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Rural Household Demographics, Livelihoods and the Environment

Alex de Sherbinin,

Center for International Earth Science Information Network (CIESIN), Columbia University

Leah VanWey,

Department of Sociology, Indiana University

Kendra McSweeney,

Department of Geography, Ohio State University

Rimjhim Aggarwal,

School of Sustainability, Arizona State University

Alisson Barbieri,

Department of Demography and Center for Regional Development and Planning (CEDEPLAR), Federal University of Minas Gerais, Brazil

Sabina Henry,

Department of Geography, Facultés Universitaires Notre Dame de la Paix, Belgium

Lori M. Hunter, and

Environment and Society Program, Institute of Behavioral Science, and Department of Sociology, University of Colorado at Boulder

Wayne Twine

School of Animal, Plant & Environmental Sciences, University of the Witwatersrand Robert Walker, Department of Geography, Michigan State University

Abstract

This paper reviews and synthesizes findings from scholarly work on linkages among rural household demographics, livelihoods and the environment. Using the livelihood approach as an organizing framework, we examine evidence on the multiple pathways linking environmental variables and the following demographic variables: fertility, migration, morbidity and mortality, and lifecycles. Although the review draws on studies from the entire developing world, we find the majority of micro-level studies have been conducted in either marginal (mountainous or arid) or frontier environments, especially Amazonia. Though the linkages are mediated by many complex and often context-specific factors, there is strong evidence that dependence on natural resources intensifies when households lose human and social capital through adult morbidity and mortality, and qualified evidence for the influence of environmental factors on household decision-making regarding fertility and migration. Two decades of research on lifecycles and land-cover change at the farm level have yielded a number of insights about how households make use of different land-use and natural resource management strategies at different stages. A thread running throughout the review is the

Alex de Sherbinin, Center for International Earth Science Information Network (CIESIN), Columbia University, P.O. Box 1000, Palisades, NY 10964 USA, Tel. 1-845-365-8936, Fax 1-845-365-8922.

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importance of managing risk through livelihood diversification, ensuring future income security, and culture-specific norms regarding appropriate and desirable activities and demographic responses. Recommendations for future research are provided.

1. Introduction

One of the major areas of population-environment research in the past decade has focused on household-level population dynamics and their relationship, through livelihood strategies, to environmental change, particularly in rural areas of the developing world. Studies have sought to go beyond the attribution of environmental degradation to high fertility and associated population increase. Instead, they have investigated the relationships among population variables (household size, age and sex composition, fertility, on-farm population density, migration, and mortality), biophysical variables (forest cover, coastal mangroves, and soil quality), and natural resources (firewood, timber, non-timber forest products, bushmeat and water) in the Amazon Basin, Central America, Southeast Asia, East Asia, Oceania, and Africa (e.g., Walker and Homma, 1996; Homewood, 1997; Pichón, 1997; Entwisle et al., 1998; Zaba and Madulu, 1998; Ezra and Kiros, 2001; Adger et al., 2002; McCracken et al., 2002; Vance and Geoghegan, 2002; Liu et al., 2005; Moran et al., 2005; Caldas et al., 2007). The research teams involved in these efforts have spanned the social and environmental sciences and have employed a wide range of methodologies, such as household surveys, participant observation, ground-level analyses of biophysical variables, and integration of remotely sensed imagery. This paper sets out to assess the lessons learned from and fruitful future directions in this large and growing body of research.

A focus on household dynamics does not imply that smallholders are necessarily the primary nor the ultimate agents of natural resource degradation or rural landscape change. Industrial agriculture, commercial lumber and mining operations, and state development schemes have arguably left a greater imprint on natural ecosystems throughout the developing world. Further, the very presence of smallholders in biodiverse but agriculturally marginal environments (rainforests, savannahs, coastlines) is all too often the result of historically produced unequal land tenure regimes and international development policies strongly biased against the poor. Nevertheless, this focus on the microdemographic dynamics of rural smallholders is based on recognition that (a) they are important players in natural resource use and landscape change, particularly in rainforest frontiers in Central Africa and Amazonia; (b) rural dwellers account for 59% of the population of the developing world (PRB, 2005) and play a vital role in provisioning cities and regional markets with foodstuffs and other resources (e.g., renewable fuels); and (c) policy interventions that target the health, livelihoods, or environments of rural people must be based on sound understandings of how these are linked. In particular, a better understanding of household dynamics can help researchers and policy makers to understand how certain kinds of demographic behavior, especially fertility and migration, relate to livelihood strategies. From the environmental perspective, household demographic dynamics can affect local environmental outcomes and resource dependence, and these dynamics may have significant repercussions for natural resource management and biodiversity conservation. Conversely, changes in the quality and quantity of natural resources can have important impacts on household fertility, morbidity, mortality, and migration. These multiple and multi-level dynamics between household demographics and environmental variables, mediated by contextual factors such as local and regional environmental variability, policies, institutions and markets, makes this a complex area of study, but also one that is ripe for new discoveries and insights (see also Zimmerer, 2004).

The importance of these links is apparent in the outpouring of recent research on this topic. Yet a comprehensive review of this diverse literature has been lacking. This paper therefore

reviews some of the major strands of this research, examines common threads and lessons learned, and identifies some remaining research questions. We begin with a discussion of the livelihood approach as an organizing framework and the importance of households as decision-making units. Section 3 then describes how we selected the literature for review, and then has four subsections addressing in turn household fertility, morbidity and mortality, migration, and lifecycles in relationship to the environment and natural resources. We offer some conclusions in Section 4.

2. The Livelihood Approach as an Organizing Framework

In this paper, we use the livelihood approach as an organizing framework and focus on demographic and environmental changes as they play out in households. In most rural areas of the developing world, the household is the basic unit of production and reproduction,¹ and the one at which most rural smallholders would say that critical decisions are made. Within the livelihood approach, a “household” has been described as “a site in which particularly intense social and economic interdependencies occur between a group of individuals” (Ellis, 2000, p.18). To be sure, the idea of a unitary household decision-making unit can be problematic—there is striking empirical evidence, for example, that gender and age differences within the household lead to divergent preferences in such critical areas as fertility and investments in children’s health and education (Birdsall, 1988; Wilk, 1990; Strauss and Thomas, 1995).² However, such intrahousehold processes appear not to have been explicitly examined in the literature linking household demographics and environment. The studies reviewed below therefore take the locally defined household as the unit of analysis.

In order to survive and prosper in what can often be difficult circumstances, rural households pursue a ‘livelihood strategy’ that may comprise a number of different activities such as farming, herding, fishing, off-farm employment and the exploitation of natural resources through hunting and gathering. In order to engage in these activities, households mobilize the assets at their disposal. A hallmark of the livelihood approach (see Reardon and Vosti, 1995; Carney, 1998; Bebbington, 1999; Ellis, 2000) is its emphasis on the capabilities of the rural poor, based on the recognition that even the poorest families hold wealth in at least some of the following categories:

Natural capital: the natural resource stock, or local environmental endowment (including water, wind, soil, forest resources);

Social capital: social resources, such as interpersonal networks, membership in groups, relationships of trust, access to wider institutions of society;

Human capital: including formal and informal education, local ecological knowledge, the ability to work, and good health;

Physical capital: including productive assets held by the household (land, tools, oxen) as well as communal assets to which they have access (roads, communication infrastructure such as radio broadcasts);

Financial capital: typically, the most fungible of assets, including cash savings, supplies of credit, or regular remittances and pensions.

¹Productive activities are those that generate cash and non-cash income—activities such as agriculture, wage labor, or craft production that ‘put food on the table’ and generate potentially tradable goods and services. Reproductive activities are those that guarantee the survival of the productive unit—i.e., household maintenance functions such as childcare, cooking and cleaning (Sousan et al., 1999).

²Thus, for instance, Birdsall (1988) in her review on economic approaches to population growth cites several studies that find that men and women express different targets for total fertility and the more educated is the woman the more effectively she is able to bargain within the household so that fertility outcomes are closer to her preference. Similarly, Strauss and and Thomas (1995) in their survey of the literature find that additional income in hands of the mother is likely to lead to significantly larger increase in children’s nutrition and education than a similar increase in income in the hands of the father.

Households' wealth is comprised of some combination of these assets. The type and amount of each that a household holds is a function of past investment and accumulation strategies, which in turn are shaped by social, cultural, political and economic opportunities and constraints. For example, a household may be considered wealthy in human capital if all adults have received a secondary education—access to which was determined in part by state investments in rural schools. As households build up their stock of one type of asset, they typically change their stock of, or access to, other forms of capital. For example, a household that liquidates forest resources in order to finance education is substituting natural capital for human capital, which may in turn yield employment opportunities that yield a steady stream of financial capital, which may then be depleted in order to invest in physical assets such as cattle.

The relationship that the household has with its environment, and by extension its impact on the environment, is mediated by its mobilization of these five forms of capital. The ability of the household to accumulate and utilize these forms of capital is further mediated by a number of factors. These include institutional factors (e.g., functioning markets and legal system, rights to organize, common property regimes, land tenure arrangements), cultural factors (status of women, culturally prescribed roles men and women can play, value of children, spiritual connections to the land), economic factors (national and global markets for locally produced goods), and global changes affecting the local environment (climate and oceanic pollution). Thus, a household, its assets, and even the local environment are all “embedded” in these contextual factors.

The body of work we review below does much to elucidate the relationships among household demography, household capital, and the environment, most notably through time-intensive, qualitatively rich research typically conducted at the level of villages or small rural regions. At this scale, contextual factors are very important for interpreting results. As the field moves towards more comparative work, we expect the development and testing of theories about the importance of context and interaction based on the divergent microlevel relationships found across study sites.

3. Household Population Dynamics, Environment and Natural Resources

Household population dynamics encompass several key variables: nuptuality, fertility, morbidity, mortality, migration, as well as the ‘lifecycle’ of a household, which is shaped by the former variables and affects a household’s size and age and sex composition. Given our focus on household-level demographics, we organize our survey of the related literature around these variables, rather than, say, by region, resource type, or bioclimatic zone.

This section is therefore organized into subsections addressing the relationships between forms of environmental change and fertility, morbidity and mortality, migration, and lifecycles. For each, we review recent scholarly work identified through searches of the Science Citation Index and the Population-Environment Research Network (PERN) eLibrary, as well as book chapters and monographs known to the co-authors, in which the researchers focus on households and give specific treatment to both demographic and environmental variables in their studies. This paper is thus a research synthesis rather than a meta-analysis. The multiplicity of independent and dependent variables would make a meta-analysis impractical, and a research synthesis allows us to bring together strands of research to advance theory in a more flexible and inclusive way.³ In each subsection we conclude with a discussion of the findings and their policy relevance, as well key questions for further research.

3.a) Fertility, Environment and Natural Resources

One popular theory to explain the existence of sustained high fertility in the face of declining environmental resources is the vicious circle model (VCM). In this model it is hypothesized that several positive feedback loops contribute to a “downward spiral” of resource depletion, growing poverty, and high fertility.⁴ An elaboration of these linkages can be found elsewhere (Marcoux, 1999; Lutz & Scherbov, 1999; O’Neill et al., 2001; de Sherbinin et al., 2007), but in its simplest form the model describes the following causal connections: poverty leads to high fertility through mechanisms such as demand for farm labor, ‘insurance births’ owing to high infant mortality, and the low status of women. High fertility then contributes to population growth which further increases demands for food and resources from an essentially static resource base; the declining per capita resource base reinforces poverty through soil fertility loss, declining yields, and poor environmental sanitation. Finally, poverty, in turn, contributes to land degradation by increasing incentives for short-term exploitation (versus long-term stewardship) and because poor farmers lack access to costly fertilizers and appropriate technologies. Seen from the perspective of the livelihoods framework, the VCM would suggest that households without access to other forms of capital seek to build their human capital (and social capital through the marriage and migration of children) in order to better exploit natural capital.

Sutherland et al. (2004) provide a review of the theory and literature on the relationships between natural resources and household fertility. Of particular relevance here are the studies they review that examine the relationship between fertility and farm size, cattle, and access to natural resources. The VCM would predict that all of these relationships are negative, with poorer households having higher fertility. We summarize here the key conclusions of the studies Sutherland et al. reviewed and then update them with some detail on more recently published work.

Farm size and farm tenure are key indicators of the physical capital of households. In contrast to the VCM, the relationship between this key productive asset and fertility (related to human capital) is expected to be positive under the land-labor-demand hypothesis advanced by Stokes and Schutjer (1984). They postulate that a larger farm size creates a demand for children as labor to keep land in production (and to retain use rights). This positive relationship has been observed in studies in Rwanda, Egypt, the Philippines, Iran, Peru and Ecuador (Hiday, 1978; Schutjer et al., 1983; Easterlin and Crimmins, 1985; Good et al., 1989; Clay and Johnson, 1992; Coomes et al., 2001; Carr et al., 2006). Alternatively, it has also been proposed that the effects of land tenure can counteract the relationship between farm size and family size. Under this land-security hypothesis, land tenure security creates economic security that lowers the need to invest in large numbers of children (Stokes and Schutjer, 1984). Greater security is associated with higher living standards, access to health care, and greater educational opportunities, all of which promote lower fertility. Studies in the Philippines, Egypt, Ecuador, Iran, India and Mexico provide evidence for the negative relationship between tenure security and fertility (Hiday, 1978; DeVaney and Sanchez, 1979; Vlasoff and Vlasoff, 1980; Schutjer et al., 1983; Good et al., 1989; Coomes et al., 2001; Carr et al., 2006).

³Recent meta-analyses of deforestation (Geist and Lambin, 2001), desertification (Geist and Lambin, 2004), and agricultural intensification (Keys and McConnell 2005) have sought to synthesize case study findings and uncover regional patterns of proximate and driving forces for each of the phenomena studied. For this paper we are unable to employ the same method because the variety of demographic phenomena examined (fertility, morbidity and mortality, migration) and the variety of natural resources affected (forests, wetlands, agricultural systems) mitigates against common metrics. Nevertheless, we have sought to identify studies that have confirmed or denied certain hypotheses.

⁴It should be noted that VCMs have been criticized as being oversimplified and as ‘blaming the victim’ rather than examining deeper political, economic and institutional imbalances that set the context for environmental degradation (Forsyth et al., 1998; Krings, 2002; Gray and Moseley 2005). A political economy perspective is indeed important for research on fertility-livelihood-environment linkages, but for the purposes of this brief review we will focus on the evidence of linkages between household-level fertility behavior and the quantity and quality of environmental resources rather than on what might be termed ‘underlying causes.’

Easterlin (1976) proposed that in frontier settings it is not the size of farm that predicts family size, but the perception of availability of land for one's children. In frontier areas, he argues, land is abundantly available, and therefore parents opt for higher fertility in expectation that land will be available for their children. As the frontier becomes settled it is expected that fertility would decline in response to the perceived scarcity of land to settle. This hypothesis has not been tested with household-level data, but macro-level studies have supported this hypothesis in Thailand, the United States and Brazil (Easterlin, 1976; Merrick, 1978; VanLandingham and Hirschman, 2001).

Cattle are second only to land as an important form of physical capital for rural families worldwide. But unlike land, cattle are portable assets that are easily transported and traded; further, they provide a stream of income from dairy products; and they represent a status symbol (Loker, 1998; Faris, 1999). Cattle grazing requires little labor and they can be sustained on land that is too poor for crops. Thus, it could be expected that cattle, like land, might factor into fertility decision making. For example, cattle could be seen as a retirement account that could reduce demand for children. However, Perz (2001) asserts (at least for the Brazilian Amazon) that cattle tend to be acquired later in life, after child bearing is completed, when households have acquired sufficient capital to invest in cattle. In this hypothesis, children are in demand by parents because they provide labor needed for early agricultural production and later, when they migrate out, remittances needed for acquisition of cattle.

More recent work continues to debate the relationships between farm size, farm tenure or cattle and fertility. In a study of Guatemala's Petén, an agricultural frontier, Sutherland et al. (2004) utilized a specially designed Demographic and Health Survey (DHS) that asked questions regarding land ownership, land use, fuelwood and water gathering, and attitudes towards conservation.⁵ Using number of living children as the dependent variable ("family size"), and controlling for maternal age, education and living standards, they found that neither farm size nor tenure security had significant effects on family size. Those perceiving land to be available for their children had significantly fewer children than those who perceived land to be scarce, which appears to undermine Easterlin's hypothesis but partially supports the notion that children may be seen as an economic safety net for those who perceive resources to be scarce.⁶ The authors posit, however, that this may actually reflect a reverse causality - that those with smaller families are more likely to report that land is available for their children. Ownership of cattle was strongly and positively associated with family size. Here again, reverse causality is more likely, since larger families are presumably older and therefore more likely to have accumulated the resources necessary for cattle ownership.

Carr et al. (2006) take advantage of a subset of longitudinal data collected in 1990 and 1999 to explore land-fertility relationships in the Ecuadorian Amazon. By using longitudinal data they were able to follow families and plots over time and analytically describe the relationship between landholdings and fertility. The data support the land security hypothesis (Stokes and Schutjer, 1984), with women in households with secure title having two-thirds fewer children than those without such titles. Consistent with the VCM hypothesis, women on the smallest farms in 1990 had more than double the number of children than did women on the largest farms. Large cattle and coffee holdings during the time period were associated with lower fertility. Generally their findings confirm hypothesized links between poverty and fertility: better off households that are more centrally located, with good access to markets and services, choose to limit fertility more than poorer households.

⁵Grandia (2005) describes the lessons learned from implementing this unique DHS.

⁶The perception of land availability question was only asked of land holders and not of landless families. On average 78% of respondents reported that they felt land was available for their children, which may simply suggest an overall "optimistic" attitude with regards to land availability in the future, despite the fact that 28% of families are landless.

Access to fuelwood and water are everyday challenges for most rural dwellers. In rural areas these tend to be collected from communal lands, such as forests and rivers. Gathering these resources is often left to women and children. Dasgupta (2000) hypothesizes that as these resources become scarce each additional child provides a marginal benefit through his or her labor. This suggests that resource dependency will result in higher fertility. There is empirical evidence supporting this hypothesis from Pakistan, Nepal, and South Africa (Aggarwal et al., 2001; Filmer and Pritchett, 2002; Biddlecom et al., 2005).

Two recent studies have focused on the importance of collecting open access resources for fertility preferences and behaviors, showing the value of human capital (children) as a complement to natural capital (open access water, fodder, and fuelwood). One is a longitudinal study from the Western Chitwan Valley of Nepal (Biddlecom et al., 2005), where three measures of local resource depletion - the time to collect fodder, the increase in time required to collect fodder in the prior three years, and household's dependence on public lands for fodder - were found to be significantly and positively correlated with desired family size, even when controlling for household wealth and numerous other factors found to influence desired fertility. Furthermore, women in households where the time to collect firewood had increased by more than an hour in the three years prior to the initial survey were more likely to have had a pregnancy in the three years after that survey. Another study, in Pakistan, found a similarly positive effect of firewood scarcity on the probability of a birth in the past five years - a relationship that varies across regions of the country, and may be partially explained by the evolution of property rights in different provinces (Filmer and Pritchett, 2002).

Much of the research on fertility-livelihood-environment linkages is predicated on the notion that childbearing decisions are largely an economic calculus, and that in rural subsistence-based societies the returns to childbearing are higher than the net costs. For example, evidence from Zambia suggests that the age at which children change from net consumers to net producers is about age 12 (Barrett and Browne, 1998). In Pakistan female children are judged to be net contributors to household activities between the ages of 11 and 16, and by age 18 female children effectively "repay" the time mothers spend caring for children and in other household tasks (Filmer and Pritchett, 2002). These studies suggest that even where children are resource gatherers, households do not begin to experience net benefits until they reach age 11, and in societies where girls marry early, the actual period of net contribution to a household's income is potentially very short. Yet there are obviously many other benefits to children beyond their immediate economic returns - including both the social/cultural benefits and longer-term benefits such as old-age security. In addition, recent demographic research has reevaluated the contributions of children to their families in traditional societies by showing how the timing of their contributions supports larger numbers of younger siblings than would otherwise be possible (Lee and Kramer, 2002) and showing how net contributions are higher when girls' contributions are measured more accurately (Sullivan and Kramer, 2006).

Discussion and Policy Relevance—The theoretical foundation of most of the work reviewed in this subsection derives from the household model of fertility (Becker 1960; Becker and Lewis 1973). This model has provided useful guidance for empirical work in terms of clarifying the various interdependent and simultaneous decisions facing households in terms of human capital (number and quality of children), production, consumption and labor market participation. This approach helps to identify how households choose different livelihood strategies, given their asset endowments and preferences. This said, however, the household modeling approach also has several limitations. Among them, the assumption of a unitary household may be misleading in several contexts where different members of the household have divergent preferences regarding family size given the asymmetry in distribution of costs and benefits of children coupled with asymmetric bargaining power. The household model also fails to take into account the complexity of social, political, cultural and religious context of

fertility. As Dasgupta (1995: 349) observes, procreation is an “activity at once so personal and so social.” In particular, proximate determinants of fertility in the form of use of contraceptives, duration of breastfeeding, and frequency of intercourse, are strongly influenced by cultural patterns (Caldwell and Caldwell, 1987; van de Walle and Meekers, 1992; Bardhan and Udry, 1999). A household in a given social context may therefore choose to have high fertility because of prevailing social and cultural norms. Since these norms change slowly, there exists the potential for high fertility to be sustained even in the context of a declining resource base.

The major focus of population policies in the developing world is on fertility and family planning. There have also been recent efforts to develop community-based population-environment programs that marry biodiversity and natural resource conservation with family planning and reproductive health programs (Grandia, 2005). Hence, these research results are potentially of considerable policy and programmatic relevance. Some researchers have made impassioned appeals for greater policy attention to fertility-environment linkages. For example, Clay and Reardon (1998) draw on their research in Rwanda and Madagascar to argue that intergenerational wealth flows from children to parents mean that it is economically rational for household heads to create a large pool of household labor through high fertility. Until this logic changes, they argue that fertility is unlikely to decline in rural Africa because households tend to “externalize” the costs of excess fertility by sending children away who are unable to contribute to household income. In terms of policy, they argue that the common practice of separating out population factors as “exogenous” to natural resource and environmental policies is mistaken, and that an understanding of household demographic responses to constraints and opportunities is fundamental to improved resource management.

One finding that bears policy attention is the importance of improving women’s status, and engaging women in activities aimed at improved natural resource management (UNFPA and IUCN, 1999; Tukahirwa, 2002). This can shift the economic calculus, as women consider the opportunity costs of having children versus engaging in income generating activities. It also results in their greater involvement in and control of fertility decision making. Improving women’s status has long been heralded as a “win-win” strategy for reducing fertility rates while improving incomes and the environment.

One of the limitations of much of the work reviewed above is that most rely on short-term—usually one-year—‘snapshots’ of rural livelihoods (although they do control for women’s age, education, and household wealth). Yet the family formation process is ongoing, and currently observed fertility rates are typically the result of prior decisions about a desired family size (Aggarwal et al., 2001). To get an accurate picture of fertility determinants, then, requires longitudinal studies (such as the Biddlecom et al, 2005 and Carr et al., 2006 studies reviewed above) to better analyze the dynamics of this process and to disentangle some of the complex endogeneity issues that arise in empirical analysis. There is also a parallel need to assess actual changes in resource stocks over time (e.g., plot size, forest extent or quality, wetland extent), and how these co-evolve with demographic decisions.

Further Research Questions—

- At what scales of analysis do posited relationships between resource availability or scarcity and fertility hold true?
- Do households “externalize” the costs of high fertility, and if so, in what ways? What is the relationship between household fertility and later migration? Do households with higher fertility send more migrants?

3.b) Morbidity and Mortality, Rural Livelihoods, and Environmental Resources

Environmental problems obviously have adverse effects on morbidity and mortality, through contamination or lack of drinking water or through decreases in crop yields and available food. The focus of this subsection is different, however. Here we explore here the ways in which morbidity and mortality at the household level influence livelihood strategies and dependency on local environmental resources. Overall, the small but growing body of literature provides evidence for significant relationships between household morbidity and mortality patterns and the natural environment, mediated through livelihood coping strategies. The primary conclusion of this emerging body of scholarship is that natural resources can have an important cushioning effect when households experience morbidity and mortality by providing a supplementary source of income, or replacing goods that might otherwise be purchased. Similar natural resource dependence is observed to occur during times of drought, famine, and natural disaster (McSweeney, 2005).

Morbidity and mortality are likely to increase the stress on household finances, particularly among households already living on the “margins” (de Waal and Tumushabe, 2003), pushing families deeper into destitution, often with concomitant increases in natural resource dependence (e.g., substitution of electricity or gas with local fuelwood). Because morbidity and mortality incur costs that are typically covered by depletion of household productive and financial assets, households become more constrained in the activities they can pursue, and thus worse-off overall. In the event of illness or death, they lose scarce capital (physical, financial, human, or even social). In some cases, however, this immediate outcome can be avoided if the household is able to liquidate natural capital held communally—as, for example, when forest products are sold to meet health costs.

In general terms, mortality leads to increased household vulnerability particularly if the deceased was a productive adult household member (White and Robinson, 2000; Yamano and Jayne, 2004). In a recent discussion of the impacts of HIV/AIDS on household livelihoods, Haddad and Gillespie (2001, p.489) bluntly state that “HIV/AIDS strips individuals, households, networks, and communities of assets.” AIDS-related adult mortality can yield degradation of nearly all forms of household capital. *Human capital* is lost as a result of lowered productivity (e.g., Barnett and Blaikie, 1992), the diversion of the labor of healthy individuals (Hunter et al. 2006), and the potential loss of remittances from employed migrant family members (Rugalema and Khanye, 2002). Intergenerational knowledge transfer also suffers (Haddad and Gillespie, 2001). HIV/AIDS also has important impacts on *financial capital*, as households lose breadwinners and incur expenses, and potentially debt, related to drug, burial and transport costs. *Social capital* may decline due to the weakening of institutions and the stigma associated with the illness. Research has also suggested that kin networks, a critical dimension of rural safety nets regarding food security, are undermined by AIDS (Mtika 2001), while *physical capital* may decline as a result of the sale of productive equipment or mortgaging of land (van Liere, 2002).

Especially relevant to this overview, the sustainability of *natural capital* may also be undermined by the HIV/AIDS pandemic through its impacts on other forms of capital (van Liere, 2002). Research suggests that such threats may take the form of lessened ability of communities and user groups to collectively manage common property resources such as rangelands (Haddad and Gillespie, 2001). At a household level, coping strategies in response to the economic impacts of morbidity or mortality of household members may include the sale of natural products such as grass mats, bark cloth, fuelwood and fruits (Barnett and Haslwimmer, 1995; Katunzi, 1999). Also, agricultural productivity may be compromised as a result of the loss of prime-age labor (e.g., de Waal and Whiteside, 2003). Less labor-intensive and less nutritious crops may be farmed, or land may lay fallow thereby threatening tenure (Haddad and Gillespie, 2001). Additional research reveals the importance of local

environmental resources as a buffer in maintaining food security, particularly in mortality-impacted households (Hunter et al., 2006).

The “buffer” provided by local environmental resources is evident in research in South Africa’s Limpopo Province. Hunter et al. (2005) examined the impact of prime-age adult mortality on household’s fuelwood provisioning strategies. This province has been hard hit by AIDS, which accounted for 21.5% of deaths in the year 2000. This is also a place where 92.3% of households use fuelwood for some portion of their energy needs. Paradoxically, the authors found little relationship between household socioeconomic and demographic characteristics and the amount of fuelwood consumed. However, interviews with household members revealed that loss of a family member resulted in important though often subtle changes in household labor and fiscal allocations, including increasing dependence on children for resource gathering tasks. They found that mortality exacerbates poverty, with natural resources serving as a buffer against poverty, and sometimes a means of generating income. Households which had lost a breadwinner were more likely to harvest fuelwood than buy it, thus saving money but decreasing their likelihood of climbing the “energy ladder” in the short to medium term.

Evidence of natural resources offering an important economic livelihood buffer has been found in Latin America as well. Amongst an Amerindian group in Honduras, Godoy et al. (1997a) found that the area of old-growth rainforest cleared for farming increased with the number of days family members were ill during the previous growing season, suggesting that households may engage in more forest clearing in order to pay off debts incurred during illness. Other research with this same Amerindian population, as well as with ribereño communities in the Peruvian Amazon, also found evidence that forest resources can act as a “safety net” in the context of household illness (McSweeney, 2004; Takasaki et al., 2004). This literature finds that where epidemiological risks are high, and formal insurance markets thin to non-existent, then some households are likely to sell forest products to cover the costs of illness. Young, undercapitalized households are more likely to self-insure this way, although only when women and children are sick, because adult males are the ones most likely to engage in remunerative extractive activities.

There is the potential for this line of research to yield important insights into the feedbacks between demographic change and environmental change by joining it with microlevel research on specific health impacts of environmental change. There is a growing literature on the health impacts of land-use transformations resulting from frontier migration, with recent studies focusing on growing malaria prevalence in Amazonia (e.g. Barbieri et al., 2005b; Castro et al., 2006; Vittor et al., 2006). This case could provide leverage for microlevel studies of reciprocal relationships because both key agents in land use change and those affected by malaria morbidity and mortality are settler households. Land transformations from migrating households produce environmental health changes that have real consequences for household morbidity and mortality, which in turn should affect natural resource use (based on the literature reviewed above).

Discussion and Policy Relevance—Natural resources have an important role to play in mitigating some of the impacts of adult morbidity and mortality on the household economy. However, this has potentially significant repercussions for ecological sustainability in rural regions of the developing world hard-hit by HIV/AIDS. At the household level, a picture emerges which counter-acts the naïve assumption that the demographic impacts of HIV/AIDS at a population level will lessen pressure on resources due to a declining people:land ratio. Rather, adult morbidity and mortality could contribute to further environmental degradation in such contexts due to the way these events shape household livelihood strategies, which may become more reliant on the exploitation of natural resources, while simultaneously eroding

human and social capital needed at a community level to manage common property natural resources.

Until recently, the environmental dimensions of HIV/AIDS have been largely neglected by both researchers and policymakers. With regard to policy, we find that since the environmental impacts of mortality and morbidity are generally mediated through household poverty, the same policies and programs that improve livelihoods, natural resource management, and public health, as well as mitigating risk or providing insurance for vulnerable families, need to be redoubled. Specific natural resource conservation interventions might encourage the establishment of low-input enterprises based on the sustainable production and use of non-timber forest products, agro-forestry efforts, and on production of wild indigenous products for meeting dietary needs (Barany et al., 2001).

Further Research Questions—

- To what extent do households substitute losses in human capital (due to illness or death) by drawing down local stocks of natural capital? In effect, just how widespread are the insurance functions of forests, or other sources of fuelwood or water, and at what cost to their long-term sustainability?
- How has growing malaria prevalence in the Amazon and elsewhere affected household labor and natural resource dependency?
- To what degree, and under what circumstances, does AIDS-driven mortality result in a substitution of child labor for adult labor within the household, and to what degree is household human capital undermined when this happens (through loss of educational opportunities, compromised quality of work and thus of farm productivity and, by extension, nutrition)?
- To what extent might investments in rural health care, microcredit lending, or insurance programs lessen the need to exploit forest products or overexploit agricultural lands during health crises?

3.c) Migration, the environment and natural resources

Much of the research on the impacts of migration on the environment looks at migration at the aggregate or societal level, divorced from household livelihood strategies, and with a particular emphasis on impacts in destination (especially frontier) areas. Migration is widely considered to be one of the most important demographic factors affecting the environment. Yet, because the types of migration (including return, repeat, circular, permanent, and temporary) are as many and varied as the intervening variables (socioeconomic status, migrant selectivity) and environmental outcomes (deforestation, fisheries depletion, etc.), it is also one of the most difficult to adequately assess (Curran, 2002). The focus here will be on out-migration as a household strategy and its relationship with the environment and natural resources at places of origin rather than places of destination. Thus, our focus on household livelihoods necessitates the exclusion of good work being done on environmental refugees and on similar community or contextual effects on migration. It does not, however, preclude an assessment of frontier areas, since established households in these areas often employ a number of migration strategies to supplement their livelihoods.

We follow the approach currently in favor in demography of examining migration from rural households as an individual behavior that results from a household level decision-making process (Stark, 1991). Households strategically deploy their human capital (both the number and education of members) across locations and economic sectors in order to increase income, access financial capital (in the absence of functioning credit markets in origin areas) and

minimize risk. The environmental impact on the sending area depends heavily on who is sent, whether the siphoning of labor to other areas reduces pressures on land or other resources, and how remittances are allocated. The impact of resource scarcity or other environmental factors on a household's decision to send migrants is not well studied, except perhaps in the case of land resources. There is ample historical evidence to suggest that scarcity of land resources has led to waves of outmigration to new lands, as occurred in European history and is repeated from the cores to the peripheries of many developing countries (e.g. from other regions of Brazil to the Amazon, from the Ecuadorian Andes to the Amazon, or from the highlands of Guatemala to the Petén). Land scarcity is a key driver of migration in Uganda (Tukahirwa, 2002) and Nepal (Shrestha, 1990); yet, VanWey (2003, 2005) finds that both a lack of land *and* a large amount of land can motivate migration in Thailand and Mexico.

Household approaches have been increasingly used to investigate the relationship between migration and the environment, particularly in areas of high biodiversity and natural value (Barbieri and Bilsborrow, 2005). One of the theoretical approaches to research in this area has been the multiphasic response (Bilsborrow and Okoth-Ogendo, 1992). Modeled on the multiphasic response theory of fertility regulation in rural settings (Davis, 1963), its application in the area of population and land-use change suggests that in response to population growth and perceived changes in the living standards, societies adopt several strategies: tenure regime change, extension of the cultivated area (extensification), technological innovation (intensification), outmigration, and fertility regulation. Bilsborrow and Okoth-Ogendo apply this at the household level, suggesting that when faced with resource scarcity households will pursue a variety of strategies, including intensification, extensification, and out-migration (first of individuals and then of the whole family).

Empirical research on the relationships between migration and environment shows mixed results. Using a multi-level longitudinal data set from Burkina Faso, Henry et al. (2004) show that the risk of out-migration is higher in villages with unfavorable agroclimatic conditions than in villages with favorable agroclimatic conditions, and is lower in villages with increased water conservation technologies. These effects are largely on short-term moves, which supports the theory that short-term migrations are part of a strategy to diversify income sources in a risky environment. In a longitudinal study of household migration strategies in the Northern Ecuadorian Amazon, Barbieri and Carr (2005) find that on-farm natural resource constraints are significant drivers of migration, with higher population density and declines in areas under forests and crops associated with higher levels of male outmigration. Overall, though females were more likely than males to migrate to urban areas, both males and females had a higher probability of moving to rural frontier areas than to urban areas, leading the authors to suggest that a "vicious cycle" may be in place whereby households that settled in the first wave of frontier migration use up resources and then send younger members to settle more distant areas, with the potential for the same pattern repeating itself in the next generation.

However, too unfavorable environmental conditions can also hinder migration. Rainfall deficits and bad harvests tend to limit people's ability to invest in long-distance moves in Mali (Findley, 1994). Other studies in Burkina Faso suggest that if resource scarcity is severe enough in source areas, household poverty levels may actually preclude the possibility of a move to more favorable regions (Cordell et al., 1996; Goldberg and Frongillo, 2001). Some additional studies find no effect of environmental factors on migration. Homewood (1997) studied land use, household viability and migration among the Fulani herders of the Sahel, and showed that neither seasonal migration nor shifting livelihoods are necessarily or even primarily driven by either economic necessity or environmental deterioration. Actually, cultural constraints and social networks emerge as very important determinants of migration decisions at all levels. Environmental variables were not significant determinants of the decision to engage in seasonal labor migration.

Any discussion of household migration-environment linkages without an assessment of the role of remittances would be incomplete, though the empirical research on remittances and the environment is sparse. Remittances may have beneficial impacts on the local environment by reducing resource dependency through the substitution of purchased goods (such as electricity or imported food) for locally produced goods. They may be invested in resource-conservation (e.g. fertilizers to improve soil fertility) or environmental activities. They may also allow households to manage the risk inherent in rural livelihoods. For example, in Lucas and Stark's (1985) influential study of remittances in Botswana, remittances support households whose incomes are sensitive to drought, especially in times of severe drought. On the other hand, remittances may have negative impacts on the environment by increasing investment in environmentally detrimental practices such as extensive pasturage or the transformation of agricultural lands into peri-urban real estate (Jokisch, 2002).

Case studies examined during a 2001 PERN cyberseminar on coastal population-environment linkages illustrate some of these dynamics. One study of the Micronesian Island of Kosrae (Naylor et al., 2002) found that 15% of the island's population was living abroad and remittance income was important to all households, especially subsistence households. In another study of coastal Vietnam, remittance income comprised 9% of household income (Adger et al., 2002). Finally, in a mangrove area of El Salvador, 73% of farming families and 56% of rural families have family members who have migrated and are sending remittances (Gammage et al., 2002). The case studies demonstrate that the financial capital available to rural households from remittances has demonstrable impacts on the environment. On Kosrae, increasing dependence on remittance income appeared to reduce dependence on the local natural resource base - but also resulted in the loss of human capital in the form of local ecological knowledge necessary to manage mangrove resources sustainably. In the case of Vietnam they were negative, insofar as they enabled local farmers to purchase more land for aquaculture, which resulted in mangrove clearance. In the case of El Salvador they were mixed, because remittances were used by some households to purchase firewood (increasing pressure on forests) and others to purchase alternative fuels (decreasing pressure).

Discussion and Policy Relevance—Future demographic change in much of the world will be dominated by migration as countries complete the demographic transition and fertility and mortality rates fall to lower levels. Policies to promote socioeconomic development and environmental sustainability in rural areas, especially those of high natural value, will be influenced to a major degree by how governments react to or shape these increasingly important migration dynamics. Yet little is known about how natural resources affect or are affected by migration and remittances. The effects of out-migration on environmental outcomes may be mediated by farming system - with impacts being less significant in cattle raising systems where labor demands are small. They are also conditioned on the institutional environment, as migration is often a strategy to access capital or mitigate risk in the absence of functioning credit and insurance markets. VanWey (2005) suggests that individuals from households with large landholdings migrate to access capital for investments in technology and other agricultural inputs. If this is the case, migration might increase environmental impacts rather than providing an escape valve for excess population, as suggested in the multiphasic response approach.

It is also particularly important to understand the relationships between natural resource degradation or constraints and the gender and age patterns of out-migration. Barbieri and Carr (2005) and VanWey and Cebulko (forthcoming) find significant gender differences in migration patterns for two areas in the Amazon, with men typically going to other rural frontier areas, and women preferring incipient frontier urban areas, with important implications for available labor for land-clearing and fertility in the next generation. Liu et al. (1999) argue for the importance of the age pattern of out-migration by showing that out-migration of young

adults from a protected area in China will reduce future pressure on resources substantially more than out-migration of older adults.

There has been a growing literature on environmental refugees—i.e., people displaced land loss and/or degradation, and natural disaster (Döös, 1997; Urdal, 2005). By definition such movements are prompted by environmental changes. However, little research on such refugees considers the role of households or conducts micro-level analyses. Although the dividing line between a migrant and a refugee is sometimes blurry, especially in cases where only some members of the household move, research could usefully examine the role of household decision-making processes that lead to the decision to leave an area, and how such movements affect the sending areas. One such piece finds few effects of environmental conditions on migration in Nepal, and what effects are present are largely on local moves rather than long-distance moves (Massey et al. 2007).

Further Research Questions—

- How is migration differently affected by long-term resource scarcity and acute environmental crises? What are the long-term impacts of these on sending regions?
- What are the effects of household out-migration on environmental quality and natural resource stocks in migrant-sending areas?
- How are gendered patterns of migration related to control over or ownership of natural resources?
- Do remittances increase household spending in environmentally beneficial or damaging ways? How do economic and cultural context condition the effects of remittances on whole household budgets?
- How do remittances with different motivations (e.g. altruistic remittances that appear quite regularly vs. insurance remittances that arrive following a crisis) differently affect land use, natural resource extraction, and other key environmental variables?

3.d) Household lifecycle and the environment

Household lifecycles are determined by changes in household-level demography - due to fertility, mortality, and migration - over time. The lifecycle begins with household formation—typically when a new residence is established by a married couple. Children are then born and are reared to the point where they become economically contributing members of the household, eventually marrying and either leaving or staying within an extended family home.⁷ The original household lifecycle “ends” when the founding couple are no longer those that make key livelihood decisions. Different points in the lifecycle are characterized by different household age and sex compositions, dependency ratios, etc., and these lifecycle dynamics can have important consequences for labor availability and household livelihoods, and thus for land use strategies—most importantly, wealth in human capital (labor) is used to accumulate other forms of capital (e.g., land, cattle). How and when that labor is devoted to what activities, and with what environmental outcomes, is at the crux of research into the links between environment and household lifecycle.

The theory upon which much research on household lifecycles and the environment is built is Chayanov’s household economy framework, which was the first attempt to conceptualize the relationship between a household’s age (i.e., stage in household lifecycle) and its landholdings (Chayanov, 1966; Walker, 2003). Chayanov, a Soviet economist, observed that peasant

⁷This simple parent-child model may be complicated in large extended family households. Also, particular arrangements vary by culture and by context (e.g., in long-settled vs. frontier areas).

farming households possessed farms of different sizes, and that well-endowed households with many family workers typically possessed larger holdings than those constrained by labor shortages; aging couples then bequeathed land to their children in a subsequent stage of asset disinvestment. Although not explicitly developed for frontier situations, his theory suggests that household size at a given time is related to the amount of land that would be cleared for cultivation in environments characterized by land abundance and labor scarcity (Walker et al., 2002; Caldas et al., 2007).

To date, household lifecycle-land/resource use links have been investigated across a broad spectrum of environmental and ethnocultural settings, most notably in Latin America. Studies have focused on new arrivals to the Brazilian and Ecuadorian frontiers (Pichón, 1997; Murphy 2001; Brondízio et al., 2002; McCracken et al., 2002; Vosti et al., 2002), indigenous colonists migrating from land-constrained environments to lowland frontiers (Weil, 1989; Bedoya Garland, 1995; Carr, 2004), long-established ribereño communities in Peru (Takasaki et al., 2001; Coomes et al., 2001, 2004), and long-settled indigenous smallholders in Bolivia and Honduras (Godoy et al., 1997b; Godoy, 2001; McSweeney, 2004).

By far the greatest work on the land use-household lifecycle issue, however, has been conducted in the context of forest frontiers, particularly in the Amazon basin. Walker et al. (2002) review a large number of studies conducted in the Amazon for evidence of household size and lifecycle impacts on land use and deforestation, among other outcome variables. Out of 20 studies reviewed, they only identified a few that found statistically significant relationships between land use or environmental dependent variables and lifecycle factors such as age of household head, duration of residence, family size, and number of children. For example, research has shown that duration of residence increases the cutting of old growth forest, and reduces the amount of forested land on colonist properties (Pichón 1997; Godoy et al., 1997b and 1998). Duration of residence is also linked to land uses such as coffee plantations and pastures that would presumably require prior clearing (Jones et al., 1995; Pichón, 1997). Besides the duration of residence effect, attributes of household structure affect land use and deforestation in several studies. Family size is positively related to the amount of land cleared (Rudel and Horowitz, 1993; Pichón, 1997), as is number of adult males and females (Sydenstricker-Neto and Vosti, 1993). These various findings are consistent with the Chayanovian framework explaining deforestation in terms of household experiences, attributes, and structures.

Recent work has built upon this framework, but still finds mixed results regarding household life cycle effects. The clearest pattern to emerge from much of the recent research in the Amazon is that there is a cycle of deforestation at the property level. In one study area (Altamira) in the Brazilian Amazon, McCracken et al. (1999) and Brondízio et al. (2002) use satellite data at the property level to show this cyclical pattern. In the first five years of settlement, colonists begin their occupation with a rapid spurt of deforestation necessary to establish rights to the land and to produce crops. After this the rate of deforestation declines as households seek to manage the areas already cleared, and try to control the aggressive regrowth of native species. Research in Uruará (Pará, Brazil) has also documented, through panel analysis, a shift in farming systems, from mixed consortiums of annuals, perennials, and pasture to a dramatic emphasis on pasture, findings consistent with the Brazilian extensification model as formally stated by Walker (2003). Barbieri et al. (2005a) find similar evidence for cycles of land use change in the Northern Ecuadorian Amazon. The proportion of land in three classes - forest, pasture and cropland - among later settlers (despite overall smaller properties) is almost identical to the proportions for earlier settlers, reflecting similar strategies at similar lifecycle stages even if their landholdings are less than half as large.

In work focusing on the vicinity of Uruará (Pará, Brazil), researchers have investigated deforestation and secondary forest dynamics using remote sensing and panel data collected

from field surveys (Perz and Walker, 2002; Walker et al., 2002; Perz et al., 2006). Regression analyses show that more household labor is associated with more deforestation, an effect that dominates any impacts associated with internal dependency due to young children and elderly individuals. More recent work in Altamira, Santarém, and Uruará (all in Pará, Brazil) questions the interpretations of past findings as household life cycle effects. Once the time since acquiring the property is controlled, the household age has no significant effect on land use (VanWey et al., 2006; Caldas et al., 2007). In addition, the pace of conversion to profit-oriented systems, especially ranching, appears to occur very quickly, too “fast” for the impacts of dependency on household decision-making to manifest, as anticipated by Chayanov (Aldrich et al., 2006). Household lifecycles may not have the expected effects because of the availability of hired labor and the focus of households on profit above and beyond subsistence (both unaddressed by Chayanov’s theoretical development; see Walker, 2003; VanWey et al., forthcoming). Instead, cycles of deforestation represent property life cycles unique to newly opened forested frontiers.

Compared with the tremendous research focus on frontiers, relatively less work has been done on the links between household lifecycle and land/resource use in long-settled rural areas. What research has been done suggests an imperfect match between the findings of household life cycle research at the frontier, and similar research conducted among long-established indigenous and ribereño communities. That is, even though researchers have found that in these long-settled contexts, younger households tend to deforest more and to extract more forest products than do “older” households (e.g., Godoy et al., 1997a; McSweeney, 2004), they may not be motivated by the same factors as young colonist households. Further, their aggregate impact on the landscape may be considerably more benign. The most important factors to consider here appear to be the ethno-social and institutional contexts. Unlike remote homesteads on the colonization frontier, indigenous and ribereño households are bound up within the tight-knit kin networks of long-settled villages. Risk is therefore carried as much by the group as by an individual household. A young indigenous family, therefore, may have less need to spread their agricultural risk through extensification; crop failure can be mitigated by the post-hoc safety net of inter-household food transfers. In addition, their risk is lessened as household members benefit from their own and their community’s agro-ecological knowledge. Further, the constraints of high child dependency can be somewhat loosened for young indigenous families through communal child-care support, on the one hand, and access to established systems of labor reciprocity on the other. In addition, land tenure is relatively secure in long-settled areas, obviating the need to clear land to stake one’s claim.

Discussion and Policy Relevance—One key insight of life cycle research has been seeing the landscape as a patchwork of properties (or used areas), each associated with households with different characteristics. This allows researchers to think about landscape change in much the way that demographers understand population change, as a result of the mixture of older and newer households on the landscape and the deforestation (or other land use change) probabilities of each. The research reviewed here has helped us to see that population-environment relations that in the past were viewed in the aggregate - using county-level population and deforestation data - are considerably more complex the closer one gets to where the machete meets the underbrush or the hoe meets the ground. Understanding incentives for production and reproduction at the household level sheds light on the policy levers that might be employed in an effort to improve household livelihood security while preserving as much forest land as possible. This does not mean, however, that the policy solutions are simple. And there is a risk that focusing on smallholders—indigenous or otherwise—may result in the neglect of other actors - such as illegal loggers, corporate soy farms, or oil prospecting - that have a far more devastating impact on tropical forests (see, e.g., Hecht, 2005; Nepstad et al., 2006).

Ultimately, the focus of research into household lifecycles and environment must expand to cover varied social and cultural contexts, which clearly modify the relationships between household lifecycle stage, household composition and environmental impact. For example, a closer look at lifecycle issues within Latin America's indigenous communities has important policy implications. This is because indigenous populations appear to be growing much faster, and are correspondingly younger, than their non-indigenous rural counterparts (McSweeney and Arps, 2005; Pagliaro et al., 2005). This implies that present and future indigenous landscapes are likely to be dominated by the imprint of youthful households. A better understanding of these households relate to their environment might contribute to a more systematic understanding of why, despite high and growing population densities, long-settled indigenous households are found to be associated with much lower per capita rates of deforestation than non-indigenous settlers (Nepstad et al., 2006; Stocks et al., 2006). In the past, indigenous peoples' light ecological footprint was explained by their low population densities, relatively low rates of market integration, and simple technologies. New data are showing that even when these conditions change, indigenous people can still be effective forest/resource stewards (Zimmerman et al., 2001; Guzmán et al., 2003).

Beyond this geographical and cultural extension, research on lifecycles must be extended to understand intergenerational change. While results from studies of first generation settlers in Amazonian frontiers shows that household life cycles ultimately explain very little of what is happening, the intergenerational dynamics of coresidence on rural properties, home-leaving by children (including where they move, see migration section above), and inheritance (or sale) of farms are essential for understanding the long-term equilibrium distribution of land use in such areas.

Research questions—

- Much of the research on household lifecycles and the environment has been in Latin America. Further investigations are warranted of how these dynamics differ in land-constrained Asia, or in Africa, where forest land in the Congo basin remains relatively abundant, yet political instability grips the region.
- How do intergenerational processes affect land use and land cover? How do we incorporate land inheritance, and the formation of new households through the marriage of children, into our models of first-generation lifecycle effects?
- How do lifecycle changes interact with institutional arrangements (e.g. availability of rural retirement or subsidies for children) to affect land use and natural resource extraction?
- How do processes of migration (and remittances) and off-farm employment change the theoretical model of the household lifecycle?

4. Conclusion

This has necessarily been a cursory examination of a large body of literature. As the reference list shows, there has been an exponential increase in the amount of research dedicated to household demographics and the environment since these studies began around 1990. There have also been many theoretical and methodological advances during this time, and a growing understanding of the complexity and place-specificity of population-environment linkages. In this sense, it will not be possible to “turn back the clock” and return to simpler mono-causal explanations for environmental change, focused as they were on abstract concepts of an aggregate population impacting on an aggregate environment.

The research also underscores one of the fundamental issues in population-environment research - which is that in studying the connections between humans and their environment, one is really studying *everything*. The question of where to draw the bounding box of what is endogenous to the system and what is exogenous becomes increasingly difficult. As Moran et al., (2005) write:

The reality is that people are interacting with the physical environment in a myriad of ways - from the cognitive act of choosing where to settle, whom to migrate with, whether they pick flat or steep terrain, whether they give priority to proximity to a water supply or not, to soil color or not, whether they interact with natives or keep to themselves, whether they collect germplasm regularly from neighbors or import it from areas of origin, whether they have the knowledge and the means to practice contraception, and how the timing of contraception fits with views they may have of desirable family size and long-term goals for those children and themselves. This complexity of human-environment interactions requires multi-disciplinary research involving theoretical flexibility and a multiplicity of data collection tools that can capture the variety of sources of change and the variety of responses by the population. (page 129)

Nevertheless, there have been admirable advances in teasing out the linkages, and this has contributed to our collective understanding of how humans, bound together in economic units called households, alternately modify their environment and respond to environmental changes and resource constraints in some of the poorest and least developed corners of the world. This research can play an important role in informing strategies for achieving the Millennium Development Goals, and for the work of the Poverty-Environment Partnership, a group of major donors seeking to reconcile poverty alleviation goals with environmental stewardship. It is worth noting, however, that much of this research has been conducted in fragile environments or in remote areas with high conservation value, where efforts to help households climb out of poverty will be particularly challenging and where research results might be specific to high-risk conditions.

The largest remaining challenge for understanding household demographics, livelihoods and environment is moving beyond case studies. While households vary in their access to natural, human, physical and financial capital, they also vary in how their endowments of these translate into livelihood strategies. To some extent, this is a function of social capital, a household's access to and use of societal institutions. However, it also depends on the social, economic and cultural organization of the society in which the household is embedded. Throughout this review we have seen the importance of managing risk through diversification, ensuring future income security, and culture-specific norms regarding appropriate and desirable activities and demographic responses. None of this will surprise scholars studying rural households throughout the world. The challenge is integrating our knowledge of these households' decision-making processes with a rigorous analysis of environmental inputs and outcomes.

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