald T.; Stanley, Julian C. *Experimental and Quasi-Experimental Designs for Research*. Chicago: Rand McNally; 1967.
- Casterline, John B., editor. *The Collection and Analysis of Community Data*. Voorburg, Netherlands: International Statistical Institute; 1985.
- Castro, Paula; Garrido, Margarida; Reis, Elizabeth; Menezes, João. Ambivalence and conservation behaviour: An exploratory study on the recycling of metal cans. *Journal of Environmental Psychology*. 2009; 29(1):24–33.
- Central Bureau of Statistics. *Population Census 2001 - National Report*. Kathmandu: CBS; 2002.
- Clark, Brett. Ebenezer Howard and the marriage of town and country: An introduction to Howard's Garden Cities of To-morrow. *Organization & Environment*. 2003; 16(1):87–97.
- Clausen, Rebecca; Brett, Clark. The Metabolic Rift and Marine Ecology: An Analysis of the Ocean Crisis within Capitalist Production. *Organization & Environment*. 2005; 18(4):422–444.
- Cohen, Joel E. *How Many People Can the Earth Support?*. New York: Norton; 1995.
- Coleman, James S. *Foundations of Social Theory*. Cambridge: Harvard University Press; 1990.
- Conway, Dennis; Shrestha, Nanda R. *Causes and Consequences of Rural-to-Rural Migration in Nepal*. Bloomington: Indiana University; 1981.
- Dahal, Dilli Ram. Anthropology of the Nepal Himalaya: A critical appraisal. In: Bramble, Charles; Brauen, Martin, editors. *Anthropology of Tibet and the Nepal Himalaya*. Zurich: Ethnological Museum, University of Zurich; 1993.
- Dickens, Peter. *Society and Nature: Changing Our Environment, Changing Ourselves*. Cambridge: Polity Press; 2004.
- Diekmann, Andreas; Preisendörfer, Peter. Environmental behavior: Discrepancies between aspirations and reality. *Rationality and Society*. 1998; 10(1):79–102.
- Dupont, Diane P. Do Children Matter? An Examination of Gender Differences in Environmental Valuation. *Ecological Economics*. 2004; 49(3):273–286.
- Durkheim, Emile. *The Division of Labor in Society*. New York: The Free Press; 1984.
- Eckholm, Erik P. *Losing Ground: Environmental Stress and World Food Prospects*. New York: Norton; 1976.
- Ehrlich, Paul; Ehrlich, Ann; Daily, Gretchen. Food Security, Population, and Environment. *Population and Development Review*. 1993; 19(1):1–32.
- Elder, Joseph W.; Ale, Mahabir; Evans, Mary A.; Gillespie, David P.; Nepali, Rohit Kumar; Poudeland, Sitaram P.; Smith, Bryce P. *Planned Resettlement in Nepal Terai: A Social Analysis of the Khujura/Bardia Punarvas Projects*. Kathmandu: Tribhuvan University Press; 1976.
- Entwisle, Barbara. Population and Land Use in Nang Rong, Thailand. Paper presented at the Population Association of America Annual Meetings; Washington, D.C. March 29–31; 2001.
- Entwisle, Barbara; Casterline, John B.; Sayed, Hussein AA. Villages as Contexts for Contraceptive Behavior in Rural Egypt. *American Sociological Review*. 1989; 54(6):1019–1034.
- Entwisle, Barbara; Mason, William M. Multilevel Effects of Socioeconomic Development and Family Planning Programs on Children Ever Born. *American Journal of Sociology*. 1985; 91(3):616–649.

- Entwisle, Barbara; Stern, Paul C., editors. *Population, Land Use, and Environment: Research Directions*. National Research Council; Washington, DC: National Academies Press; 2005.
- Evans, Tom P.; Moran, Emilio F. Spatial Integration of Social and Biophysical Factors Related to Land Cover Change. *Population and Development Review*. 2002; 28(supplement):165–186.
- Fischer-Kowalski, Marina; Haberl, Helmut. Sustainable development: socio-economic metabolism and colonization of nature. *International Social Science Journal*. 1998; 50(158):573–587.
- Foster, Andrew. A Review of 10 years of work on Economic Growth and Population Change in Rural India. In: Entwisle, Barbara; Stern, Paul C., editors. *Population, Land Use, and Environment: Research Directions*. National Research Council. Washington, DC: National Academies Press; 2005.
- Foster, Andrew; Rosenzweig, Mark R. Agricultural Productivity Growth, Rural Economic Diversity, and Economic Reforms: India, 1970–2000. *Economic Development and Cultural Change*. 2004; 52(3):509–542.
- Foster, Andrew D.; Rosenzweig, Mark R.; Behrman, Jere R. *Population, Income and Forest Growth: Management of Village Common land in India*. Brown University; 2000.
- Foster, John B. Marx's Theory of Metabolic Rift: Classical Foundation for Environmental Sociology. *American Journal of Sociology*. 1999; 105(2):366–405.
- Foster, John Bellamy; Burkett, Paul. The dialectic of organic/inorganic relations: Marx and the Hegelian philosophy of nature. *Organization & Environment*. 2000; 13(4):403–425.
- Foster, John Bellamy; Clark, Brett. Ecological imperialism: The curse of capitalism. In: Panitch, Leo; Leys, Colin, editors. *The New Imperialist Challenge (Socialist register 2004)*. London: Merlin Press; 2003. p. 186–201.
- Fox, Jefferson; Rindfuss, Ronald R.; Walsh, Stephen J.; Mishra, Viod. *People and the Environment: Approaches for Linking Household and Community Surveys to Remote Sensing and GIS*. Boston: Kluwer Academic Publishers; 2003.
- Freedman, David. Statistical Models and Shoe Leather. *Sociological Methodology*. 1991; 21:291–314.
- Fricke, Tom. *Himalayan Households: Tamang Demography and Domestic Processes*. Columbia University Press; 1994.
- Geertz, Clifford. *Agricultural Involution, the Process of Ecological Change in Indonesia*. Berkeley: University of California Press; 1968.
- Ghimire, Dirgha J.; Axinn, William G. Family Change in Nepal: Evidence from Western Chitwan. *Contributions to Nepalese Studies*. 2006; 33(2):177–201.
- Ghimire, Dirgha J.; Axinn, William G. Social Organization, Land Use and the Hazard of First Birth. *Rural Sociology*. 2010; 75(3):478–513. [PubMed: 20877584]
- Ghimire, Dirgha J.; Axinn, William G.; Yabiku, Scott T.; Thornton, Arland. Social Change, Premarital Nonfamily Experience, and Spouse Choice in an Arranged Marriage Society. *American Journal of Sociology*. 2006; 111(4):1181–1218.
- Ghimire, Dirgha J.; Hoelter, Lynette F. Land Use and First Birth Timing in an Agricultural Setting. *Population and Environment*. 2007; 28(6):289–320.
- Ghimire, Dirgha J.; Mohai, Paul. Environmentalism and Contraceptive Use: How People in Less Developed Settings Approach Environmental Issues. *Population and Environment*. 2005; 27(1): 29–61.
- Goldscheider, Frances K.; Waite, Linda J. Effects of Nest-Leaving Patterns On The Transition To Marriage for Young Men and Women. *Journal of Marriage and the Family*. 1987; 49(3):507–516.
- Gurung, Harka B. *Vignettes of Nepal*. Kathmandu: Sajha Prakashan; 1980.
- Gurung, Sant Bahadur. The Land and the People. In: Shumshere, Pashupati; Rana, JB.; Dhungel, Dwarika Nath, editors. *Contemporary Nepal*. New Delhi: Vikas; 1998. p. 1–13.
- Gutmann, Mayron P. The Meaning of Sustainability in a Developed Landscape: The U.S. Great Plains in the 20 the Century. Paper presented at the Population Association of America Annual Meetings; Washington DC. March 29–31; 2001.
- Gutmann, Mayron P.; Cunfer, Geoff. A New look at the causes of the Dust Bowl. In: Moore, SL., editor. *The Charles L Wood Agriculture Lecture Series*. Texas Tech University: International Center for Arid and Semiarid Land Studies; 1999.

- Hamilton, Lawrence C. Who Cares About Water Pollution? Opinions in a Small-Town Crisis. *Sociological Inquiry*. 1985; 55(2):170–181.
- Hamilton, Lawrence; Seyfrit, Carole L.; Bellinger, Christina. Environment and Sex Ratios among Alaskan Natives: An Historical Perspective. *Population and Environment*. 1997; 18(3):283–299.
- Haustein, Sonja; Hunecke, Marcel. Reduced Use of Environmentally Friendly Modes of Transportation Cause by Perceived Mobility Necessities: An Extension of the Theory of Planned Behavior. *Journal of Applied Social Psychology*. 2007; 37(8):1856–1883.
- Heckman, James J. Dummy Endogenous Variables in a Simultaneous Equation System. *Econometrica*. 1978; 46(4):931–960.
- Heckman, James J. Causal Parameters and Policy Analysis In Economics: A Twentieth Century Retrospective. *Quarterly Journal of Economics*. 2000; 115(1):45–97.
- Heilig, Gerhard K. Anthropogenic Factors in Land-Use Change in China. *Population and Development Review*. 1997; 23(1):139–168.
- Hill, Allan G. Demographic Responses to Food Shortages in the Sahel. In: McNicoll, G.; Cain, M., editors. *Rural development and population: Institutions and policy*. New York: Oxford University Press; 1990. p. 168–192.
- His Majesty's Government. *Population Monograph of Nepal*. Kathmandu: Central Bureau of Statistics; 1987.
- Hoelter, Lynette F.; Axinn, William G.; Ghimire, Dirgha J. Social Change, Premarital Non-Family Experiences, and Marital Dynamics. *Journal of Marriage and Family*. 2004; 66(5):1131–1151.
- Hunter, Lori M. *Population Matters Series*. Santa Monica, CA: RAND; 2001. The Environmental Implications of Population Dynamics.
- Jolly, Carole L.; Torrey, Barbara B. *Population and Land Use in Developing Countries: Report of a Workshop*. Committee on Population, National Research Council; Washington, DC: National Academies Press; 1993.
- Liu, Jianguo; An, Li; Batie, Sandra S.; Bearer, Scott L.; Chen, Xiaodong; Groop, Richard E.; He, Guangming; Liang, Zai; Linderman, Marc A.; Mertig, Angela G.; Ouyang, Zhiyun; Qi, Jianguo; Zhang, Hermin; Zhou, Shiquiang. Beyond Population Size: Examining Intricate Interactions Among Population Structure, Land Use, and Environment in Wolong Nature Reserve, China. In: Entwisle, Barbara; Stern, Paul C., editors. *Population, Land Use, and Environment: Research Directions*. National Research Council; Washington, DC: National Academies Press; 2005.
- Liverman, Diana M.; Moran, Emilio F.; Rindfuss, Ronald R.; Stern, Paul C. *People and Pixels: Linking Remote Sensing and Social Science*. Washington, DC: National Academies Press; 1998.
- Macht, Cynthia; Axinn, William G.; Ghimire, Dirgha. *Population Studies Center Research Report No. 07–692*. Ann Arbor: University of Michigan; 2007. Household energy consumption: Community context and the fuelwood transition.
- Maples, Jerry J.; Murphy, Susan A.; Axinn, William G. Two-Level Proportional Hazards Models. *Biometrics*. 2002; 58(4):754–763. [PubMed: 12495129]
- Marini, Margaret; Singer, Burton. Causality in the Social Sciences. *Sociological Methodology*. 1988; 18:347–409.
- Marsden, Peter V. *Sociological Methodology*. Oxford: Blackwell; 1992.
- Marx, Karl. *Capital: A Critique of Political Economy*. Vol. 1. New York: Vintage; 1976. 1867
- Marx, Karl. *Capital: A Critique of Political Economy*. Vol. 3. New York: Vintage; 1981. [1863–65]
- Massey, Douglas S.; Axinn, William; Ghimire, Dirgha. *Environmental Change and Out-Migration: Evidence from Nepal*. Population and Environment. 2010
- Massey, Douglas S.; Denton, Nancy A. Residential Segregation of Asian-origin Groups in United States Metropolitan Areas. *Sociology and Social Research*. 1992; 76(4):170–177.
- Massey, Douglas S.; Espinosa, Kristin E. What's Driving Mexico-U.S. Migration? A Theoretical, Empirical, and Policy Analysis. *American Journal of Sociology*. 1997; 102(4):939–999.
- Massey, Douglas S.; Williams, Nathalie; Axinn, William G.; Ghimire, Dirgha. Community Services and Out-Migration. *International Migration*. 2010; 48(3):1–41. [PubMed: 20645469]
- May, John F. Policies on Population, Land Use, and Environment in Rwanda. *Population and Environment*. 1995; 16(4):321–334.

- McAuley, William J.; Nutty, Cheri L. Residential Preferences and Moving Behavior: A Family Life-cycle Analysis. *Journal of Marriage and the Family*. 1982; 44(2):301–309.
- McCalla, Alex F. From Subsistence System to Commercial Agriculture: The Need for a New Development Paradigm: Discussion. *American Journal of Agriculture Economics*. 1997; 79(2): 643–645.
- Miracle, Marvin P. 'Subsistence Agriculture': Analytical problems and Alternative Concepts. *American Journal of Agriculture Economics*. 1968; 50(2):292–310.
- Moffitt, Robert. Causal Analysis in Population Research: An Economist's Perspective. *Population and Development Review*. 2003; 29(3):448–458.
- Moffitt, Robert. Remarks on the Analysis of Causal Relationships in Population Research. *Demography*. 2005; 42(1):91–108. [PubMed: 15782897]
- Moore, Jason W. Environmental crises and the metabolic rift in world-historical perspective. *Organization & Environment*. 2000; 13(2):123–157.
- Moore, Jason W. The modern world-system as environmental history? Ecology and the rise of capitalism. *Theory and Society*. 2003; 32:307–377.
- Moran, Emilio. The Development Cycle of Domestic Groups and Deforestation in the Amazon. Paper presented at the Population Association of America Annual Meetings; Washington, DC. March 29–31; 2001.
- Moran, Emilio F.; Brondizio, Eduardo S.; VanWey, Leah K. Population and Environment in Amazonia: Landscape and Household Dynamics. In: Entwistle, Barbara; Stern, Paul C., editors. *Population, Land Use, and Environment: Research Directions*. National Research Council; Washington, DC: National Academies Press; 2005.
- Mortimore, Michael. Land Transformation under Agricultural Intensification. In: Jolly, Carole L.; Torry, Barbara Boyle, editors. *Population and Land Use in Developing Countries: Report of a Workshop*. Committee on Population, National Research Council; Washington, DC: National Academies Press; 1993.
- Mouw, Ted. Are Black Workers Missing the Connection? The Effect of Spatial Distance and Employee Referrals on Interfirm Racial Segregation. *Demography*. 2002; 39(3):507–528. [PubMed: 12205755]
- Müller-Böker, Ulrike. Pahariya- Migration to the Tharu's Settlement Area of the Inner Terai (Chitwan). In: von der Heide, Susanne; Hoffmann, Thomas, editors. *Aspects of Migration and Mobility in Nepal*. Ratna Pustak Bhandari; Kathmandu Nepal: 2001.
- Myers, Norman. The World's Forests and Human Populations: the Environmental Interconnections. In: Davis, Kingsley; Bernstam, Mikhail S., editors. *Resources, Environment, and Population*. Oxford: Oxford University Press; 1991.
- Ogburn, William F.; Nimkoff, MF. *Technology and the Changing Family*. Westport, CT: Greenwood Press; 1976. 1955
- Ogburn, William F.; Tibbits, Clark. The Family and its Function. In: Ross, EA., editor. *The Principles of Sociology*. New York: Henry Holt; 1934. p. 421-432.
- Perz, Stephen G. The Environment as a Determinant of Child Mortality among Migrants in Frontier Areas of Para and Rondonia, Brazil, 1980. *Population and Environment*. 1997; 18(3):301–324.
- Pingali, Prabhu L. From Subsistence to Commercial Production Systems: The Transformation of Asian Agriculture. *American Journal of Agricultural Economics*. 1997; 79(2):628–634.
- Pingali, Prabhu L.; Rosegrant, Mark W. Agricultural Commercialization and Diversification: Processes and Policies. *Food Policy*. 1995; 20:171–185.
- Piotrowski, Martin. Mass Media and Rural Out-Migration in the Context of Social Change: Evidence from Rural Nepal. *International Migration*. 2010; 48
- Pokharel, Bhola N.; Shivakoti, Ganesh P. Impact of Development Efforts on Agricultural Wage Labor. *Winrock Rural Poverty Research Paper Series*. 1986; 1
- Raftery, Adrian E. Technical Report 121. Department of Statistics, University of Washington; 1988. Approximate Bayes factors for generalised linear models.
- Raudenbush, Stephen W.; Bryk, Anthony S. *Hierarchical Linear Models: Applications and Data Analysis Methods*. 2. Thousand Oaks: Sage Publications; 2002.

- Rees, William. Revisiting Carrying Capacity: Area-Based Indicators of Sustainability. *Population and Environment*. 1996; 17(3):195–215.
- Rindfuss, Ronald R.; Philip Morgan, S.; Swicegood, Gray. *First Births in America: Changes in the Timing of Parenthood*. Berkeley: University of California Press; 1988.
- Rosenzweig, Mark. Population Growth, Economic Change and Forest Degradation in India. Paper presented at the Population Association of America Annual Meetings; Washington, DC. March 29–31; 2001.
- Rubin, Donald B. Estimating Causal Effects of Treatments in Randomized and Non-randomized Studies. *Journal of Educational Psychology*. 1974; 66(5):688–701.
- Sastry, Narayan. Community Characteristics, Individual and Household Attributes, and Child Survival in Brazil. *Demography*. 1996; 33(2):211–229. [PubMed: 8827166]
- Schmidt-Vogt, Dietrich. Deforestation in the Nepal Himalaya: Causes, Scope, Consequences. *European Bulletin of Himalayan Research*. 1994; 7:18–24.
- Shapiro, David. Population Growth, Changing Agricultural Practices, and Environmental Degradation in Zaire. *Population and Environment*. 1995; 16(3):221–236.
- Shivakoti, Ganesh P.; Axinn, William G.; Bhandari, Prem; Chhetri, Netra B. The Impact of Community Context on Land Use in an Agricultural Society. *Population and Environment*. 1999; 20(3):191–213.
- Shivakoti, Ganesh P.; Pokharel, Bhola N. Marketing of Major Crops in Chitwan: A Case Study of Six Village Panchayats. *Winrock Research Report Series*. 1989; 8
- Shrestha, Nanda R. Frontier Settlement and Landlessness among Himalayan Migrants in Nepal Tarai. *Annals of the Association of American Geographers*. 1989; 79(3):370–389.
- Shrestha, Nanda R. *Landlessness and Migration in Nepal*. Oxford: Westview Press; 1990.
- Shrestha, Sundar S.; Bhandari, Prem. Environmental Security and Labor Migration in Nepal. *Population and Environment*. 2007; 29(1):25–38.
- Simmons, IG. Transformation of the land in pre-industrial time. In: Wolman, MG.; Fournier, FGA., editors. *Land Transformation in Agriculture*. New York: Wiley; 1987. p. 45-75.
- Smith, Christian; Denton, Melinda L. *Soul Searching: The Religious and Spiritual Lives of American Teenagers*. Oxford: Oxford University Press; 2005.
- Stern, Paul C.; Dietz, Thomas; Ruttan, Vernon W.; Socolow, Robert H.; Sweeney, James L. *Environmentally Significant Consumption*. Washington, DC: National Academies Press; 1997. Consumption as a Problem for Environmental Science. Preface to National Research Council's.
- Stolzenberg, Ross M.; Blairloy, Mary; Waite, Linda. Religious Participation In Early Adulthood: Age And Family-Life Cycle Effects On Church Membership. *American Sociological Review*. 1995; 60(1):84–103.
- Teal, Gretchen A.; Loomis, John B. Effects of Gender and Parental Status on the Economic Valuation of Increasing Wetlands, Reducing Wildlife Contamination and Increasing Salmon Populations. *Society and Natural Resources*. 2000; 13(1):1–14.
- Thapa, Gopal B. Land use, Land Management and Environment in a Subsistence Mountain Economy in Nepal. *Agriculture, Ecosystem and Environment*. 1996; 57(1):57–71.
- Thornton, Arland; Axinn, William G.; Hill, Daniel H. Reciprocal Effects Of Religiosity, Cohabitation, And Marriage. *American Journal of Sociology*. 1992; 98(3):628–651.
- Thornton, Arland; Fricke, Thomas E. Social Change and the Family: Comparative Perspectives from the West, China, and South Asia. *Sociological Forum*. 1987; 2(4):746–779.
- Thornton, Arland; Lin, Hui-Sheng. *Social Change and the Family in Taiwan*. Chicago: University of Chicago Press; 1994.
- Tiwari PC. Land use changes in the Himalaya and their impact on the plains ecosystem: need for sustainable land use. *Land Use Policy*. 2000; 17(2):101–111.
- Tuladhar, Jayanti. *The Persistence of High Fertility in Nepal*. New Delhi: Inter-India Publications; 1989.
- Walsh, Stephen J.; Rindfuss, Ronald R.; Prasartkul, Pramote; Entwisle, Barbara; Chamratrithirong, Aphichat. *Population Change and Landscape Dynamics: The Nana Rong, Thailand, Studies*. In:

- Entwisle, Barbara; Stern, Paul C., editors. *Population, Land Use, and Environment: Research Directions*. National Research Council; Washington, DC: National Academies Press; 2005.
- Williams, Nathalie. Education, Gender, and Migration in the Context of Social Change. *Social Science Research*. 2009; 38(4):883–896. [PubMed: 20645440]
- Wilson, William J. *The Truly Disadvantaged: The Inner City, the Underclass, and Public Policy*. Chicago: University of Chicago Press; 1987.
- Winship, Christopher; Morgan, Stephen L. The Estimation of Causal Effects From Observational Data. *Annual Review of Sociology*. 1999; 25:659–707.
- Gordon, Wolman M. Population, Land Use, and Environment: A Long History. In: Jolly, Carole L.; Torry, Barbara Boyle, editors. *Population and Land Use in Developing Countries: Report of a Workshop*. Committee on Population, National Research Council; Washington, DC: National Academies Press; 1993.
- Xie, Yu; Shauman, Kim A. Sex Differences in Research Productivity: New Evidence About an Old Puzzle. *American Sociological Review*. 1998; 63(6):847–870.
- Yabiku, Scott T. Marriage Timing in Nepal: Organizational Effects and Individual Mechanisms. *Social Forces*. 2004; 83(2):559–586.
- Yabiku, Scott T. The Effect of Non-family Experiences on Age of Marriage in a Setting of Rapid Social Change. *Population Studies*. 2005; 59(3):339–354. [PubMed: 16249154]
- Yabiku, Scott T. Land Use and Marriage Timing in Nepal. *Population and Environment*. 2006a; 27(5–6):445–461.
- Yabiku, Scott T. Neighbors and Neighborhoods: Effects on Marriage Timing. *Population Research and Policy Review*. 2006b; 25(4):305–327.
- York, Richard; Rosa, Eugene A.; Dietz, Thomas. Bridging Environmental Science with Environmental Policy: Plasticity of Population, Affluence, and Technology. *Social Science Quarterly*. 2002; 83(1):18–34.
- York, Richard; Rosa, Eugene A.; Dietz, Thomas. STIRPAT, IPAT and ImPACT: analytic tools for unpacking the driving forces of environmental impacts. *Ecological Economics*. 2003a; 46(3): 351–365.
- York, Richard; Rosa, Eugene A.; Dietz, Thomas. Footprints on the earth: the environmental consequences of modernity. *American Sociological Review*. 2003b; 68(2):279–300.

Table 1

Land Use Over Time by Three Categories of Land (Fixed Land Area, N=136)

Land Use	1995	2005	Significance
Percent Area Green	77.83	75.08	*** (+)
Percent Area Public Infrastructure	9.71	10.49	* (-)
Percent Area Private Building	12.33	14.30	** (-)

*
p < 0.05**
P < 0. 01***
P < 0.001.

Statistical significance of difference in land area under specific use between 1995 and 2005.

Table 2

Descriptive Statistics of Variables Used in the Analyses of Land Use (N=136).

Variables	Mean	Standard Deviation	Minimum	Maximum
<i>Community Context</i>				
Change in community context between 1950–1995 (change in minutes walk to nearest non-family services ¹)	681.61	10.80	647.50	698.17
Change in community context between 1995–2005 (change in minutes walk to nearest non-family services)	5.61	9.11	-13.33	41.17
<i>Population Change</i>				
Change in number of persons	6.38	16.07	-27.00	70.00
Change in number of households	2.53	3.76	-6.00	18.00
Total number of birth in a neighborhood	11.31	6.77	0.00	31.00
<i>Other Controls (1996)</i>				
Electrification (1 = yes)	0.37	0.49	0.00	1.00
Proportion of households that rented out land	0.11	0.13	0.00	0.66
Neighborhood wealth	21.80	7.28	3.73	41.05
Neighborhood income level	2.22	0.51	0.83	3.33
Number of people	50.30	20.89	9.00	103.00
Number of households	10.49	4.15	2.00	20.00
Total area in 100,000 square feet	8.28	6.64	0.47	32.23
Distance to Narayanghat	8.60	3.58	0.82	17.57

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

Table 3

OLS Regression Estimates of Neighborhood-Level Models Predicting Percent of Land Area Devoted to Vegetation in 2005

	Percent of Land Area Devoted to Vegetation		
<u>Social Organization</u>			
Change in community context between 1950 and 1995 (average minutes walk to nearest non-family services ^I)	-0.48 ** (3.84)	-0.13 * (1.76)	-0.34 ** (2.61)
Change in community context between 1995 and 2005 (change in average minutes walk to nearest non-family services)			-0.28 * (1.94)
<u>Affluence</u>			
Proportion of households that rented out land	-7.55 (0.75)	-1.53 (0.26)	0.25 (0.04)
Neighborhood wealth	0.73 ** (3.82)	0.15 (1.27)	0.12 (1.08)
Neighborhood income level	-3.05 (1.19)	1.43 (0.95)	2.09 [†] (1.37)
Neighborhood electrification	-3.67 (1.20)	0.41 (0.23)	0.41 (0.23)
<u>Controls for Time 1 Conditions</u>			
Percent land devoted to vegetation in 1996		0.93 ** (16.10)	0.93 ** (16.34)
<u>Other Controls</u>			
Distance to Narayanghat	-0.39 (0.89)	0.16 (0.62)	0.21 (0.84)
Total neighborhood land area in 100,000 square feet	1.09 ** (5.34)	0.17 [†] (1.31)	0.11 (0.87)
R² –Adjusted	0.43	0.81	0.81
N (neighborhoods)	136	136	136

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 were estimated using multivariate OLS regression.

¹ Non-family services include school, health services, bus stop, employment center, market and agricultural cooperatives.

Table 4

OLS Regression Estimates of Population Influence on Percent of Land Area Devoted to Vegetation in 2005 at the Neighborhood Level.

	Percent Land Area Devoted to Vegetation in 2005					
	1	2	3	4	5	6
Population Change Between 1996 and 2005						
Number of people	-0.09* (2.11)					
Number of households		-0.40* (2.01)				
Number of births			-0.27* (1.86)			
Social Organization						
Change in community context between 1950–1995 (average minutes walk to nearest non-family services [†])	-0.31** (2.42)	-0.30* (2.31)	-0.33** (2.61)			
Change in community context between 1995–2005 (change in average minutes walk to nearest non-family services)	-0.26* (1.82)	-0.26* (1.81)	-0.27* (1.84)			
Affluence						
Proportion of households that rented out land	-0.11 (0.02)	-0.07 (0.01)	-2.12 (0.36)	-1.89 (0.33)	-1.90 (0.33)	-3.98 (0.67)
Neighborhood wealth	0.07 (0.60)	0.07 (0.60)	0.09 (0.74)	0.10 (0.88)	0.10 (0.82)	0.13 (1.10)
Neighborhood income level	2.13 [†] (1.40)	1.99 [†] (1.31)	1.89 (1.23)	1.27 (0.85)	1.18 (0.79)	0.97 (0.64)
Neighborhood electrification	0.33 (0.19)	0.38 (0.22)	-0.10 (0.06)	0.16 (0.09)	0.22 (0.13)	-0.31 (0.17)
Controls for Time 1 Conditions						
Percent land devoted to vegetation in 1996	0.95** (16.46)	0.95** (15.87)	0.95** (16.36)	0.97** (17.24)	0.97** (16.63)	0.97** (17.06)
Number of people in 1996	0.01 (0.42)		0.08 (1.62)	0.01 (0.22)		0.07 (1.46)
Number of households in 1996		-0.05 (0.30)			-0.08 (0.41)	
Other Controls						
Distance to Narayanhata	0.18 (0.74)	0.22 (0.88)	0.21 (0.82)	0.21 (0.85)	0.24 (0.96)	0.25 (0.99)
Total neighborhood area in 100,000 square feet	0.13 (0.95)	0.16 (1.18)	0.08 (0.61)	0.17 (1.26)	0.20 (1.52)	0.12 (0.87)
R² –Adjusted	0.82	0.82	0.82	0.81	0.81	0.82
N (neighborhoods)	136	136	136	136	136	136

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 were estimated using multivariate OLS regression.

Table 5

OLS Regression Estimates of Neighborhood-Level Models Predicting Percent of Land Area Under Private Buildings and Public Infrastructures in 2005

	Private Buildings	Public Infrastructure
<u>Population change between 1996 and 2005</u>		
Number of births	−0.07 (0.46)	0.17* (1.91)
Number of people	0.12** (2.45)	−0.04 (1.50)
<u>Social Organization</u>		
Change in community context between 1950–1995 (average minutes walk to nearest non-family services ¹)	0.24* (2.28)	0.03 (0.47)
Change in community context between 1995–2005 (change in average minutes walk to nearest non-family services)	0.26* (2.12)	−0.02 (0.33)
<u>Affluence</u>		
Proportion of households that rented out land	0.36 (0.07)	−0.73 (0.24)
Neighborhood wealth	−0.09 (1.00)	0.04 (0.74)
Neighborhood income level	−2.22* (1.74)	0.59 (0.78)
Neighborhood electrification	−0.10 (0.07)	0.18 (0.20)
<u>Controls for Time 1 Conditions</u>		
Percent land devoted to specific use in 1996	0.84** (12.93)	1.14** (24.48)
Number of people in 1996	0.03 (0.72)	−0.06* (2.34)
<u>Other Controls</u>		
Distance to Narayanghat	−0.30 [†] (1.43)	0.11 (0.90)
Total area in 100,000 square feet	−0.19 [†] (1.60)	0.00 (0.03)
R² –Adjusted	0.74	0.85
N (neighborhoods)	136	136

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 were estimated using multivariate OLS regression.

Table 6

Household-Level-Vegetation Consumption: Odd Ratios from Logistic Regression Estimates of Common Land Use in 2005 (Asymptotic z-ratios in parentheses)

<u>Population Measures</u>		
Household has birth 1996–2005 (1 = yes)	1.38* (1.73)	1.45* (1.73)
Change in number of people between from 1996 to 2005		1.38* (1.94)
<u>Social Organization</u>		
Change in average minutes walk to nearest services ^I between 1950 and 1995 non-family	−0.95** (3.76)	−0.95** (3.77)
Change in average minutes walk to nearest services between 1995 and 2005 non-family	−0.98 (0.86)	−0.99 (0.88)
<u>Affluence</u>		
Electrification	−0.95 (0.22)	−0.95 (0.22)
Wealth index	−0.94* (1.76)	−0.94* (1.70)
Income	−0.90* (1.86)	−0.90* (1.73)
Renting out land	−0.88 (0.49)	−0.89 (0.45)
Average years of school	−0.92** (2.86)	−0.92** (2.88)
Average years of non-family work	−0.99 (0.86)	−0.99 (0.94)
<u>Controls for Time-1 Conditions</u>		
<i>Common land use</i>		
Household used common land	4.00** (8.62)	3.98** (8.22)
<i>Population measures</i>		
Number of people	1.08** (2.37)	1.07* (1.82)
<i>Ethnicity (Brahmin\chhetri reference group)</i>		
Dalit	1.14 (0.51)	1.15 (0.52)
Newar	−0.60 (1.20)	−0.59 (1.21)
Terai Indigenous	−0.70 (1.46)	−0.73 (1.29)
Hill Indigenous	1.19 (0.73)	1.19 (0.77)
<u>Other Controls</u>		
Distance to Narayanghat (urban center)	−0.96 (1.50)	−0.96 (1.49)
Total neighborhood land area in 100,000 square feet	−0.99 (0.36)	−0.99 (0.37)
−2 Log Likelihood	1038.39	1041.17
N (Households)	1242	1242

Note:

* p < 0.05

** P < 0.01

*** P < 0.001

^I Non-family services include school, health service, bus stop, employment center, market and cooperatives.