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Fighting an Uphill Battle: Demographic Pressure, the Structure of Landholding, and Land Degradation in Rwanda

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Fighting an Uphill Battle: Demographic Pressure, the Structure of Landholding, and Land Degradation in Rwanda

Population pressure has induced dramatic changes in the structure of landholding in Rwanda. More than ever before farmers must rent the land they operate, their holdings have radically diminished in size, they must travel longer distances to and from their parcels, and they see no alternative to farming the steep and fragile slopes once held almost exclusively in pasture, woodlot and fallow. Based on data derived from a nationwide sample of 1,240 farm households in Rwanda, linkages between these changes in the structure of landholding and land degradation are examined. With regard to the particular investments farmers make to improve the productivity of their holdings, it is found that traditional inputs such as compost, manure, and mulch invariably go onto fields owned by the farmers and especially onto those located nearer to the family compound. The same holds true for field improvements such as the installation of terraces, grass strips, drainage ditches and the planting of trees. However, despite a considerably higher level of investment, these prize parcels are the most seriously degraded of all. Rwandan farmers are clearly losing an uphill battle against soil depletion and erosion. Until more is known about how farmers perceive the notion of resource conservation, and until programs can be developed to encourage farmers to embark on long-term strategies that meet their needs, from both environmental and family planning perspectives, the situation will most assuredly intensify.

Introduction

Mounting demographic pressure in Third World countries alters the structure of landholding in at least four profoundly important ways. First, and perhaps most obvious, is that farm holdings generally become smaller as an ever-increasing number of households enter the agricultural work force and seek to derive their livelihood from the same fixed resource base. Second, holdings tend to become more fragmented, not necessarily in the number of parcels operated but in the distances between parcels, as farmers look harder and farther for whatever bits and pieces of land may be available. Third, and closely tied to the second, land scarcity obliges farmers to cultivate marginal, less productive land previously held in pasture and woodlot. Fourth, many households, particularly those owning little land or with an abundance of family labor, find it necessary to expand their holdings by renting land from others in the community.

Though such demographically induced changes in the structure of landholding have drawn considerable research attention in and of themselves, the focus of this research concerns the impact these changes exert on land degradation—notably soil erosion and the depletion of soil fertility--and on the constellation of investments farmers make in order to conserve their scarce landholdings (see Figure 1). By altering the physical properties (e.g., size, dispersion, steepness of slope, and tenure attributes) of farm holdings, the farmer's ability and willingness to invest in the long-term sustainability of his/her land can be

compromised. The application of fertilizers, lime, mulch and other inputs to improve soil fertility are both costly and labor intensive. The same holds true for technologies designed to help control soil loss such as the installation of terraces and hedgerows, and the planting of trees. Unless farmers can anticipate an economic return commensurate with their level of investment there will be little incentive for them to adopt such practices. It cannot be assumed that conservation technologies will be attractive to farmers simply because they are known to protect the resource base (Reardon and Islam 1989). As fields become more distant, less stable (steeper slopes), and increasingly farmed under short-term lease agreements, cost-benefit ratios of conservation technologies will become even less favorable to the individual farmer--the net result being an acceleration of land degradation.

The research reported here focuses on the farm population of Rwanda and the ways in which patterns of landholding in this densely populated corner of the East African highlands affect changes in land productivity (degradation) as reported by local farmers. Steep slopes and abundant rainfall prevail in Rwanda, making the tasks of field preparation and erosion control uncommonly difficult for the country's many small holders. Steadily rising demographic pressure has reduced average farm holdings in Rwanda by 12% over a period of just 5 years (DSA 1991), and increasing numbers of farmers are finding it necessary to piece together holdings by travelling longer distances to and from fields and by renting parcels of land from their more affluent neighbors. Indeed, Rwandan farmers now rent in 18.7% of all parcels operated--an increase of about one percent per year since 1983.[1]

In similar fashion, land scarcity has compelled farmers to cultivate fragile, steep-slope holdings. In Rwanda's fertile northwestern region, where the potential for agricultural productivity is high, the expansion of agriculture onto marginal lands is already resulting in serious slope failures (slumps and landslides) (Nyamulinda 1988). The increase in degradation processes acting on hill slopes will eventually lead to excessive deposition in the valley bottoms -- conditions now reported to be common in neighboring Burundi (Mathieu 1987) and which, over time, can precipitate flood damage and the destruction of lowland crops (Clay and Lewis 1990).

Drawing upon nationwide household survey data in Rwanda, linkages between demographically induced changes in the structure of landholding and land degradation are examined for conceptual validity and empirical substance. Special attention is given to the intervening effects of farmer investments in soil conservation and in improving soil fertility. We conclude with a discussion of agricultural and demographic policy implications and research needs.

The Structure of Landholding and Soil Conservation

Land Tenure

It is often stated that ownership rights are a necessary precondition for farmers to invest in the improvement of their operational holdings, particularly for some of the more costly soil conservation investments such as terracing and bunding. Short-term use rights discourage investment since the long-term return is not guaranteed for the farmer, and is almost never passed on to his or her heirs. Cook and Grut (1989) report that the same

argument may be especially cogent for investments in agroforestry, the returns to which are generally accrued over a longer time horizon. They caution however that in parts of rural Africa the tenure issue may have more to do with customary rights over how land is used than with formal laws and regulations. Thus they assert that the evidence is not entirely clear as to whether improved land tenure arrangements would motivate farmers to invest in agroforestry technologies for soil conservation.

Migot-Adholla, et al. (1990) report that the investment behavior of farmers in Ghana is highly dependent upon the security of land tenure. Land parcels that are operated under ownership or long-term use rights are considerably more likely to be improved than those operated under short-term use rights. This was found to be true not only for investments in fertilizers, mulching, and irrigation, but for investments in tree crops as well. By contrast, the relationship between tenure and land improvements among farmers in Kenya was found by the same authors to be rather weak -- probably because Kenyan farmers feel relatively secure about their ability to cultivate rented parcels on a continuous basis.

In 1988 the World Bank in association with Rwanda's Service des Enquêtes et des Statistiques Agricoles (SESA) conducted a study on the effects of land tenure on agricultural production in three prefectures in Rwanda: Butare, Gitarama and Ruhengeri.[2] One objective of this study was to ascertain how tenure arrangements influence farmer investments in their holdings, and, in turn, how such investments affect crop yields. Consistent with findings cited above from Ghana, Blarel (1989) reported that Rwandan farmers were far more likely to invest in their own fields than in fields rented from others. Yet, despite the higher level of investment, yields on fields farmers owned were significantly lower than on the fields they rented. One plausible interpretation of these findings is that the fields owned by farmers, though receiving inputs and physical improvements, are more seriously degraded (probably due to over-cultivation) and thus less productive than fields over which they have use rights only. The validity of this interpretation will be examined in the light of more recent findings later in this paper.

Size of Holdings

The size of farm holdings is thought to affect soil conservation in various and sometimes inconsistent ways. On one hand, large-holders are generally in a better position than small-holders to maintain traditional fallowing practices and to set aside a portion of their holdings for pasture or woodlot--all land use practices that help control soil loss and fertility depletion ( ). Moreover, these farmers are generally more wealthy and as such have greater flexibility to invest in the kinds of inputs and improvements that will raise the productivity of their holdings in the long term, and endure the short-term consequences of taking land out of production to create space for the installation of anti-erosion technologies ( ). On the other hand, small farms are typically endowed with a relative abundance of labor which can be drawn upon for the construction and maintenance of terraces, bunds, hedgerows, drainage ditches, and other soil conservation measures that require a significant supply of labor.

[cite other African lit here on farm size and degr].

Farms in Rwanda are shrinking in size as farmers continue to subdivide already meager holdings equally among their sons. Though the impact of this phenomenon on the degradation of agricultural lands has received little direct attention from the local research community, bits and pieces of indirect evidence exist which, at the very least, permit us to formulate a few initial thoughts on the question. In his search for an optimal distribution of landholdings, one that would maximize crop yields, Blarel (1989) found that farm size and crop yields in Rwanda were inversely related. Small-holders, it was reasoned, intensify their farm operations through more rigorous use of available family labor, a substitution toward higher-yielding crops, sowing seeds more densely, and growing more crops in association. While more intensive use of family labor has indeed hastened the installation of terraces, living fences, mulching and other soil conservation technologies (Cook and Grut 1989), it seems unlikely that some of the other forms of intensification mentioned, particularly changes in plant densities, would be as likely to improve soil fertility. Quite to the contrary, without additional inputs or fallowing, such intensification will undoubtedly precipitate even greater depletion of the soil.

Dispersion of Holdings

The World Bank Land Tenure Study also addressed the issue of land fragmentation (*morcellement*) in Rwanda and its impact on crop yields. It is important to note that fragmentation is distinct from the process by which farms become smaller over time due to a pattern of land inheritance that benefits all sons equally. By fragmentation we adopt the definition employed by the World Bank (Blarel 1989) which emphasizes the "geographic dispersion" of land holdings. Large farms and small farms alike can be pieced together from parcels that are spread far and wide. For purposes of understanding the structure of landholding in Rwanda, we are more concerned with the *distance* (time) farmers must travel on foot to work and improve their fields than with the number of parcels operated or the size of individual parcels.

Blarel reports that the dispersion of holdings has not had a negative effect on crop yields in Rwanda. Indeed, dispersed farms and parcels show higher yields overall than consolidated farms. We suspect, however, that at least part of the reason why more distant parcels may be more productive is that, like parcels rented from other farmers (as suggested above), soil depletion and degradation through erosion is less advanced than on parcels that are owner-operated. More distant parcels are often located at the base of the hillside and in the valleys (*marais*) where the degenerative effects of soil erosion are less severe, and where lands have been brought into production more recently.

In the Anloga region of Ghana it has been observed that farmers are more apt to invest labor and capital in fields that are closer to the household residence, which is ordinarily built up on sand bars (Migot-Adholla, et al. 1990). It is argued that because of the particular location these fields vis-à-vis sand bars, they are more prone to damage from heavy rains and therefore require heavier preventative and reparative investment. Though susceptibility to rain damage may be one important factor in the farmer's decision to invest in nearby fields, this pattern of investment may also be a reflection of the "tyranny of space," or the additional costs incurred (time spent en route, energy required to haul materials, etc.) in improving less proximate parcels.

[Elsewhere in Africa... compete section]

Cultivation of Marginal Lands

Increasing cultivation of marginal lands and their subsequent degradation is a phenomenon common to densely populated countries around the globe. 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 ecology (Hawley 1950 ??). The particular form of environmental degradation that results from ecological expansion is generally quite context-specific. In Guatemala, for example, it is deforestation and watershed destruction; in Sudan, desertification and rangeland stress are priority environmental concerns (Bilsborrow and DeLargy 1990). The confrontation between human subsistence needs and environmental conservation is intense and pervasive in Rwanda. Deforestation and protection of the Mountain Gorilla population are issues that have recently received extraordinary international recognition. But for the average farm household, there are changes of more immediate and profound consequence--such as the cultivation of fragile lands once reserved for pasture and woodlot.

Historically, Rwandan farmers settled along the upper ridges of their hillsides where soils were more fertile and cultivation was a simpler task than it was farther down, on the steeper slopes and in the marshy valleys. Immediately surrounding the household compound (*urugo*), farmers have traditionally planted groves of bananas and other essential crops. Bananas have special significance in Rwandan culture because they are used for making a unique home-brewed beer which is served at virtually all formal and informal social gatherings, and is a principal source of income for a majority of farm households. Beyond the inner ring of bananas, a series of outer rings can be identified which farmers have customarily used to meet other nutritional needs of their households (Nwafor 1979, p. 59). The first such ring is farmed intensively with annual crops for both home consumption and sale. A bit farther down the hillside, coffee is grown. Coffee is the country's principal export crop and as such is vigorously promoted by the government of Rwanda.

Beyond the coffee plots, the slope of the hillside is often at its steepest. Consequently, these areas have traditionally been reserved for pasture and woodlots but also many of the less important crops are grown here and frequent fallow periods are commonly required. At the very outer rings, toward the base of the slope and in the swampy valleys, crops are grown along ridges that are built up to facilitate water drainage. Sweet potatoes and other vegetables are grown in these more distant plots to ensure a continuous food supply between harvest seasons.

Increasing land scarcity due to population growth has obliged many farmers in recent decades to depart from this traditional system. As the preferred lands along the upper slopes became occupied, young farmers were faced with the decision to either cultivate smaller and less fertile plots farther down the hillside or to migrate elsewhere in search of sufficient land resources. Similarly, recent findings from the Rwanda Non-farm Strategies Survey (Rwanda, 1988) demonstrate that land in fallow and pasture have been declining in recent years because of the need to increase food production (Clay and Lewis 1990). Only woodlots seem not to

have suffered over the past few years, thanks to a strong government campaign aimed at replanting and maintaining them at both the household and communal levels.

Though some of the lost fallow and pasture may be land that is being converted into woodlots, other findings point to the fact that households with insufficient landholdings are being forced to plant ever-increasing proportions of their holdings with manioc and other tubers (Clay and Magnani 1987; Loveridge, et al. 1988). These tubers have a higher calorific value than do other crops, and tend to grow relatively well in poorer soils (Gleave and White 1969), such as those commonly found on steeper slopes, but they do not compare with the traditional uses of these slopes (i.e., woodlots and pasture) in their ability to control soil erosion. In fact, it has been shown elsewhere that they are associated with accelerated soil loss (Ashby 1985).

In summary, though farm size, dispersion, slope location and tenure represent four different dimensions of the overall structure of landholding in Rwanda, they are indirectly associated with one another through their concomitant variation with changes in demographic pressure. Population growth in recent decades has meant greater land scarcity. In turn, the individual farmer must now feed his family from smaller holdings than operated by his father, he must travel farther and onto slopes once thought to be too steep and fragile to farm, and he must supplement his meager holdings by renting small and distant parcels from others--presumably from those whose resource endowment exceeds the supply of family labor. What do these dramatic developments mean for soil loss and the depletion of soil fertility in Rwanda? And how are farmer investments in soil conservation conditioned by such changes? These inviting questions form the subject of the analysis to follow.

Research Setting, Data and Method

The Republic of Rwanda is a geographically small, landlocked country situated in the East African highlands. Over 93 percent of its population lives in rural areas and virtually all rural households are engaged in agriculture (Rwanda 1982). Farm production is oriented toward subsistence; on average, households operate slightly less than one hectare of land (SESA 1991). Beans and sorghum, supplemented by sweet potatoes, manioc and peas, are the principal food staples. Coffee and tea are important cash crops for some farmers and important sources of foreign exchange for the nation. Rwanda's agricultural system is labor intensive; hoes and machetes are the basic farm implements. Livestock comprise an integral part of the farming system, but the progressive conversion of pasture into cropland has caused a reduction in average household livestock production in recent decades, and a parallel decline in the amount of manure available for improving soil fertility (Rwamasirabo, et al. 1991).

The 1983 National Fertility Survey shows Rwanda as having the highest total fertility rate (TFR) of any nation in the world: 8.6 live births per woman, on average, by age 49 (Haub and Kent 1991 ?? ; May 1988). Consequently, the rate of population growth is also exceptionally high (3.7% annually). Small in area relative to population, Rwanda's average population density of 271 inhabitants per square kilometer is the highest in Africa (Rwanda 1991). Virtually all arable land is now being used for agricultural purposes.

At marriage, young couples leave their respective parental households and form their own, independent households. Traditionally they have settled nearby, on the land of the groom's father or wherever available land could be found, but recent population growth has forced many to adopt a stem-family system of the patriarchal type (LePlay 1878), leaving their home communities in search of land or alternative employment opportunities (Clay, et al. 1989; Olson 1989), yet maintaining close ties with the parental homestead (Clay and Vander Haar 1992). Household size in rural Rwanda currently averages 5.3 members (DSA 1991), ranging from one person to 15 or more.

Our data derive from a nationwide stratified random sample of 1,240 farm households, undertaken as part of the 1991 Survey of Agroforestry in Rwanda.[3] Direct interviews with heads of households and/or their spouses were conducted over a six-week period beginning in June, 1991. On average, questionnaires took about one and a half hours to administer. Information was collected on a variety of topics at two levels of observation. First, at the household level, questions were asked about the use, marketing and problems associated with fuelwood and other types of wood and wood products. Second, data were obtained at the parcel (*bloc*) level. For each of the 6,464 parcels operated by the sampled households, questions were asked (or measurements taken) on such topics as: land tenure, steepness of slope, location of the field on the slope, soil conservation methods used, the use of fertilizer and other inputs, number and species of trees planted, distance from the household residence, and crops grown.[4]

Of particular importance to the present study is a series of questions asked of farmers concerning the changes they observed in the productivity of each parcel of land. Farmers first were asked whether they had observed a change in the productivity of the parcel's soil (either improvement or decline) over time. If a change had been observed, they were asked to indicate whether the change was small, moderate, or substantial, and then to explain the reason for the change. In slightly over half of the parcels, no change was reported. Among those parcels for which a change was reported, relatively few (20.5%) had seen an improvement in productivity over time. For the vast majority (79.5%), farmers reported that soil productivity had declined. These observations of declining soil productivity constitute our principal measure of soil/land degradation at the parcel level.

Findings and Discussion

Steady growth in the land rental market in Rwanda, an outgrowth of mounting demographic pressure, has raised concern about the potential impact of this trend on land degradation. Conventional wisdom and overwhelming empirical evidence, some of which has been reviewed above, tells us that farmers generally invest more in fields they own than in fields they rent from others. Our data, too, are supportive of this association; Table 1 confirms that owner-operated parcels in Rwanda are vastly more likely to have received fertility-enhancing inputs such as manure or compost (gamma= -.73), to have been improved through the installation of anti-erosion technologies such as terraces, grass strips, etc. (gamma=-.39), and to have trees planted on them (gamma=-.68).

Paradoxically, despite heavier investments, Rwandan farmers observe a significantly greater decline in productivity on parcels they own than on parcels they operate as tenants.

In like manner, we find that declining productivity is positively associated with investments in inputs, improvements, and trees, as shown in Table 2. The implication here is that the level of investment farmers are currently making in their own fields is not sufficiently large to overcome years of intensive cultivation and the loss of nutrients associated with this "mining of the soil." This explanation also helps us understand why Blarel (1990) found higher yields on parcels operated under short-term use rights than under ownership rights.

Though farms are becoming smaller over time as a function of population growth, this trend does not, as yet, appear to be detrimental to soil productivity. Table 1 shows no relationship between farm size and land degradation in Rwanda. Large-holders are known to have greater flexibility in land use practices than do small-holders, for whom the immediate demands of daily subsistence necessitate that nearly all holdings be intensively farmed rather than held in pasture, woodlot, fallow or other environmentally beneficial uses. By the same token, however, those with small operational holdings are able to compensate for less desirable land use practices by focusing available family labor and scarce inputs on the production and conservation of a reduced number of fields. The net result is that soil loss and depletion are unaffected by scale of operation. The same is true for the investments farmers make in improving the productivity of their holdings. Farm size is flatly unrelated to the use of inputs, anti-erosion improvements and the tree planting.

Our third dimension of the structure of landholdings is the geographic dispersion of holdings, which is here operationalized as the "distance" (in minutes, on foot) between parcels and the household residence. Competition for scarce land resources is forcing Rwanda's farm households to travel to increasingly distant locations in search of land to supplement the family holdings. During the 8-year period from 1983 to 1991 the proportion of holdings located more than 15 minutes away from the household increased at a rate of approximately one percent per year to a total of 22.7 percent.[5] The impact of this dispersion of holdings on the farmer's willingness to invest in improving soil fertility is exceptionally strong (Table 1), and fully consistent with established theory and observation reported elsewhere. Farmers in Rwanda invest relatively little in holdings located more than a few minutes' walk from the household residence. This may be conditioned by the fact that distant fields are more likely to be operated under short-term use rights, but more, it is a reflection of the relatively high cost of transporting inputs and materials needed for soil conservation, as well as the farmers' awareness that their holdings in more distant locations have not yet reached the same degree of exhaustion as those in closer proximity (gamma=-.21).

Not only are farmers in Rwanda travelling farther from home in search of supplementary holdings, but they now occupy fragile lands once thought to be too steep and unproductive to cultivate. Formerly these slopes were often held in pasture, but the demand for food from a rapidly growing farm population has caused many households to abandon livestock production in favor of crop production. In just 5 years, from 1984 to 1989, land held in pasture has declined from 10% to 4% of total operational holdings in Rwanda (DSA 1991). Despite efforts to improve these steep slopes through the installation of anti-erosion technologies and by planting trees on them, their degradation is reported to be the most severe of all (Table 1).

How does the structure of landholding influence degradation once the intervening effects of farmer investments have been controlled? And, alternatively, to what degree do

such investments provide the intermediate mechanism through which landholdings variables impact the degradation of holdings in this context of intense demographic pressure? From the analysis of variance presented in Table 3 we can begin to respond to these important questions. In place of the dichotomous degradation variable reported earlier we have substituted the original rank order variable reflecting a scale of four different degrees of decline in productivity from "no decline" to "substantial decline." As investments are introduced into the model as covariates they, too, take on either their initial rank order (number of inputs, number of improvements) or ratio (number of trees) form.

The grand mean of .75 represents the average value of all parcels on the degradation scale. Broken out by tenure status of the parcel the unadjusted means exhibit precisely the same relationship described earlier. Degradation is lower (by 37 percent) on owner-operated parcels than on lands rented from others. However, by adjusting for other landholding variables the difference is reduced to just 22 percent. This is because of the strong relationship between tenure and steepness of slope--owner-operated fields are 68 percent more likely than rented fields to be located on slopes of 21 degrees or more. Thus, part of the reason why owner-operated fields are so badly degraded is that, for historical reasons, they are located on steep slopes making them especially prone to soil erosion. Moreover they are the closest to home and thus subject to more intensive cultivation. Third, and perhaps most important, one must bear in mind that to motivate a farmer to pay for the use of a parcel, or to travel a significant distance to work it, the productivity of that parcel must be reasonably high, at least by comparison to his own weary holdings. Viewed in this light it also seems intuitively sensible that, as Table 3 confirms, distant fields should be less degraded than those located closer to home.

Conclusions and Study Implications

Population pressure is often cited as a leading cause of environmental degradation in the Third World, but rarely does our understanding of the population-environment relationship manage to penetrate this superficial level. We speak in general terms of how growing populations eventually exceed environmental "carrying capacities," without giving even cursory recognition to the socioeconomic and physical mechanisms through which resource scarcity translates into resource abuse. The research reported here has endeavored to identify and explore a small set of these mechanisms, specifically those involving demographically induced changes in the structure of landholding, i.e., the particular pattern of social and spatial relationships maintained between farmers and their land. Emphasis has been placed on four important landholding variables of profound importance to farmers in Rwanda--tenure arrangements (ownership versus use rights), size of holdings, geographical dispersion of holdings, and hillside location (steepness of slope). Previous studies and current findings reveal that population pressure in Rwanda has been accompanied by dramatic changes along all four of these dimensions of landholding--more than ever before farmers must rent the land they operate, their holdings have radically diminished in size, they must travel longer distances to and from their parcels, and they see no alternative to farming the steep and fragile slopes once held almost exclusively in pasture, woodlot and fallow.

How have these changes affected the long-term sustainability of farming in Rwanda? Not entirely in ways we might expect. With regard to the particular investments farmers

make to improve the productivity of their holdings, there are few surprises. Traditional inputs such as compost, manure, and mulch invariably go on fields owned by the farmers and especially on those located nearer to the family compound. The same holds true for field improvements such as the installation of terraces, grass strips, drainage ditches and the planting of trees--rented fields and distant fields are largely ignored. But in terms of observed degradation, our findings do not conform to initial expectations. Holdings that by all counts must be viewed as the most important to the farm household--parcels owned by, improved by, and situated close to the household--are the most seriously degraded of all. Parcels rented by the household and those in more distant locations prove to be the least degraded, and, as Blarel (1990) found, the more productive. While this may seem initially paradoxical, from another perspective it is quite understandable. Farmers will not pay rent for land or travel long distances to work it unless its productivity can justify the cost. But what this also means is that farmers are losing the battle at home. Despite receiving substantially greater investment, the farmer's prize holdings, those he will pass on to his children, have been worked to exhaustion.

However, just because these owner-operated and improved fields are badly degraded, one cannot conclude that farmers' efforts and good intentions are not paying off. These important lands would undoubtedly be in worse condition still, had farmers done nothing. It is conceivable that many would have been abandoned long ago had they not received what protective measures their owners have managed to initiate. But clearly much more is still needed. Existing programs must be continued and expanded. The broad-based government campaign to enlarge public and private woodlots has met with relative success at the household level. Of the traditional uses of steep-slope lands, only area in woodlot has not declined over the past five years, while pasture and fallow land have been seriously diminished. Motivating farmers to plan for the long term is no easy matter. Innovative programs are needed. There must be incentive schemes, locally sponsored, that simultaneously extend viable technologies to farmers and encourage them to adopt those best suited to their own particular needs. It is apparent that the integration of trees into cropping systems has not yet been well extended in Rwanda. Our study results show that on scarcely more than one percent of all parcels is green manure applied, and on just 14.6 percent of parcels have hedgerows been installed. Soil conservation in Rwanda is still a long way from what has been achieved in Nepal, Thailand, Peru, and other nations where mountain agriculture prevails. Unfortunately, lessons to be learned from Rwanda's neighboring states are few. In Zaïre, Uganda and Tanzania, problems of land scarcity have been far less intense and more localized than in Rwanda; all are relatively land-rich and less mountainous. Burundi, on the other hand, has much in common with Rwanda, but it too is still looking for answers.

An obvious shortcoming of the present study is that in focusing on the structure of landholding we have ignored important related questions concerning patterns of land use--particularly those dealing with changes in cropping patterns. Earlier research in this area has concluded that altering the ways in which land is used is not a strategy adopted by Rwandan farmers in their struggle against soil erosion (Clay and Lewis 1990). Crops with protective qualities are no more likely to be found on steep, erodible slopes than on gentle slopes or flatlands. But how cropping patterns are linked to observed degradation will have to remain the subject of future study. We must also caution that the present study has not addressed

the "off-farm" issue of deforestation, which is closely tied to "on-farm" changes and is an equally menacing problem in Rwanda today.

Though there is much to be learned from the kinds of nationwide survey data examined here, our understanding of the constraints facing farmers in the application of specific conservation technologies, and of indigenous knowledge and practices already in use, is rather limited. There is a fundamental need for supplementary information of a more qualitative nature on these important questions. Until more is known about how farmers perceive the notion of resource conservation, and until programs can be developed to encourage farmers to embark on longer-term strategies that meet their needs, from both environmental and family planning perspectives, the situation will most assuredly intensify. Poorly equipped and faced with the daunting charge of producing more food from smaller and depleted holdings, one must conclude that Rwandan farmers today are not well placed to engage in long-range strategic planning for the environment—they are indeed fighting an uphill battle.

Notes

1. Data on increasing distances to and from parcels and on proportion of parcels held under lease agreements are reported in the analysis section of this paper.

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

3. The complete sample frame includes a total of 1,248 households. However, due to military/political tensions in the prefecture of Byumba, along the Uganda border, interviewers were unable to conduct fieldwork in the region, and eight (0.6%) of the 1,248 sampled households had to be omitted from this study. Sampling weights have been adjusted accordingly.

4. Data on crops grown in each parcel were obtained several months earlier as part of DSA's seasonal area and production survey.

5. Figures for 1983 based on unpublised tables from the Enquête National Agricole, 1983-84.

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

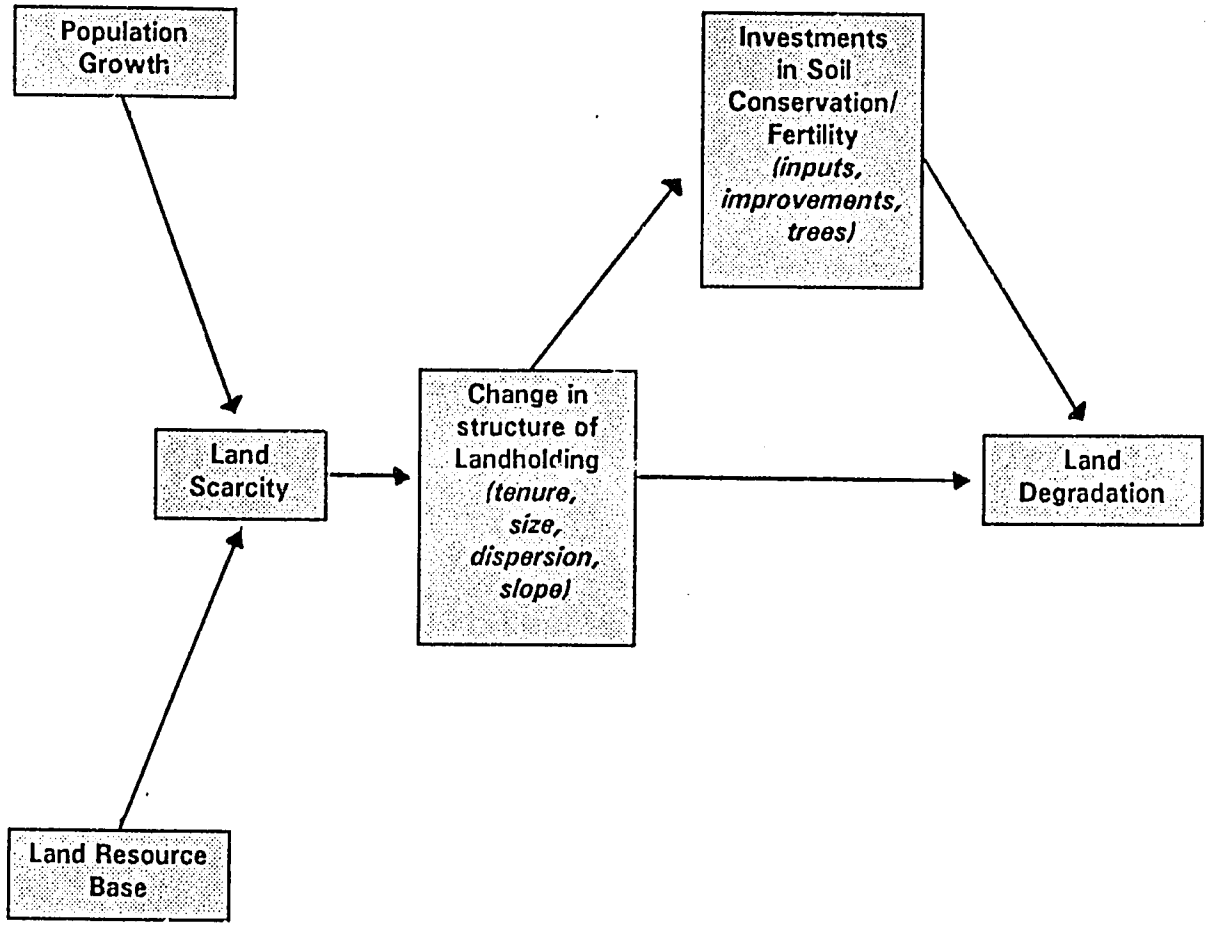

Table 1
Investments in Parcels and Decline in Soil Productivity by Structure of Landholding

Structure of Landholding	Use of Inputs: No Inputs (%)	Use of Inputs: Inputs (%)	Anti-erosion Improvements: No Improv. (%)	Anti-erosion Improvements: Improv. (%)	Trees Planted: No Trees (%)	Trees Planted: Trees (%)	Decline in Productivity of Soil: No Decline (%)	Decline in Productivity of Soil: Decline (%)	Total (%)	N=
Land Tenure										
Operated by Owner	70.7	94.0	75.4	87.4	63.9	90.3	77.8	87.7	81.3	5,249
Operated by Tenant	29.3	6.0	24.6	12.6	36.1	9.7	22.2	12.3	18.7	1,210
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	6,459
Gamma	*-.73*		*-.39*		*-.68*		*-.34*			
Significance	*.0000*		*.0000*		*.0000*		*.0000*			
Size of Farm										
≤.40 ha	16.8	16.7	17.5	15.9	17.2	16.5	17.3	15.4	16.7	757
.41 - .75 ha	26.6	27.7	28.3	25.8	28.4	26.4	27.0	27.3	27.1	1,226
.76 - 1.20 ha	26.7	26.4	24.8	28.4	26.3	26.7	25.5	28.7	26.6	1,203
≥1.21 ha	29.9	29.2	29.4	29.8	28.2	30.4	30.2	28.6	29.6	1,341
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	4,527
Gamma	*-.01*		*.04*		*.04*		*.01*			
Significance	*.8767*		*.0184*		*.3374*		*.0621*			
Distance from Residence *(dispersion)*										
< 2 Min.	8.2	45.5	14.0	37.0	7.6	34.5	20.6	34.0	25.2	1,623
2-5 Min.	28.1	29.6	28.5	29.0	27.9	29.2	29.1	28.0	28.7	1,847
5-15 Min.	30.3	15.0	28.9	17.6	31.2	19.2	25.9	18.7	23.4	1,501
16+ Min.	33.4	9.9	28.6	16.4	33.3	17.1	24.4	19.3	22.7	1,456
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	6,427
Gamma	*-.64*		*-.39*		*-.47*		*-.21*			
Significance	*.0000*		*.0000*		*.0000*		*.0000*			
Steepness of Slope										
0-5 Degrees	28.7	25.7	36.8	17.3	41.1	20.1	31.3	19.8	27.3	1,764
6-10 Degrees	20.4	22.5	19.0	23.8	21.7	21.2	21.9	20.5	21.4	1,381
11-20 Degrees	27.1	31.0	23.6	34.5	23.7	31.6	26.4	33.6	28.9	1,867
21+ Degrees	23.8	20.8	20.6	24.4	13.5	27.1	20.4	26.1	22.4	1,447
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	6,460
Gamma	*.01*		*.25*		*.37*		*.20*			
Significance	*.0000*		*.0000*		*.0000*		*.0000*			

Table 2
Decline in Productivity of Soil (Since First Cultivation of Parcel) by Type of Investment

Type of Investment	Observed Decline in Productivity of Soil: No Decline Observed (%)	Observed Decline in Productivity of Soil: Decline Observed (%)	Total (%)	N=
Inputs *(fertilizer, manure, lime, mulch)*				
No Inputs	59.1	46.0	54.5	3,524
1 or More Inputs	40.9	54.0	45.5	2,940
Total	100.0	100.0	100.0	6,464
Gamma	*.26*			
Significance	*.0000*			
Anti-erosion Improvements *(terraces, hedgerows, grass strips, drainage ditches)*				
No Improvements	59.3	36.2	51.2	3,310
1 or More Improvements	40.8	63.8	48.8	3,154
Total	100.0	100.0	100.0	6,464
Gamma	*.44*			
Significance	*.0000*			
Number of Trees in Parcel				
No Trees	38.2	27.1	34.4	2,220
1 or More Trees	61.8	72.9	65.7	4,244
Total	100.0	100.0	100.0	6,464
Gamma	*.25*			
Significance	*.0000*			

Table 3
Analysis of Variance on Decline in Productivity of Soil by Structure of Landholding (Tenure, Size, Dispersion and Slope), Adjusted for Effects of Investments (Inputs, Improvements and Trees)

Structure of Landholding	Mean Decline in Productivity of Soil: Unadjusted Mean	Adjusted for all Other Landholding Variables	Adjusted for Investments (Inputs, Improvements, Trees)	N=
Grand Mean (All Parcels)	.75	.75	.75	4,499
Land Tenure				
Operated by Owner	.81	.78	.78	3,649
Operated by Tenant	.51	.61	.62	850
Eta	*.10*	*.06*	*.06*	
Significance	*≤.01*	*≤.01*	*≤.01*	
% Diff between first & last categories	*37%*	*22%*	*21%*	
Size of Farm				
≤.40 ha	.72	.71	.73	752
.41 - .75 ha	.75	.78	.78	1,222
.76 - 1.20 ha	.82	.81	.80	1,203
≥1.21 ha	.71	.70	.70	1,323
Eta	*.04*	*.04*	*.03*	
Significance	*.08*	*.09*	*.08*	
% Diff between first & last categories	*1%*	*1%*	*4%*	
Distance from Residence *(dispersion)*				
< 2 Min.	1.01	.98	.90	1,125
2-5 Min.	.73	.72	.72	1,301
5-15 Min.	.60	.62	.65	1,027
16+ Min.	.66	.68	.72	1,046
Eta	*.13*	*.11*	*.08*	
Significance	*≤.01*	*≤.01*	*≤.01*	
% Diff between first & last categories	*35%*	*31%*	*20%*	
Steepness of Slope				
0-5 Degrees	.54	.57	.61	1,262
6-10 Degrees	.69	.69	.66	985
11-20 Degrees	.87	.85	.82	1,262
21+ Degrees	.93	.91	.93	989
Eta	*.14*	*.12*	*.11*	
Significance	*≤.01*	*≤.01*	*≤.01*	
% Diff between first & last categories	*42%*	*37%*	*34%*	