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Population and Land Degradation

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Michigan State University

No. 14 August 1994

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Abstract

In this paper, we argue that there exist no significant direct links between human populations and their environments and that the intervening processes create the context within which land degradation occurs. We examine some of the intermediate mechanisms through which mounting demographic pressure leads to soil erosion and the depletion of soil fertility. The focus of attention is on set of variables defined in this paper as the structure of landholding (size of holdings, fragmentation/ dispersion, fragility, tenure, etc.). How demographically-induced changes in the structure of landholding affect land management strategies (investments and land use) is key to understanding land degradation. Traditional perspectives on population and agricultural intensification, such as those developed by Malthus and Boserup, are incomplete at best. This is because they fail to fully incorporate the intermediate linkages both to and from the changing structure of landholding. As a result, avenues for policy research and intervention have been limited. On the population side, the answer has been to control growth (mostly through family planning). On the natural resources side, the thrust has been the dissemination of resource-saving technologies. The paper concludes with a discussion of the implications of this review for future research and policy action.

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Contents

Introduction

Land degradation often occurs under conditions of rapid population growth. Indeed, generations of social and environmental scientists have viewed the impact of population growth on the natural resource base as a given. For those focusing on more "manageable" aspects of the degradation problem, such as conservation engineering, the population-environment link is no more than a convenient point of departure. And the logic does seem simple: demographic pressure implies more intensive use of natural resources, which translates into environmental decline. However, there is a basic weakness in the equation: it limits our potential for research and policy intervention to only two arenas. One is purely demographic and underscores the need for populations to lower their fertility. The other is the development and dissemination of new agricultural technologies to help control land degradation while increasing production, a central theme of mainstream environmental research today.

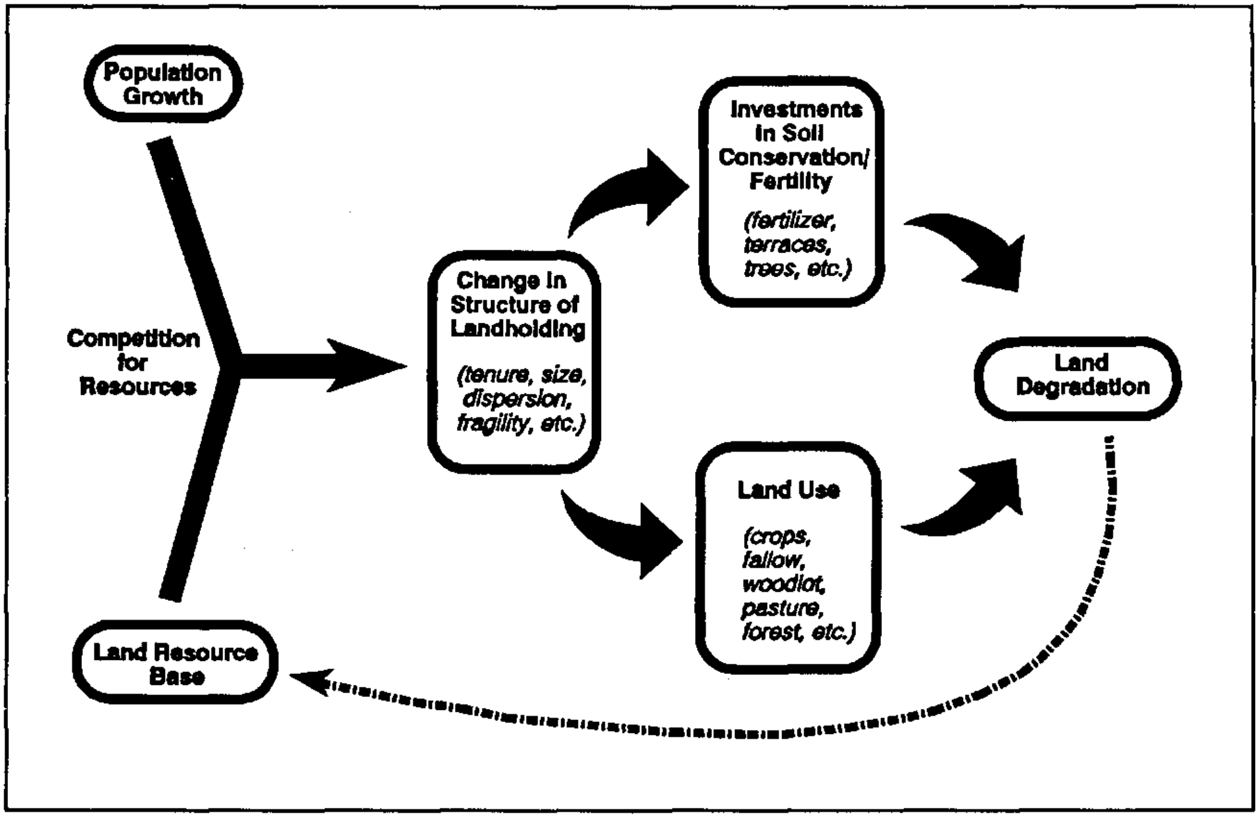
Acceptance of this oversimplified, two-dimensional representation has been frustrating for those seeking to understand the environmental effects of social change. Nowhere has this conceptual shortcoming been more apparent than at the Earth Summit held in Rio de Janeiro. Environmentalists avoided the population question because they saw it burdened by highly sensitive family planning issues. Yet, in the conference aftermath, experts recognize that the issue was oversimplified. We do not yet understand even the basics of population and degradation dynamics (Holloway 1992).

In this paper, we challenge conventional wisdom by asserting that there are no significant direct links between human populations and their environments. Consistent with classical theories of human and cultural ecology (Hawley 1950, Steward 1955, Cohen 1968), we maintain that human populations are "cushioned" from their natural environments by elaborate cultural and organizational systems. These systems change and adapt as populations expand and as resources grow scarce. For this reason, environmental decisionmakers are recognizing that we cannot solve population-resource problems simply by slowing population growth or increasing available resources through technological innovation (Simmons 1988:152).

To be sure, independent research efforts on both sides of the equation are vital and exhibit many context-specific successes and failures. However, we now need to begin to explain, in conceptual and empirical detail, the particular social, cultural, and economic *mechanisms* through which mounting demographic pressure affects land degradation. Understanding these intermediate relationships will vastly broaden our spheres of policy action in the struggle to conserve precious land resources. This is particularly true in those areas of Africa, Asia, and Latin America where rising population densities are threatening long-term environmental sustainability.

The present research focuses on one particular set of intermediate variables through which demographic changes can alter the natural environment. We refer to them collectively as the *structure of landholding*. These variables are especially important because they include the main physical and social properties that define the relationship between farmers and their land. Size of holdings, fragmentation (dispersion), and fragility are among the more obvious physical attributes that differentiate one farmer's holdings from another's. Along the social dimension, land tenure (use/ownership rights) stands out above all others. We contend that increasing demographic pressure and the resulting competition for scarce resources promotes restructuring of the physical and social attributes of landholding. In turn, these changes can damage soil productivity. They operate indirectly by impacting land management practices, including land use, conservation technologies, fertilizers, lime, and other inputs (see figure 1).

Figure 1. Conceptual Framework Linking Demographic Pressure and Land Degradation Through Changes in the Structure of Landholding and Land Management (Land Use and Investments in Soil Conservation and Fertility)



We must caution that the sequence of interrelationships in figure 1 is far from a full accounting of the process of land degradation in low-income, agrarian societies. Such a model would be vastly more complex and comprehensive. It would have to equally emphasize other factors such as class structure, market forces, the availability and affordability of purchased inputs, and variations in basic agroecological conditions. Rather, this model provides a framework for considering only relationships that help us understand the critical paths of influence between population pressure and land degradation. We also restricted the research geographically to land degradation in developing countries. We do not want to downplay the environmental impacts of population in industrialized countries or the global implications of resource use by those nations. Rather, we emphasize the extreme conditions of declining productivity and food shortage faced by the millions of rural people living in the world's primarily agrarian societies.

Presented here is a systematic review and discussion of the interrelationships that comprise figure 1. We will examine each in both conceptual and empirical terms as we relate to the findings and perspectives expressed in existing segments of the research literature. The review begins with a generalized discussion of how population growth, particularly in resource-scarce environments, can lead to changes in the structure of landholding (size of holdings, fragmentation/dispersion, fragility, tenure, *etc.)*. We show that traditional perspectives on population and agricultural intensification, such as those developed by Malthus and Boserup, are incomplete at best. This is because they fail to fully incorporate the intermediate linkages both to and from the changing structure of landholding. In subsequent sections, we review research findings on landholding changes and land management (investments and land use). In turn, we show how these relationships can lead to a sustained decline in soil productivity. We conclude with a discussion of the implications of this review for future research and policy action.

Resource Scarcity and the Changing Structure of Landholding

Human populations derive their livelihoods from the resources of their habitats. They differ from other populations in that they develop specialized technologies and work patterns (sociocultural systems) to exploit these resources. Beneath this "cushion of culture," however, societies are subject to the fact that they neither have unlimited environmental resources nor the unlimited ability to exploit them. Indeed, according to Boserup (1965) and others, it may be precisely from these limitations that the tools, knowledge, and division of labor unique to human cultures will emerge. Any system of exploitation is limited in the number of people that it can sustain through time. Populations must achieve a delicate balance between their demand for resources and the environment's ability to supply them. A population that exists in ecological equilibrium has a production system that satisfies both demand and supply in a harmonious relationship over time. Wilkinson (1973:21) elaborates on that notion, suggesting that:

> The concept of an ecological equilibrium is meant to cover any combination of a method and rate of resource use which the environment can sustain indefinitely. It may refer to a situation in which the population restricts its demand for resources to a level which the environment can supply naturally, or it may refer to a balance struck on the basis of particular cultural patterns of resource management by which the environment's production of particular renewable resources is artificially increased.

Either an increase in the population's demand for resources or a decrease in the environment's ability to supply resources will upset the ecological system. Growing population pressure is a major source of such disturbance. Scarcity and competition for resources characterize systems in ecological disequilibrium. The impact of demographically-induced land scarcity on agricultural growth and sustainability has been a subject of considerable debate since the time of Malthus. To this day, proponents of Malthusian doctrine say that population increases will eventually reduce food surpluses, arrest agricultural development, and lead to starvation and other "positive checks" (Dupaquier 1983).

In contrast to the Malthusian position is a school of thought articulated by Boserup (1965, 1981, 1985). She contends that resource scarcity brought on by population growth will promote agricultural intensification and increased productivity. She has linked population pressure to various economic processes, such as changing labor productivity. These processes which are "constrained" by nature, society and culture, infrastructure, education, and technology. Boserup seeks to know "how the process of modern economic growth is influenced by the demographic and technological changes that distinguish this century from others" (Schultz 1990: 2).

Empirical study from densely-populated regions around the world suggests that both perspectives have flaws. For every demographically-induced agricultural development, there exists a similar situation where such change did not occur. In some cases, the well-being of the rural population actually declined. Both Malthus' and Boserup's models suffer from a profound weakness. They do not account fully for the intermediate effects of a changing structure of landholding. These are changes in the basic relationship between farmers and their land.

Boserup does not systematically address the physical aspects of landholding such as fragility or dispersion. However, she does hint at the importance of demographically-induced changes in land tenure. Yet even here, her treatment concerns only the tendency of farmers to move from collective land ownership to individual ownership as land becomes increasingly scarce. Since individual ownership gives farmers greater incentive to invest in the productivity of their holdings, Boserup contends that productivity will increase under population pressure. This argument fails to address whether the induced production changes are sustainable. It also does not deal with the continuing changes in tenure that often occur after the change to individual ownership.

In most countries where there is serious population pressure on resources, collective ownership of farmland is no longer common. In densely-populated Rwanda, for example, this change began decades ago and is now nearly complete.[2] In Botswana, the shift to individual ownership has done little to lessen the degradation of formerly communal lands. Instead, it has contributed to greater inequity in land distribution.

More important, in many such countries, is the demographically-induced shift toward tenant farming and absentee ownership. While farmers may still individually hold land, they are less likely to farm it themselves. In Rwanda, more farmers now piece together holdings by travelling longer distances to fields and by renting land from their more affluent neighbors. Indeed, Rwandan farmers now rent 18.7% of all parcels operated, an increase of about 1% per year since 1983.[3]

An important hypothesis in the following section suggests that tenant farmers in Rwanda and elsewhere are less likely to invest in soil conservation and productivity-enhancing inputs. In contrast, the argument goes, landowners are more likely to invest. Similarly, renters may be less likely to use their land for pasture, woodlot, perennial crops, or fallow, all of which are environmentally safe uses compared to annual crop production. Moreover, changes in the tenure system form only part of the picture. Population pressure also alters the physical properties of farmers' holdings (size, dispersion, fragility), which can reduce farmer investment and lead to degradation. Boserup has also overlooked these changes that may help us to understand those cases where her hypothesis falls short.

All across the developing world, farm size is shrinking as farmers continue to subdivide holdings among their children. In countries such as Malawi, Rwanda, Haiti, and Bangladesh, population growth rates are high, and the non-farm sector is still in its early stages of development Farms now average less than 0.5 hectares in some areas. Ever-increasing numbers of farm households in these settings have become nearly or entirely landless. Almost half of the population is not yet in their childbearing years or of an age to inherit land from their parents. When the population does reach this stage within the next 10 years, declining farm size and landlessness in these countries may reach staggering proportions.[4]

Not only do farms become smaller as a result of population pressure, they also can become more fragmented (dispersed). Fragmentation usually occurs when a single farm divides into several disconnected, separate parcels (Bently 1990, King and Burlton 1982). Fragmentation is different from the process by which farms become smaller over time from patterns of land inheritance among children. Farmers that become smaller do not necessarily become more fragmented. The World Bank's definition of fragmentation (Blarel 1989) emphasizes the "geographic dispersion" of land holdings. Parcels spread far and wide can piece together into both large farms and small farms. This change in the structure of landholding can impact land management practices and degradation. We need to look at the dispersion factor as the distance (time) farmers must travel, usually on foot, to work and improve their fields. Less significant are the number and size of individual parcels. Of course, the number of parcels farmers operate and the time they spend journeying between them usually vary together. In Rwanda, for example, the correlation between fragmentation and dispersion of holdings is relatively strong (r=.27). And the average distance travelled by farmers with 10 or more parcels is 14.8 minutes, compared to 7.1 minutes for those with fewer than 5 parcels.[5]

Demographic pressure forces farmers to travel farther from their homes in search of additional land. While they sometimes manage to purchase these distant parcels, increasingly they must rent them. In other cases, farmers acquire holdings from the breakup of commonly-held lands. While close to some households, these formerly communal lands are often many kilometers away. Farmers in land-scarce settings will operate whatever holdings they can to ensure their families' needs.

As they will travel long distances, fanners, pressured by a growing population, will also move onto marginal lands in response to population pressure. These lands are traditionally thought to be unproductive or too fragile for seasonal cropping. They may expand into frontier lands or clear and cultivate their own pastures, woodlots, or other less intensive use areas. Increasing cultivation of marginal lands and their subsequent degradation is a phenomenon common to densely-populated countries around the globe (Gregersen, *et al.* 1992). But it is particularly common in the highland regions of East Africa (Getahun 1991) and in the Brazilian Amazon (Hecht 1982). Without sufficient off-farm opportunities, rural populations look to the process of ecological expansion—the exploitation of resources formerly outside of their immediate ecology (Hawley 1950). At one time, farmers left these marginal lands in forest, pasture, or under long-fallow cultivation. Increasingly, farmers now use them to produce annual food crops. High erosion and intense use has meant rapid degradation for many of these fragile lands.

Farm size, dispersion, soil fragility, and tenure represent four different dimensions of the structure of landholding. They tend to vary together because each is affected by changes in demographic pressure. In short, population growth in many regions of the developing world has led to land scarcity. In turn, farmers must now feed their families from smaller holdings than those operated by their parents. They must travel farther and onto slopes once thought to be too steep and fragile to farm. And they must supplement their meager holdings by renting small and distant parcels from others—presumably from those who have more land than labor.

What do these demographically-induced changes mean for soil loss and the depletion of soil fertility? And how are farmer investments in soil conservation and land use conditioned by such changes? These inviting questions form the subject of discussion in the following sections.

The Structure of Landholding, Land Management, and Degradation

The next step in our conceptual framework highlights the linkages between landholding structure (land tenure, farm size, fragmentation/dispersion, and fragility) and land management practices. As shown in figure 1, land management practices include investments in productivity and conservation as well as patterns of land use.

Investment strategies include the adoption of new technologies such as irrigation, drainage, soil conservation structures, and use of chemical fertilizers. They may also include the abandonment of traditional technologies or strategies such as fallow periods and the application of manure. Land-use changes that result from the restructuring of landholding are of several types. They include fallowing practices (duration and amount of land), cropping patterns (types of crops grown, multiple cropping, intercropping), pastoral practices, and agroforestry. We also address how these changes in land management subsequently affect soil loss and fertility depletion.

Land Tenure

Land tenure defines farmers' access to land resources. Thus, it conditions the decisions they make about how to use land and the kinds of investments to make. Researchers do not adequately understand the intermediate role of tenure systems in the relationship between population pressure and land degradation. This is partly because conventional analysis of land degradation has understated the complexities of land tenure, especially during rapid population growth and the restructuring of landholding. Also, much of the literature is based on assumptions about economic behavior rather than on empirical evidence. Indeed, one well-stated perspective on land degradation begins with the neo-classical economic assumption that markets are the best and most efficient means for allocating and managing natural resources. Degradation of natural resources is thus seen as the result of faulty markets or incentive systems.

Research often cites overuse of common property resources as the cause of land degradation. Hardin (1972) and Clark (1974) assert that farmers overuse a commonly-held property to compete with other users. Gradual mining of the soil eventually leads to severe degradation as described in Hardin's classic (1968) "Tragedy of the Commons." One policy implication emerging from this approach to degradation is that investments in land productivity are more likely to occur when owners farm their own lands.

By contrast, other researchers (Guillet 1981, Bullock and Baden 1977, Trivers 1971) suggest that farmers do not have to degrade common property. In many areas, strong social and cultural sanctions and a communal ethic can induce farmers to sustain rather than degrade the land. Moreover, many traditional tenure systems fail to conform to the rigid categories imposed by Western researchers. In Fiji, for example, ownership and use rights are very strong for more productive bottom lands but virtually non-existent for marginal lands (Rutz, 1978). And traditional land tenure systems in the Amazon region, now undergoing a rapid restructuring of landholding, continue to challenge conventional viewpoints on agriculture and land degradation (Alcorn 1989). In short, some argue that indigenous agricultural systems are "much more sophisticated than previously assumed" (Posey 1985: 39) and thus do not always conform to conventional models.

Boserup (1965, 1987, and 1990) contends that the tenure system will evolve naturally from communal to individual property as a result of population pressure and the need for agricultural intensification. Indeed, the evolution in land tenure is necessary, Boserup hypothesizes, before countries can achieve significant gains in agricultural output. Once intensification reaches a point where land improvements are necessary, the tenure security of private property makes it possible for farmers to get credit to finance these improvements.

However, as individual owners acquire land, the potential grows for concentration of land in the hands of a few. In turn, this leads to rental and share arrangements between large landowners and those without sufficient productive land. Renters are less likely to make long-term investments, increasing the potential for degradation.

Researchers have seen this process operate in diverse agricultural and ecological conditions. For example, in her examination of tenure in southern Honduras, Stonich (1989) found that rented lands were the most degraded. Rented parcels there are more likely to be on steep and degraded slopes. Renters lack security of tenure; most have access to parcels for no more than three years at a time. Thus, they have little incentive or means to invest in costly mechanical soil conservation technologies. Moreover, rents are high, leaving farmers with few resources to invest in labor or other inputs even if they want. Renters thus rarely fertilize fields but bum them before cultivating, a labor-saving but highly detrimental practice.

Migot-Adholla, *et al.* (1990) similarly reveal that the investment behavior of farmers in Ghana depends on the security of land tenure. Farmers are considerably more likely to improve lands they own, or for which they have long-term use rights, than lands they operate under short-term use rights. Improvements not only include fertilizers, mulching, and irrigation but also investments in tree crops. In comparison to Ghanian farmers, Kenyan farmers report higher security of land tenure and, in turn, a greater willingness to invest in their holdings.

In 1988, the World Bank and Rwanda's Service des Enqueues et des Statistiques Agricoles (SESA) conducted a joint study on the effects of land tenure on agricultural production in three regions of Rwanda.[6] Researchers wanted to learn how tenure arrangements influence farmer investments in their holdings and how such investments then affect crop yields. Consistent with findings cited above from Honduras, Ghana, and Kenya, Blarel (1989) reports that Rwandan farmers were far more likely to invest in their own fields than in fields rented from others.

Alternatively, there are findings that contradict the argument that tenant farmers invest less in improvements and prefer alternative ownership arrangements. Yoshinori and Hayami (1989) found one such example in a study of tenurial arrangements among small farmers in Java. Contrary to previous assumptions, sharecropping, as practiced under certain conditions, was not a deterrent to investment.

Ervin (1982) examined studies of the relationship between tenancy and soil conservation investment in the United States. He, too, cautions against automatic acceptance of the view that renters and sharecroppers will have little or no incentive to invest in soil conservation. Ervin reports no consistent relationship between soil conservation investments and tenancy. Factors, such as whether the tenant is a family member rather than a neighbor or aspires to purchase or inherit the land, can have significant implications for investment. However, like those cited from Honduras, Ghana, Kenya, and Rwanda, this study suggests that the *stability* of tenure, rather than ownership, is the more important factor conditioning farmers' decisions to invest in soil productivity.

Cook and Grut (1989) raise a further challenge to assumptions that land ownership encourages investment in their review of agroforestry practices in Sub-Saharan Africa. The economic argument may seem especially convincing for investments in agroforestry that bring in return over a longer time period. However, this review concludes that, in parts of rural Africa, the tenure issue may have more to do with customary rights over land use than with formal laws and regulations. Cook and Grut conclude that the evidence is not entirely clear whether individual ownership motivates farmers to invest in agroforestry technologies for soil conservation.

Thus, the question is not collective versus individual ownership or even ownership versus rental. Rather, it is more a question of obtaining stable, long-term use rights. These are rights which will permit farmers to draw benefits from their investments over the long term. Farmers' ability to recover investments in soil productivity do tend to be less certain when they collectively own the land or operate it under a lease agreement. However, the literature shows that neither constitutes a necessary nor a sufficient condition for low levels of investment

Turning from investments to land-use patterns, we find that land tenure plays an equally important role in this second dimension of land management practices. Land-use patterns, like investments, often reflect the stability of use rights. Farmers operating under long-term use rights are more likely to plant perennial crops, produce wood, or hold the land in long fallow. Farmers sharing land or renting under short-term agreements are less likely to plant for the long term.

Again, if farmers are not assured of reaping the longer-term benefits, they will use their holdings to maximize near-term returns. For example, the importance of security of tenure has emerged in studies of indigenous agriculture in the Amazon region. Alcorn (1990) observes that the security of tenure there has traditionally fostered a long-fallow agricultural system. Newer settlers to the region, however, have limited security of tenure. Thus, they have developed an extractive, short-term agricultural system, resulting in rapid depletion of soil nutrients and increased erosion. Land-use controls that were important to the success of slash and burn systems in the region have broken down. This happened because of development policies emphasizing short-term economic growth at the expense of diversification and sustainability (Schmink and Wood 1987).

In the absence of focused research on the interrelationships among tenure systems, land management, and degradation, we have presented conclusions from several studies which treat tenure systems and land management (investments and land use) in a broader and secondary sense. From this review, we conclude that tenure systems profoundly affect the ways farmers use land and invest in farming. We view changes occurring along a continuum from communal to individual to rented/shared land. An increase in investment level often arises as land-holding evolves from communal to individual ownership. There is a subsequent decline as short-term use rights become more common. Despite the widespread historical trend, there are numerous examples which fail to conform to this pattern. It appears that the *stability* of tenure, rather than ownership, may be more important in encouraging farmers to invest in soil productivity and adopt sustainable land-use practices.

Farm Size

Farm size can affect land management in many, though sometimes inconsistent ways. Large holders are often more able than small holders to maintain traditional fallowing practices. They also can set aside a large portion of their holdings for non-food uses such as pasture or woodlot and other land-use practices that help control soil loss and fertility depletioa Moreover, because these farmers are also comparatively wealthy, they can invest more in inputs and improvements that will raise their long-term productivity (Grabowski 1990). Large holders also can endure the short-term consequences of taking land out of production to create space for anti-erosion technologies such as grass strips, trees, and hedge rows. Conversely, small farms in densely-populated regions of the world have a relative abundance of labor to construct and maintain terraces, hedge rows, drainage ditches, and other soil conservation measures. And those with small holdings often need more careful management with the related improvements in productivity. Their lower production level puts them closer to the margin and at greater risk should portions of their holdings fail to produce adequate yields.

In this context, Boserup (1965) maintains that as population density increases, land becomes scarce and farms grow smaller. In response, she argues, farmers must shorten fallow periods, and increase investments in productive technologies if they are to avoid the hardships of migration and/or a declining standard of living. Although Boserup uses length of fallow as the key variable in defining the degree of intensification, inputs such as fertilizers, irrigation, and soil conservation can substitute for long fallow periods.

There is empirical support for Boserup's paradigm reported by Maro (1988). He describes several changes in investment and land use which have occurred in Tanzania as a result of decreased farm size. Complex networks of irrigation channels form the basis for agricultural intensification in one area, while farmers have terraced steep slopes in others.

Riddell and Campbell (1986) provide further evidence from their work in the Mandara mountain region of Cameroon. In this region, high population densities and small farm sizes have made the development of intensive farming systems a necessity. Over time, farmers have developed a complex farming system based on soil-building strategies, integration of animal husbandry with cultivation, and soil conservation.

Paradoxically, as more people leave the mountains to farm on the lowlands, problems of soil degradation have begun to emerge. A decline in population density from out-migration has curtailed labor available for soil conservation and manuring activities—labor necessary for maintaining the system's productivity. As Riddell and Campbell (1986: 86) note: "Traditional technology that keeps tropical soils in near-continuous production requires dense populations to ensure adequate labor. The Mandara material suggests that these systems collapse as soon as population density is reduced below some critical threshold."

Stonich (1989) concludes that large and medium holders in Honduras can leave land in fallow for longer periods. They are also more likely to invest in soil conservation measures than are farmers with more limited land resources. And Ford (1990) reports similar findings from densely-populated Rwanda. The observation that smaller farms rely less on fallow periods supports Boserup's hypothesis. Conversely, farmers' lower investment in soil conservation reduces their prospects for increased production. This highlights Boserup's failure to account for other intermediate effects, such as variations in income and land ownership, both of which emerge from resource scarcity.

Liverman (1990) also observes that small farmers in the state of Sonora, Mexico are more vulnerable than large holders to the effects of drought. In part, this is because small holders are less likely to invest in soil conservation and inputs such as fertilizers, seeds, and irrigation technologies. Lower levels of investment undoubtedly reflect the prevalent poverty of small farmers in the area. Conversely, in many parts of Central and South America, it is common to find an inverse relationship between farm size and intensity of land use (Williams, 1977). This is particularly true where labor inputs are the crucial factor. Khusro (1964) has documented the same relationship in India.

Farmers also intensify agricultural production through multiple cropping, increasing the number of cropping cycles per year. Boserup (1987) describes multiple cropping as a strategy to increase yields in the face of declining holdings. She defines it as one of the highest degrees of agricultural intensification.

Yet, somewhat paradoxically, multiple cropping is generally not scale neutral. Usually larger landholders use it as they can afford increased labor costs and the necessary inputs of fertilizers and irrigation. Further, when introducing multiple cropping strategies, farmers often compensate by reducing the diversity of crops and land uses. Increased labor and inputs for multiple cropping may reduce investments in lower-yielding crops that are integral to the long-term vitality of the agroecosystem.

The effect of multiple cropping on soil degradation is not entirely clear. Irrigation technologies can increase production and productivity in the short and medium run, but degraded soils can damage future production. Erosion and nutrient loss are common consequences of multiple cropping. Further, the use of inappropriate technologies to maintain yields can devastate farmland. Salinization often occurs with improperly designed and managed irrigation systems. Severe salinization can waste otherwise productive farmland for long periods. This problem is especially acute when it affects small holders, who have little hope of reclaiming affected land. Moreover, multiple cropping usually means additional tilling and longer periods of bare soil, vulnerable to the forces of wind and water which cause erosion.

Intercropping is a strategy where multiple crops are grown interspersed on the same plots. Besides raising yields without purchased inputs, benefits of intercropping include soil moisture retention, erosion control, and fewer weeds and pests. Risk minimization is an important adaptation to population pressure that is especially crucial in drought-prone areas. However, as farmers adopt higher technology strategies, they may be less apt to pursue intercropping. Generally, large holders who utilize imported, modem farming practices reduce the diversity of species they plant In tropical regions, such as the Amazon, monocultures are extremely vulnerable to pests, disease, and increased leaching and erosion. Alternatively, for small holders operating in traditional systems where population pressure continues to diminish holdings, intercropping is a practical strategy that also allows farmers to maintain crop diversity.

Much of the literature examined here supports Boserup's argument. She contends that population growth leads to smaller farms and agricultural intensification through changes in land use and production technologies. Less clear is how agricultural intensification affects land degradation. Boserup (1976:25) asserts that environmental deterioration occurs when a given population increases, by natural growth or immigration, until it exceeds the carrying capacity of the land under that system. For example, pastoral societies may overgraze grasslands while other groups cultivate steep hillsides, resulting in soil erosion. But sustained demographic growth does not always lead to environmental degradation according to Boserup. She says, "The possibility exists that the population, when it outgrows the carrying capacity of the land with the existing subsistence technology, may change to another subsistence system with a higher carrying capacity" (1976: 25). However, such an assertion assumes that social groups can readily adapt traditional subsistence practices that may have evolved over thousands of years.

Further, implicit in Boserup's argument is the assumption that extensive adaptation can continue indefinitely and under conditions of population pressure never experienced in human history. However, Boserup does not explicitly address the ability of ecological systems to adapt to changing human uses. Increasingly, ecologists are concluding that, despite the resilience of nature, agro-ecological systems have limited capacity to adjust to rapid changes in human land use. Traditional agricultural systems develop over long periods and may be best suited for the environments from which they have arisen. The loss of land can devastate agricultural systems that depend on crop diversity. For example, reduced fallow periods in slash and bum agriculture can lead to wholesale abandonment of the agricultural system and a loss of ecological stability (Fearnside 1985).

Here, agroecological systems represent a set of interactions between human land uses and nature. The kinds of adaptations Boserup describes are a departure from the agroecological system as a critical component for the success of farming. Agroecosystems may, simply, be unable to adjust to the rapid and radical adaptations that Boserup asserts are a necessary part of coping with increased population pressure. Consequently, we may have to accept a measurable degree of environmental deterioration. Boserup's perspective on environmental degradation emphasizes declining levels of commodity production. As long as production increases to meet the needs of the growing population, people perceive degradation either nonexistent or irrelevant

What is not taken into account is how changes in land use and investments may affect the potential for sustainable production. Even with adaptations in the farming system towards greater intensification and higher production, degradation may still be occurring. This fact is central to Stocking's (1984: 9) review of soil erosion and productivity. He remarks, "The loss may be hidden: compensated for by additional inputs, especially fertilizers; or covered by extra labor or bringing more land into production; or simply tolerated as ever-declining agricultural production..."

In summary, some changes in investments and land use associated with agricultural intensification are beneficial, notably those designed to improve soil conservation. Others, which might influence short- and medium-run increases in production, often mask a very real decline in productivity. Although researchers suggest that farmers with less access to land will have excess labor for construction and maintenance of conservation technologies, this reasoning is not born out by empirical study.

Fragmentation

Both agricultural policymakers and social scientists often believe the division of farm holdings into many, disconnected, and increasingly distant parcels is detrimental to agricultural production. The focus of concern is on the high cost of moving laborers, equipment, and inputs to these many and sometimes distant holdings. In cases where agriculture is mechanized, there are additional problems. One is maneuvering large equipment in small fields; another involves production losses stemming from a high ratio of field edges to total area.

Conversely, there is a growing minority of researchers who have underscored the advantages to land fragmentation. These advantages include the farmer's ability to exploit a greater diversity of agroecological conditions. This, in turn, helps sequence crops and reduces the risk of total crop failure (Bently 1990). Igbozurike (1970) contends that fragmentation is actually beneficial to small farmers in West Africa simply because agroecological diversity allows for a greater number of farmers to survive. This occurs although very small field sizes may limit options for crop types and the introduction of mechanized production.

How farmers view the trade-offs undoubtedly affects land use, investment strategies, and the process of land degradation. Trade-offs include the greater flexibility (control over a larger number of micro-environments) compared to increased costs (time and labor spent traveling from one parcel to another). However, the research literature on fragmentation concentrates on the effects of declining farm size (Igbozurike 1970). It often fails to distinguish between the two processes. There are few empirical studies of how fragmentation influences land use, investment strategies, and productivity.

A study by Migot-Adholla, *et al.* (1990) in the Anloga region of Ghana provides one notable exception. There, researchers observed that farmers are more apt to invest labor and capital in fields that are closer to their homes, usually built up on sand bars. Because of the location of these fields on the sand bars, they are more prone to damage from heavy rains. Therefore, they require more investment in flood prevention and repair. Susceptibility to rain damage may be one important factor in the farmer's decision to invest in nearby fields.

However, this pattern of investment may also reflect the "tyranny of space," the additional costs (time spent en route, energy required to haul materials, *etc)* in improving distant parcels. Higher investment in nearby parcels also reflects the higher productivity and importance of sand bar agriculture. A second exception is Pingali's and Binswanger's (1984) study of the returns to investments in soil conservation. Their findings support the conclusion that farmers usually get higher returns from their investments in closer locations. However, they concede that soils in closer fields may be more productive than those located farther from the household compound.

Thus, despite the advantages of greater agro-environmental diversity, there may be good reason to believe that farm fragmentation prohibits farmers from enhancing productivity. The greater level of investment and the increased risk of investing in distant parcels may diminish the incentives for certain types of conservation investments. Farm fragmentation, as a demographically-induced change in landholding structure is, therefore, integral to our understanding of how population pressure can lead to land degradation.

Fragility

Increasing cultivation of marginal lands and their subsequent degradation is a phenomenon common to densely-populated countries around the globe (Gregersen, *et al.* 1992). In many arid and semi-arid areas, and in most forest ecosystems in the tropics and semi-tropics, the problem is acute (Getahun 1991). In the absence of sufficient off-farm opportunities, rural populations look to the process of ecological expansion—the exploitation of resources formerly outside of their immediate environments (Hawley 1950).

Migration onto marginal lands, seen here as a significant change in the structure of landholding, is well recognized for its impact on the environment (Hecht 1985; Millikan 1992). Research on the conversion of marginal lands, and on the destruction that often follows, has focused on two substantive issues. The first arises from increased competition between herders and cultivators. As a result, pastoral systems have changed in several environmentally-important ways. Competition has forced pastoralists onto drier, more fragile lands. In addition, their integration with cultivation systems has declined as in Rwanda (Rwamasirabo *et al.* 1991). The second is the process of deforestation. Reduced forest cover results primarily from the conversion of forest lands for agricultural purposes and from increased demand for fuelwood.

The particular form of environmental degradation that results from movements onto marginal lands is quite context-specific. In Guatemala, for example, it is deforestation and watershed destruction. In Sudan, desertification and rangeland stress have followed changes in the management of fragile lands (Bilsborrow and DeLargy 1990). Whatever the case, as farmers/herders attempt to increase production in fragile areas, the dynamics of human-environment relationships in those areas change dramatically.

How does this shift onto fragile lands affect farmer investments and land-use strategies? And what resulting problems of land degradation have emerged? We now address these basic questions.

We focus on two important aspects of this demographically-induced change in the structure of landholding: 1) expansion onto previously unexploited lands, and 2) intensification of use on fragile holdings operated by farmers.

In situations where population growth and land scarcity have pushed farmers to occupy mid and upper slopes, erosion problems are particularly common. The characteristic lightness and thinness of these soils make them especially prone to erosion. These characteristics also keep yields low and diminish returns to investments in soil conservation. Thus, a downward spiral of low production and low investment is easily set into motion (Pingali and Binswanger, 1984). It begins when these marginal lands are taken out of their traditional uses (forest, long fallow, rangeland, *etc.)* and put under more intensive cultivation. Expansion of cultivation onto marginal lands has resulted in degradation This has occurred largely because the traditional uses of these lands, rangeland, long fallow, and forest, are less disruptive to the soil than are seasonal or annual cropping. Clearing these fragile areas of trees and vegetation for cultivation leaves the bare soils most vulnerable to accelerated wind and water erosion. Indeed, maintaining vegetative cover is an effective means of controlling erosion in many environments.

Crops and other types of vegetative cover vary greatly in the degree that they protect the soil from erosion.[7] Similarly, crops differ in the types and levels of inputs they require. As the size of farms decreases, options for cropping become more limited, and, when forced onto marginal lands, choices become more limited still. Specific slope and soil characteristics not only constrain the choices available to farmers but also condition the effect of cropping patterns on land degradation.

Land use and crop selection is a dynamic process affected by external structures and local conditions. Market and policy constraints affect farmers' decisions to grow crops or employ practices ill-suited for environments that are new to them. As technologies change or degradation occurs, farmers adapt by adopting practices suitable to new conditions or by moving into ever more fragile environments.

In Rwanda, increasing land scarcity from population growth has forced many farmers in recent decades to depart from their traditional agricultural system. Historically, Rwandan farmers settled along the upper ridges of their hillsides. Here the soils were more fertile and cultivation was simpler than it was farther down on steeper slopes and in marshy valleys. As preferred lands along upper slopes became occupied, young farmers had to choose. They could either cultivate smaller and less fertile plots farther down the hillside or migrate elsewhere in search of sufficient land. Similarly, a recent study of non-farm strategies in Rwanda (Rwanda 1988) shows that fallow and pasture land has been declining in recent years to increase food production (Clay and Lewis 1990).

Farmers may have converted some of the lost fallow and pasture into woodlot. However, other findings suggest that households with insufficient land have to plant ever-increasing proportions of their holdings with sweet potatoes and other tubers (Clay and Magnani 1987; Loveridge, *et al.* 1988). These tubers have a higher caloric value than do other crops. They also grow relatively well in poorer soils such as those found on steeper slopes (Gleave and White 1969). But as annual crops, they cannot compare with the traditional woodlot and pasture uses for these slopes in controlling soil erosion. In fact, studies in Africa (Lewis 1985) and in Latin America (Ashby 1985) show that they have accelerated soil loss.

Moran (1987) examined the implications of converting fragile forest land to cultivation in the Amazon region. The forest canopy formerly protected the soil, but loss of nutrients and erosion has now degraded the land. Reasons for degradation and exploitation of these fragile Amazonian lands vary, but all seem to link to demographic pressure.

Short-term intensive cultivation and large pasture tracts for cattle (Fearnside 1985; Schmink and Wood 1987) have replaced indigenous agriculture based on long fallow cycles. Hecht (1985) links deforestation in the Amazon to policies intended to encourage migration to the region. Millikan (1992) draws attention to increased rural unemployment and landlessness, two symptoms of population pressure, in a study of environmental degradation in the region.

In nearby Ecuador, Hess (1990) describes the movement of farmers into the fragile high altitude grasslands as a result of population growth. Farmers there have to cultivate steeper slopes and confine their livestock to the upper elevations. Erosion has increased in previously uncultivated areas and those where livestock densities have increased markedly in recent years.

Similarly, in the Philippines, environmental degradation has occurred from Green Revolution technologies and from farmers moving from traditional to more marginal areas (Western 1988). And in Kenya, Fury (1988) reports an increase in cultivated land in areas previously reserved for pastoralism. Consequently, land available to herders has diminished in both area and quality. Elsewhere in Africa, Manger (1990), in a study of dryland areas of Sudan, reported competition between farmers and herders and accompanying problems of land degradation. He identified expanded cultivation, commercialization of agriculture, and increasing livestock densities as three components of demographically-induced intensification and the main cause of the area's degradation.

Increasing land use pressure, resulting partly from population growth, is Campbell's (1981) focus of concern in a study of marginal rangelands in Kenya. Land-use competition between herders and cultivators there continues to threaten the ecological stability of these fragile lands and contributes to desertification Other researchers have also identified competition between herders and cultivators as the immediate cause of land degradation problems in other semi-arid regions of Africa (Glantz, *et al.* 1987; Ibrahim 1987; Little 1987; Bassett 1988; Mwalyosi 1991). They commonly cite demographic pressure as the precipitating cause.

However, the changing structure of landholding that is occurring in pastoral areas also relates to broader processes that define the political, social and economic context of land-use change. We must also consider ecological variability, especially climatic variability, in marginal areas where land-use competition is acute.

Conclusions and Policy Considerations

The commonly-held notion that land degradation occurs as a direct result of demographic pressure is an over simplification of what is actually a very complex relationship. The simplicity of the logic is enticing, but it is equally incomplete. Social and environmental scientists who focus exclusively on the demographic and environmental sides of the equation selectively confine their avenues for policy research and intervention. Fertility control (family planning) is one avenue and the development and dissemination of new resource-saving technologies is the other.

We contend that there exist no significant direct links between human populations and their environments and that the intervening processes create the context within which land degradation occurs. In this paper, we have examined some of the intermediate mechanisms through which mounting demographic pressure leads to soil erosion and the depletion of soil fertility. We have focused on a unique set of intermediate variables that we refer to collectively as the structure of landholding. These variables are important because they are the essential physical and social properties that define farmers' relationships to their operational holdings.

Mounting demographic pressure, and resulting competition for scarce resources in developing countries, alters the structure of landholding in at least four profoundly important ways. First, many households, particularly those owning little land or with excess family labor, find it necessary to expand their holdings by renting land from others. The research literature confirms that it is not the change in ownership rights alone that will lead to environmental decline. Rather, it is the stability of use rights that counts. Security of tenure is a prerequisite to long-term investment in soil productivity, regardless of whether ownership is in individual or collective hands. In countries where population pressure has left many farmers landless, increased absentee ownership and short-term use rights has blocked policymakers from preventing land deterioration.

The second, and perhaps most obvious, change is that farm holdings become smaller. This happens as ever-increasing numbers of households enter the agricultural work force and seek to derive their livelihood from the same fixed-resource base. Reduced farm size accompanies intense cultivation of increasingly degraded fields, a shift toward annual crops, reduced fallow, and fewer investments in conservation measures such as terracing and agroforestry. Small holders are often in desperate need of effective strategies for maintaining the productivity of their holdings. But they are poorly equipped to adopt practices that require significant cash outlays and/or access to credit

Third, as farm size shrinks, farmers have to either lease or purchase lands farther away from their homes. Holdings thus become more fragmented, not in the number of parcels operated but in the distances between parcels. The cultivation of more distant fields usually reduces farmer investments. However, there is still some controversy surrounding the conclusion that the fragmentation of holdings is completely undesirable. In some circumstances, fragmentation means greater agroecological diversity, a condition that helps insure farmers against the risk of total crop failure.

Fourth, land scarcity forces farmers to cultivate marginal, less productive land by converting it from forest, pasture, woodlot, and long fallow. These are all traditional uses that reduce degradation. Fragile lands have come under increased pressure in recent decades, particularly in forest and semiarid ecosystems throughout the developing world. The research literature is full of examples of how governments and non-governmental organizations have pursued policies to increase land-use intensity in marginal ecosystems. State-sponsored development projects have increased irrigation, brought infrastructure to less accessible areas, and encouraged migration from densely populated areas to fragile lands.

Each of these four demographically-induced changes in the structure of landholding has drawn considerable research attention However, this paper has focused on the collective impact of these changes on land degradation—notably soil erosion and the depletion of soil fertility. Farmers make particular combinations of investments and adopt certain kinds of land-use practices to conserve their scarce landholdings. The changing structure of landholding deeply affects these choices. In turn, these two important dimensions of land management are the farmer's best hope for controlling soil loss and fertility depletion.

Farmers' ability and willingness to invest in long-term sustainability of their lands are at risk if the physical properties (size, dispersion, fragility) and tenure change. Fertilizers, lime, mulch, and other inputs to improve soil fertility are both costly and labor intensive. The same is true for technologies to help control soil loss such as the installation of terraces, hedge rows, and planting trees.

Unless farmers can expect an economic return equal to their level of investment, there will be little incentive for them to adopt such practices. We cannot assume that conservation technologies will be attractive to farmers simply because they protect the resource base (Reardon and Islam 1989). As fields become more distant, less stable, and increasingly farmed under short-term lease agreements, cost-benefit ratios of conservation technologies will become even less favorable to farmers. The net result will be an acceleration of land degradation.

Population growth is not necessarily harmful to agricultural productivity, nor will relieving demographic pressure necessarily curb land degradation. However, if we can monitor and control demographically-induced changes in the landholding structure, we can diminish their damaging effects on land resources. But these are hard choices.

The subdivision and consolidation of landholdings *(e.g.* land reform), absentee landholding, and use of fragile lands are all parts of the structure of landholding. These are emotional issues and are subject to changes in government policy. The kinds of incentives and sanctions surrounding the structure of landholding are factors that can change it. Because of sociocultural, agroclimatic, and historical uniqueness, these factors differ vastly from one country to the next.

For this reason, the present research does not prescribe one particular set of policy interventions over another. Its message has broader application. Policymakers, and the research community on which they rely, must acquire a deeper appreciation 1) for ways that demographic pressure affects farm size, fragmentation, the use of fragile lands, and tenure security in their local environments, and 2) for how changes in these factors will in turn influence productivity-enhancing investments and land-use practices.

We must also recognize that policies targeting the structure of landholding may have repercussions that will affect the demographics side of the equation, notably family planning practices. This is particularly true for policies designed to reduce fragmentation and declining farm size by regulating land markets (sales and leases) and land inheritance patterns. Indeed, family planning, the structure of landholding, and soil conservation do not constitute three independent policy arenas. A policy intervention in one will undoubtedly precipitate change in the others and thus policymakers must introduce them in ways that are compatible.

Confounding the desire to devise agricultural, environmental, and population policies that reinforce each other is the absence of a conceptual framework that bridges these spheres of research. This paper represents a potential starting point for those who endeavor to narrow the gap. There is still much to contribute toward refining this framework. Only empirical, policy-oriented research, focusing specifically on the structure of landholding as the basic link between demographic change and land degradation, will enable us to assess its true utility.

Endnotes

1. The authors recognize that the definition of land degradation is rather controversial. Since our interest in this chapter is in how land degradation results in lower crop production (from the farmer's perspective) we borrow from Blaikie and Brookfield's (1987: 6) notion that degraded land is that which has suffered "a loss of intrinsic qualities or a decline in capability." Relating this concept to agrarian systems we refer to land degradation as a decline in soil productivity. Soil erosion and the depletion of nutrients due to overuse (soil-exhaustion) are the two most common causes of declining productivity cited in the research literature reviewed in this chapter, and are often used here as synonyms for land degradation.

2. The disappearance of communally-held land in Rwanda coincided with the termination of the government-sponsored resettlement program *(paysannat)* in the 1970s. During the 1960s and 1970s this program displaced over 80,000 farmers and their families into previously unoccupied areas of the country (Clay *et al,* 1989).

3. These figures are based on a comparison of estimates derived from national level data collected by the Division des Statistiques Agricoles in 1983 and in 1991.

4. The percentage of the population aged less than 15 years in 1989 for the selected countries are: Malawi 46.5, Rwanda 48.3, Haiti 40.1, and Bangladesh 44.6 (World Bank 1991).

5. This correlation is based on unpublished results derived from a nationwide survey (1,240 households) of agroforestry and land degradation in Rwanda. The survey was conducted in 1991 by the Agricultural Statistics Division of the Rwanda Ministry of Agriculture and Livestock.

6. This study was conducted as a part of the same research initiative cited above (Migot-Adholla 1990) with reference to Ghana and Kenya.

7. A well-known measure that reflects this protective quality of crops is the C-value. The C-value compares the soil loss ratio from land utilized with specific tillage practices and land held in tilled continuous fallow. For any given field, the crop cover, canopy, and tillage practices can vary throughout the year. The C-value represents the average soil loss ratio resulting from these factors over the growing season.

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