Sustainable Intensification in the Highland Tropics: Rwandan Farmers' Investments in Land Conservation and Soil Fertility*

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I. Introduction

The horrors of genocide and civil war have recently turned the world's attention to Rwanda. But before that conflict and since, smallholder agriculture in this highland African nation has been defined by severe land scarcity and degradation, declining land productivity, poverty, and hunger. This article focuses on how smallholders are trying to meet this challenge of agricultural decline and what determines their investments in the sustainable intensification of farming.

Historically, Rwandan farmers settled along the upper ridges of 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.[1] But rapid population growth has in recent decades brought several changes in the traditional agricultural system: (1) farm holdings have become smaller due to constraints on land availability; (2) holdings are more fragmented; (3) cultivation has pushed onto bottomlands and fragile margins on steep slopes previously held in pasture and woodlot; (4) many households now rent land, particularly households owning little land or those with large families; (5) and fallow periods have become shorter, and cultivation periods have grown longer.[2]

A consequence of farming more intensively and farming on steep slopes is the high incidence of soil loss due to erosion, and, along with it, declining soil fertility. Rwanda's National Agricultural Commission estimated that half the country's farmland suffers from moderate to severe erosion.[3] D. C. Clay reports that farmers observe a decline in the productivity of nearly half their holdings due to land degradation.[4] F.

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Byiringiro and T. Reardon show that erosion severely reduces farm yields in Rwanda.[5] R. E. Ford, citing research results in the steeply sloped Ruhengeri zone of Rwanda, notes that four-fifths of the sampled farmers have observed declines in the productivity of their soil; Ford also notes that soil loss from erosion has been high in the zone and that this is the most serious threat to the agricultural resource base.[6] John F. May finds that demographic pressure is driving soil degradation in Rwanda.[7]

Farmers have responded to land use pressure and concomitant declining productivity by intensifying agriculture. E. Boserup outlines a number of technology and investment paths to agricultural intensification that farmers follow in the wake of increased land constraints[8]—conditions that result from population growth, increased demand for agricultural products, and reduced transportation costs.[9] To set the stage for our subsequent discussion, we distill from her work two broad paths.

The first we refer to as ''capital-led'' intensification, which entails substantial use of capital, broadly defined to include nonlabor variable inputs that enhance soil fertility (such as fertilizer) and quasi-fixed capital that protects the land (such as terraces). In Rwanda, capital farm inputs include (1) land conservation infrastructure (grass strips, antierosion ditches, hedgerows, and radical terraces), (2) organic inputs (composting, manure, green manure, mulch), and (3) chemical inputs (fertilizer, pesticide, and lime). If one classifies the planting of perennials as a long-term capital investment, one can also say that planting and maintaining cash perennials such as coffee and bananas fall under the capital-led intensification path. In turn, this capital is either acquired through purchase or produced on-farm, often with substantial labor input (e.g., antierosion ditches are dug using farm labor and other farm capital, such as hoes).[10]

The second path makes little or no use of ''capital'' (as defined above), so we refer to it as ''labor-led'' intensification. Characteristically, farmers following this path will merely add (unaugmented) labor to the production process on a given unit of land, so that they crop more densely, weed and harvest more assiduously, and so on.

The two paths can be thought of as polar ends to a continuum. In practice, relatively few farmers follow either the labor-led or the capital-led path in its pure form, tending instead to adopt intensification practices that place them somewhere in between the two extremes.

Empirical research on intensification in Africa has illustrated the two intensification paths initially described by Boserup and labeled here as capital-led and labor-led paths. Several studies have categorized the agricultural systems in regions of Africa where demographic pressure has pushed farmers to intensify along these paths. P. Matlon and D. S. C. Spencer note that the capital-led path is more sustainable and productive in fragile, resource-poor areas.[11] U. Lele and S. W. Stone categorize a variety of agroclimatic and policy settings in terms of these two paths, focusing especially on the need for the capital-led path (which they term ''policy-led'').[12] They maintain that the labor-led path (the ''autonomous model,'' in their words) has not led to land productivity growth in sub-Saharan Africa, and that policy-led intensification is needed so that land quality and productivity will be maintained and even enhanced as cropping is intensified.

In sum, in much of the African tropics, the labor-led path to intensification—without addition of capital to enhance soil fertility and to protect land—is unsustainable and leads to land degradation and to stagnation of land productivity.[13] This danger is at its maximum in the East African highland tropics, which are characterized by heavy rainfall and steep slopes. In this context, the capital-led path of intensification that incorporates land conservation investments with the use of organic matter and chemical fertilizer is much more sustainable. By contrast, farm households that follow only the labor-led path are on course for long-run ecological degradation and poverty. Hence, the question of what determines the technology adoption and capital investment paths that households follow is of critical importance in the current debate on sustainable development.

In general, conceptual and empirical work in the tropics has focused on how broad groups of farmers in particular agroclimatic zones and policy contexts face incentives (such as relative prices) and conditions (such as access to markets or new technologies) for following one or the other intensification path. For example, P. Pingali, Y. Bigot, and H. P. Binswanger examine how costs and returns to intensification by use of animal traction can be categorized according to the economic and physical characteristics of agroclimatic zones.[14] J. Smith et al. and Ade H. Freeman examine the nature of intensification in maize production over locations in Nigeria with differential access to infrastructure, technology, and prices.[15] B. L. Turner II, G. Hyden, and R. Kates have examined several case studies of the relation between population growth and agricultural intensification in Africa.[16]

Yet much less empirical research, especially in Africa, has systematically addressed the issue of what determines the paths taken by rural households over different agroecological zones and, in a given zone, over different types of farm households. Unanswered are the questions of whether and why particular types of households, in given agroclimatic and policy contexts and facing similar incentives to intensify, take the labor-led versus the capital-led intensification path. Specifically, there have been relatively few studies that analyze the determinants of smallholder investments in land conservation capital and the use of non-labor variable inputs such as organic matter and chemical fertilizers in settings of rapid population growth and degradation. Recent exceptions are F. Place and P. Hazell, who focus on the effects of land tenure on land improvements in Rwanda; M. A. Lopez-Pereira et al., who analyze soil conservation measures on the hillsides of Honduras; and S. M. Ndiaye and A. J. Sofranko, who analyze land improvements in the Ruhengeri zone of Rwanda.[17]

We address this gap in research using farm survey data from Rwanda. Our contribution is twofold. First, we add an empirical analysis of the capital-led path of intensification, focusing on household-level differences in the determinants of intensification (manifested in land improvements and soil amendments) within a given agroclimatic zone (the East African highland tropics) and policy context (Rwanda).

Second, we highlight household-level determinants of sustainable intensification that have not commonly been treated in the literature on intensification. Specifically, (1) we show the importance of household-level intersectoral links—reverse linkages, where nonfarm income affects farm investment—to enhancing the capacity of households to follow the capital-led path, and (2) we address the subject of landholding structure that recent literature has brought to center stage.[18] With respect to the latter, we examine the links between demographic pressure, changes in the structure of landholding, and, in turn, the technology paths taken by farmers.

The article proceeds as follows. In Section II we discuss our general model. In Section III we present the regression specification and our working hypotheses. In Section IV we describe the data examined in this study and in Section V the research setting and general patterns in the model variables. In Section VI we present and discuss regression results. Section VII concludes with a review of findings and implications for policy and research.

II. General Model

We set out a general model for farm investments, which is then broken out in the following section into four regression equations for the land and input use and land conservation investments under study. We follow the literature on firm- and farm-level investment theory, and model farm-level investments as a function of five sets of variables:[19]

$$\text{Investment} = f(\text{1. financial incentives, 2. physical incentives, 3. risk, 4. wealth, and 5. agro-socio-economic context}). \tag{1}$$

In general, a higher return (financial or physical) on investment will stimulate a higher rate of investment. Conversely, greater risk leads to lower investment for risk-averse farmers. G. Feder et al. break risk into two categories, risks (e.g., from price or rainfall instability) affecting confidence in the short term, and risks (e.g., from insecurity of land tenure, hence risk of appropriation of capital) affecting confidence in the long term.[20]

While the incentive to invest can be great, capacity to invest may be low. Thus, wealth, broadly defined to include cash for purchases, human capital, and own-labor sources for home production of capital goods, constitutes an important general determinant of such investments. In theory, household liquidity is important where the credit market is underdeveloped or absent (the case in the tropical highlands of East Africa).

III. Regression Specification and Hypotheses

The general model explains investment in terms of the incentives and disincentives facing farm households and the capacity of households to undertake investments. Table 1 shows the regression specification, reproduced as follows:

$$\begin{aligned}\text{Land conservation investments } (m/\text{ha}) = f(&\text{1. financial incentives,}\\ &\text{2. physical incentives,}\\ &\text{3. risk, 4. wealth,}\\ &\text{5. agro-socio-economic}\\ &\text{local context),}\end{aligned} \tag{2}$$

$$\text{Use of organic inputs} = f(1, 2, 3, 4, 5), \tag{3}$$

$$\text{Use of chemical inputs} = f(1, 2, 3, 4, 5), \tag{4}$$

$$\text{Land use erosivity } (C\text{-value}) = f(1, 2, 3, 4, 5). \tag{5}$$

The dependent variables are land conservation investments, nonlabor variable input use (organic inputs and chemical inputs, separately), and land use erosivity. These three variables reflect what, for simplicity, we term "capital investments" that protect the land and enhance the soil. Land conservation investments are the combined investments (measured in meters per hectare) of on-farm infrastructure (grass strips, ditches, hedgerows, and radical terraces). Organic input use (composting, manure, green manure, mulch) and chemical input use (chemical fertilizer, pesticides, and lime) are each measured as binary variables (used or not used on the plot), as we do not have data on quantities used.

The fourth dependent variable is the C-value, an indicator of the erosivity of land use.[21] As the C-value falls, so does the erosivity of land use. Controlling for production techniques, the C-value reflects crop mix—it tends to be less erosive with more perennials (coffee, bananas) and more erosive with more annuals (tubers, pulses, grains). This land use equation explicitly reflects choice of an outcome (erosivity), but is also a decision about crop choice between cash perennials and cash and subsistence annual crops. The decision is based on two sets of variables (controlling for physical, cultural, and economic constraints): (1) to reduce erosion, which is a long-term objective that requires short-term

TABLE 1

LAND USE–CONSERVATION INVESTMENTS–INPUTS MODEL VARIABLES

Model Variable	Overall Mean or Percentage	Coefficient of Variation	Level of Observation
Land use–conservation investments–inputs:			
Land use (C-value)	.16	.43	Parcel
All conservation investments (meters–hectare [m–ha])	424	1.18	Parcel
Grass strips	205	1.34	Parcel
Antierosion ditches	161	1.68	Parcel
Hedgerows	56	2.86	Parcel
Radical terraces	1.17	25.20	Parcel
Organic inputs (% using)	69.5	. . .	Parcel
Chemical inputs (% using)	4.9	. . .	Parcel
Independent variables:			
Monetary incentive to invest:			
Agricultural profitability index (Rwandan francs [FRW])	105.9	.41	Prefecture
Nonagricultural wage in prefecture (FRW)	216	.39	Prefecture
Price of banana (FRW)	23.9	.14	Prefecture
Price of sweet potato (FRW)	14.6	.22	Prefecture
Distance to nearest market (minutes)	4.6	.33	Sector
Distance to paved road (minutes)	24.5	1.10	Sector
Physical incentive to invest:			
Share of holdings under fallow	.16	1.06	Household
Share of holdings under woodlot	.09	1.56	Household
Share of holdings under pasture	.04	2.50	Household
Slope (degrees)	16.7	.65	Parcel

Location on slope (1 = summit, 5 = valley)	.52	.33	Parcel
Farm fragmentation (Simpson)	.51	.52	Household
Size of parcel (ha)	.80	1.02	Parcel
Distance from residence (minutes)	7.4	2.13	Parcel
Years operated	22.2	.66	Parcel
Annual rainfall (mm)	1095	.34	Sector
Risk of investment:			
Share of holdings rented in (% rented in)	8	. . .	Parcel
Price variation (1986–92)	.20	.25	Prefecture
Wealth and liquidity sources:			
Noncropping income (FRW)	26,489	.00	Household
Cash-crop income (FRW)	15,428	.00	Household
Value of livestock (FRW)	20,494	.00	Household
Landholdings owned (ha)	1.53	.83	Household
Human capital:			
Number of adults (ages 15–65)	3.16	.51	Household
Dependency ratio	115	.78	Household
Literacy of head of household (% literate)	50.3	. . .	Household
Knowledge of conservation and production technologies	2.37	1.01	Household
Age of head of household (years)	47.96	.30	Household
Sex of head of household (% male)	79.2	. . .	Household
Sector-level variables:			
Sector land use patterns (C-value)	.13	.15	Sector
Sector conservation investments (m/ha)	411	.53	Sector
Sector use of organic inputs (average % area using)	.67	.22	Sector
Sector use of chemical inputs (average % area using)	.05	1.60	Sector

NOTE.—For level of observation, parcel = 5,596, household = 1,240, sector = 78, and prefecture = 10. Summary statistics reported at the parcel level are for all holdings under cultivation or fallow (thus excluding pasture and woodlot). Parcel-level summary statistics may differ slightly from those aggregated and reported elsewhere at the household level.

(crop) choices, and (2) to maximize returns to land and labor, which is a short-term objective that requires a short-term choice of crops with high returns. We have thus modeled this dual variable as a function of variables that reflect incentives related to the long-term objective of controlling erosion (e.g., steeper slopes of fields should spur investment in perennials to control runoff) and of variables that reflect short-term profitability considerations (e.g., the price of bananas relative to sweet potatoes).

Regressors are listed in table 1 in the following four categories: (1) monetary incentives to invest; (2) physical incentives to invest; (3) risk of investment; (4) cash sources, physical wealth, and human capital; and (5) sector-level variables (local context). Note that some variables are classified for simplicity as either incentive or capacity variables, but actually are both (an example is farm size). The variables in each of the five categories are defined below, along with our hypotheses concerning their effects on the dependent variables.

Monetary Incentives to Invest

Returns to agricultural and nonagricultural activities. We expect better returns to agriculture to lead to more land conservation and soil fertility investments. Return to agriculture is measured here as the average value product of labor per prefecture, using aggregated sample household data valued at market prices. Moreover, as market prices do not fully reflect the actual prices received by farmers, we introduce "distance of the household to the nearest main market" and "distance to a paved road," both of which reflect transaction costs. We expect both to be inversely related to investments in agriculture.

By contrast, we have ambiguous expectations for the effect of the return to nonagricultural activities (measured here by the off-farm wage). On the one hand, better returns off-farm mean competition with on-farm investment. This is not necessarily bad, however; labor and cash diverted to off-farm uses might also reduce pressure on the land by providing cash to buy food. And it may encourage households to use land in less labor-demanding ways, such as perennial crops, fallow, and pasture—ways that are also less erosive and contribute less to the degradation of soil fertility. On the other hand, greater off-farm income means more cash available to the household to invest on-farm.

Crop prices and transaction costs. We include prices in the model, as explained above, to reflect short-term profitability considerations related to crop choice. We expect better prices for perennial crops to induce less erosive land use patterns (i.e., with lower C-values). Perennial crops are represented by the banana price, as the coffee price is set administratively and does not vary over prefectures. We represent annual crop prices with the price of sweet potatoes. Because the prices of annual crops are highly correlated, we were unable to include a vector of prices of annual crops.

Physical Incentives to Invest

Share of farm under fallow, woodlot, and pasture. We expect that farmers with more land in noncropping uses will be less likely to invest in capital to intensify the use of their cultivated land. Fallow and pasture have been declining in recent years because of increased population density and the subsequent need to increase food production.[22] Only woodlots seem not to have suffered, thanks to a strong government campaign aimed at woodlot replanting and maintenance at both household and communal levels. Though some of the lost fallow and pasture has been converted into woodlot, studies suggest that smaller farms are forced to plant more land in sweet potatoes and other tubers,[23] as tubers have higher yields in terms of calories per hectare than other crops do, and they tend to grow relatively well in poorer soils such as those commonly found on steeper slopes.[24] But tubers are more erosive than woodlot and pasture, the traditional uses for these hillsides. Elsewhere in Africa and in Latin America, tubers have been associated with accelerated soil loss.[25]

Plot slope and plot location on the hillside. Steeper slopes (particularly where rainfall is high) increase the incentive to invest in land protection and to adopt less erosive forms of land use. Steeper plots are more susceptible to erosion. But we expect that steepness will discourage the use of chemical and organic inputs because of runoff. Plot slope has become an issue as population density has increased. In Rwanda, the steepest areas have traditionally been reserved for pasture, woodlot, and minor crops, and frequent fallow periods were commonly required. At the outer rings of cultivation, toward the base of the slope and in the swampy valleys, crops are grown along ridges that are built for water drainage. Increasing land scarcity has obliged many farmers in recent decades to depart from this traditional system. As the preferred lands along the upper slopes became occupied and eroded, young farmers were faced with a decision: either cultivate smaller and less fertile plots farther down the hillside or migrate in search of land. Thus, our interest is both in steepness of slope and in hillside location (i.e., upper, middle, or lower, with the value of the regression variable increasing as one descends the slope).

Farm fragmentation, plot size, and distance from residence. Fragmentation is the geographic dispersion of plots (measured by the Simpson index). We expect that, as fragmentation increases and plots are more dispersed, farmers will have less incentive to make land improvements because of higher transaction costs; the same reasoning can be applied to plot size and distance from residence.[26] Moreover, smaller and more distant parcels are often found at the base of the hillside and in valleys where soil erosion is less severe and where lands have been brought into production more recently.

Plot age. We measure this as years since operation began by the current operator or a member of the operator's family. We estimate that for more than 85% of the plots, age of plot reflects the number of years since clearing and first cultivation. In the past, Rwandan farmers could migrate in response to growing demographic pressure; they tended to move to the drier, eastern provinces, once the exclusive domain of the pastoralists. Today, however, in the absence of unoccupied lands, farmers cultivate the same holdings year after year and in increasingly intensive ways. Our hypothesis is ambiguous: long-term cultivation might increase the likelihood of investment in a given parcel; however, all else being equal, long-term cultivation leads to soil fatigue and perhaps a disincentive to invest.

Annual rainfall. More rainfall is expected to lead to less erosive land use practices and more land conservation investments. This was discussed above in the section concerning plot slope.

Risk of Investment

Land tenure and plot use rights. We measure this as a binary variable, 0 for own, 1 for rent. This variable reflects what Feder et al. term degree of "confidence in the long term."[27] We expect farmers to make fewer longer-term land improvements such as hedgerows and terraces on holdings that are rented-in. These holdings are operated under short-term use rights and, as such, put long-term investments at risk of reappropriation by the owner. But empirical evidence for similar contexts is mixed. For a smaller sample in Rwanda (in three prefectures: Butare, Gitarama, and Ruhengeri), Place and Hazell found that farmers tended to invest less in rented land.[28] And S. E. Migot-Adholla, P. B. Hazell, and F. Place show for Ghana that plots owned or under long-term use rights are more likely to be improved (fertilized, mulched, irrigated, or have trees planted on them) than those under short-term use rights such as rental.[29] But for Kenya they found the relationship between tenure and land improvements to be weak—because farmers feel secure in their ability to cultivate rented plots continuously. Moreover, we expect, as do C. C. Cook and M. Grut, that rented holdings will tend to be used for annual crop production rather than for more protective perennial crops and woodlot whose value is returned over a longer time.[30]

Price risk. We measure price risk as a prefecture-level coefficient of annual-price variation over 1986–92. This variable is classified by Feder et al. as a variable affecting "confidence in the short term."[31] In Rwanda, price variability is tied to rainfall variability, and we expect it to be a disincentive to investment.

Wealth

Cash income. We represent this with two variables: (1) noncropping income, which we measure as the sum of off-farm labor sales plus receipts from noncropping business (including such activities as brewing banana wine, construction, and so on), and (2) cash crop income (sales of bananas, coffee, and white potatoes). With perfectly functioning credit markets and perfect information, household wealth and own-cash sources (off-farm activity and crop sales) should not affect investment. But where there are imperfections in the credit market, as is probably the case in rural Rwanda, theory suggests that own-cash sources will be critical to on-farm investments.[32] Moreover, even where the credit market is functioning but underdeveloped, T. Reardon and S. Vosti contend that the least likely investments to receive credit are land conservation measures.[33]

We can posit no clear hypothesis about the effect of noncropping income on investment. As a two-edged sword, noncropping activity provides cash for on-farm investments but also potentially competes (as a destination for such income) with these investments. By contrast, we expect cash crop income to unambiguously increase farm investment as its presence suggests agricultural profitability and a cash source. In the absence of data on formal or informal credit availability, we use ''distance to road'' as a rough proxy for access to formal credit.

Livestock holdings. We expect that livestock holdings will spur farm investments. Livestock holdings are measured in terms of aggregated cash value.

Landholdings. Our hypothesis concerning farm size is ambiguous. On the one hand, larger farmers are better able to spare land for anti-erosion infrastructure, for fallow, and for pasture or woodlot. Larger farmers also tend to be wealthier, so they have more cash to hire labor and to buy inputs for land improvements.[34] In the highland tropics, fallowing is a substitute for the use of organic inputs and land conservation capital (and vice versa).

On the other hand, smaller farmers tend to have more household labor available per hectare. This labor can be used to build and maintain land conservation infrastructure—a job that requires a substantial and continuous supply of labor. Farmers with smaller landholdings also have a greater incentive to improve their land as they depend (ceteris paribus) more on their smallholdings (than do large farmers) and they must pursue intensification as a substitute for fallowing.[35] Maro, for example, shows that increased population density in highland areas of Tanzania has led to agricultural intensification using irrigation in one area and terracing of steep slopes in another.[36]

However, the very smallness of their farms and the riskiness of their environments mean that the desire to divert resources to diversifying their incomes is stronger among smallholders. Yet the cash from these off-farm activities can help them make improvements, a subject treated below.

Own-labor holdings. This is measured as the number of adults in the household. Own labor is expected to be a crucial determinant of investments that require a significant labor counterpart (such as collecting manure, and digging and maintaining antierosion ditches, hedgerows, and mulching).[37] We thus expect that larger households, ceteris paribus, will be more able to undertake such investments. The dependency ratio is the number of children and elderly household members relative to the number of economically active household members. It is expected to affect investments negatively, as children and elderly household members are an alternative destination for time and money.

Human capital. This is proxied by variables reflecting literacy, age, and knowledge of conservation practices, each pertaining to the household head. The more literate, experienced, and knowledgeable in conservation practices the household head is, the more we expect the household to make investments and manage resources carefully. ''Gender of household head'' (0 for man, 1 for woman) is included to reflect access to resources.

Sector-Level Variables

Our nationwide sample of 1,240 households comprises 78 sectors (primary sampling units of about 16 households each). We aggregated household observations for each of the four dependent variables across the households in each sector to create sector-level variables. They represent (1) social and administrative conditions in the immediate area, (2) imitation effects, and (3) positive externalities of neighbors' undertaking land protection measures. John Kerr and N. K. Sanghi argue, using examples from watersheds in India, that this third point should have a positive effect on a given household's investments.[38] The sector-level variables are expected to have a positive influence on the dependent variables (especially in the case of land improvements).[39] We confirmed that the sector variables are not correlated with the more aggregate prefecture-level variables or with the error terms.

IV. Data

One reason for the dearth of empirical research on the determinants of land improvement investments by African rural households is the difficult data requirement. Such research requires not only detailed information on farmers' conservation investments but it also requires a broader set of data to understand the farm management and household strategy context of these investments. Household farm and nonfarm income, assets, demographic characteristics, and the ecological properties of farm holdings are examples of the kinds of information required. Such multilevel data are rare.

The data examined here, however, meet these varied requirements. They derive principally from a nationwide stratified-random sample of 1,240 farm households (operating 6,464 plots), interviewed during the 1991 agroforestry survey by the Agricultural Statistics Division (DSA) of Rwanda's Ministry of Agriculture. These households were drawn from all five major agroecological zones.[40] Interviews with heads of households or their spouses were conducted over a 6-week period beginning in June 1991. The survey instrument treated both household-level variables (e.g., nonfarm income) and plot-level variables (e.g., land conservation investments, land tenure, and steepness of slope). To complete the data set for present purposes, we integrated these data with those on farm and livestock enterprise management from the ministry's national longitudinal survey on the same sample of households. The input use observations are for use in 1991 (the year of the cross section), and the soil conservation investments are meters of improvements on the parcels at the time of the one-shot agroforestry survey in 1991.

V. Data Patterns and Context

Fully 93% of Rwanda's population live in rural areas, and nearly all rural households are engaged in farming. On average, households cultivate slightly less than one hectare of land; the distribution of landholdings is inequitable by the standards of African smallholder agriculture (with a sevenfold difference in land per person between highest and lowest landholder quartiles). Farm holdings are fragmented into many smaller plots. The vast majority of landholdings are owner operated; only 8% are rented.

Beans, sorghum, sweet potatoes, and cassava are the main food staples, and coffee, bananas, and white potatoes are the main cash crops. Farming is labor intensive; women's labor is particularly important in food crop production, while men's labor is crucial in cash crop production and animal husbandry. Hoes and machetes are the basic farm implements; animal traction is nonexistent. Livestock husbandry is integral to the farming system, but the progressive conversion of pasture into cropland has caused a reduction in livestock production in recent decades and a parallel decline in the amount of manure available for improving soil fertility. Rwanda's average population density is among the highest in Africa. Virtually all arable land is now used for agriculture; marginal lands once set aside for pasture or left in long fallow are now coming under more intensive cultivation. Rural informal and formal credit markets are severely underdeveloped.

The model variables are grouped and listed in table 1 according to the model specified above. Note that many of the summary statistics are reported at the plot level, while others are reported at the household or prefectural levels (as indicated). Also, because of our focus on conservation investments and input use, observations on parcels in pasture and woodlot (13.4% of all parcels) have been excluded from this analysis; however, observations on parcels in fallow are included.

Land use is on average fairly nonerosive (with a C-value of .16) though variation across parcels is high (with a coefficient of variation of

.43). The average level of land conservation investment (measured in meters per hectare) in the sample is 424. There is, however, great variation across farm households in the degree to which they invest in land conservation measures, with a coefficient of variation of 1.18. Grass strips are most common, followed by antierosion ditches, then hedgerows, then radical terraces. Ditches and terraces are the most labor- and equipment-intensive to build and maintain, and grass strips the least. Hence, the abundance of grass strips can be explained by the relative ease of their production. Most (69.5%) of the parcels receive organic matter, but very few (4.9%) receive chemical fertilizer, lime, or pesticides.[41]

To provide more detail on patterns of investment and input use, we calculated (not shown in table 1) the shares of farmland receiving land conservation measures, organic matter, and chemical fertilizer.[42] Labor-led intensification, in its purest form, where farmland receives none of the improvements, characterizes only 15% of Rwandan farmland. Conversely, full capital-led intensification, where all three improvements are made, accounts for only 4% of farmland. Most farmland falls on the continuum in between. Conservation measures are not used on 23% of the land; 65% of this unconserved land receives neither organic matter nor chemical inputs while 35% receives organic inputs only. Conservation measures are used on 76% of the land; of this conserved land, 82% receives organic inputs and 6% receives chemical inputs. Hence, there are two clusters between the poles—farmland that receives land conservation measures (land that tends also to receive organic inputs) and farmland that does not receive conservation measures (land that tends also not to receive organic inputs). This clustering is consistent with the key role of land conservation investments in preventing runoff of organic matter and chemicals applied to the land.

Almost all land in rotation is cropped; little is kept under fallow. Larger farms have a greater share of fallow land than do smaller farms. Figure 1 shows that the quartile of smallest farms (in arable land per adult equivalent) cultivates 86% of its arable land, whereas the quartile of largest farms cultivates only 57%. Fields tend to be on slopes, and annual rainfall is high. These factors provide a strong incentive for farmers to take appropriate measures aimed at controlling soil loss.

Nonfarm income (wages from hired agricultural and nonagricultural work plus own-business income) constitutes about one-third of total income, and about two-thirds of households earn some nonfarm income. Most households own a few small ruminants; less than a quarter owns cattle. There is strong variation over households in their (self-reported) knowledge of various land conservation and productivity-enhancing practices. Agricultural profitability as well as price variability over time show considerable variation across prefectures.

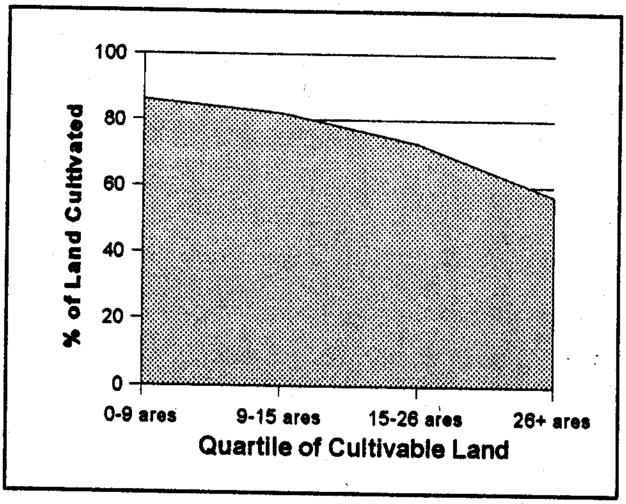

FIG. 1.—Proportion of land under cultivation by farm size

VI. Regression Results and Discussion

In this section we examine the determinants of land management strategies in Rwanda. Random-effects, generalized least squares (GLS) regressions are estimated to explain land conservation investments, organic input use, chemical input use, and land use (C-values). We use the regressors described above.[43]

The results for conservation investments and input use are discussed first, followed by those for land use. Regression results are reported in table 2. Only results with significance above the .10 level are discussed.

Correlations among Regressands

There is a negative association between use of organic inputs and erosivity of land use (table 2), as one would expect; where cropping patterns are less erosive, there is less loss due to runoff and thus more effective use of inputs.[44] Moreover, there are correlations between land conservation investments on the one hand and use of organic and chemical inputs on the other. Again, the former guards against runoff, thereby enhancing the effectiveness of the latter. Finally, there is a relationship between organic input use and chemical input use. Agronomic recommendations are for the two to be used together, and their positive correlation implies that, by and large, farmer behavior is consistent with these recommendations.

Determinants of Land Conservation Investments

Monetary and physical incentives. First, short-term economic incentives play less of a role than do some of the nonprice, structural condi-

TABLE 2

RANDOM-EFFECTS GLS REGRESSIONS: INVESTMENTS–INPUTS–LAND USE MODEL

INDEPENDENT VARIABLE	INVESTMENTS–INPUTS–LAND USE			
	Conservation Investments (m/ha)	Organic Inputs	Chemical Inputs	Land Use (C-Value)
Correlation matrix:				
Conservation investments	. . .			
Organic inputs	.21**			
Chemical inputs	.06**	.11**		
Land use (C-value)	.05**	−.18**	−.02	. . .
Monetary incentive to invest:				
Agricultural profitability index	.02	.01	−.05	−.02
Nonagricultural wage	−.08	−.08**	−.05	−.04
Price of bananas	.07	−.06**	−.03	.03
Price of sweet potatoes	.03	.02	−.04	−.01
Distance to nearest market	.01	.02	.01	−.01
Distance to paved road	.02	−.05**	−.04*	.02
Physical incentive to invest:				
Share of holdings under fallow	−.06	−.04*	−.00	−.09**
Share of holdings under woodlot	.09	.01	.06**	−.12**
Share of holdings under pasture	−.07	−.09**	−.08**	−.08**
Slope (degrees)	−.01	−.13**	−.14**	−.08*
Location on slope (1 = summit, 5 = valley)	−.20**	−.17**	−.02**	.07**
Farm fragmentation (Simpson index)	−.09*	−.01	−.02	−.04**
Size of parcel	−.03**	.41**	.22**	−.17**

Distance from residence	−.03**	−.29**	.04**	.10**
Years operated	.01	.10**	−.04**	−.01
Annual rainfall	.04	.02	.02	.06**
Risk of investment:				
Share of landholdings rented in (0 = own, 1 = lease)	−.06**	−.22**	−.01**	.25**
Price variation (1986–92)	.11*	−.07**	.01	.01
Wealth and liquidity sources and human capital:				
Noncropping income	.16*	.06*	.01	.01
Cash crop income	.00	.02	.02	−.06**
Value of livestock	.06	.13**	.03	.02
Landholdings owned (ha)	−.32**	−.32**	−.01	.19**
Human capital:				
Number of adults (ages 15–65)	.06	.01	.02	.04*
Dependency ratio	.01	.00	.01	.03*
Literacy of head of household (0 = no, 1 = yes)	.04	−.02	−.00	.00
Knowledge of conservation and production technologies	.03	.05**	.03	−.02
Age of head of household (years)	−.01	−.10**	.02	.03
Sex of head of household (0 = male, 1 = female)	−.02	.02	−.02	.01
Sector-level variables:				
Sector land use patterns	.03	−.01	.02	.39**
Sector conservation investments	.45**	.02	−.02	−.02
Sector use of organic inputs	−.05	.15**	−.02	.01
Sector use of chemical inputs	.05	.03*	.28**	.08**
R^2 within	.04	.32	.03	.12
R^2 between	.16	.34	.19	.50
R^2 overall	.19	.35	.19	.24
$P > \chi^2$	.00	.00	.00	.00
Breusch-Pagan $P > \chi^2$	.00	.00	.00	.00

* $T \leq .10$.

** $T \leq .05$.

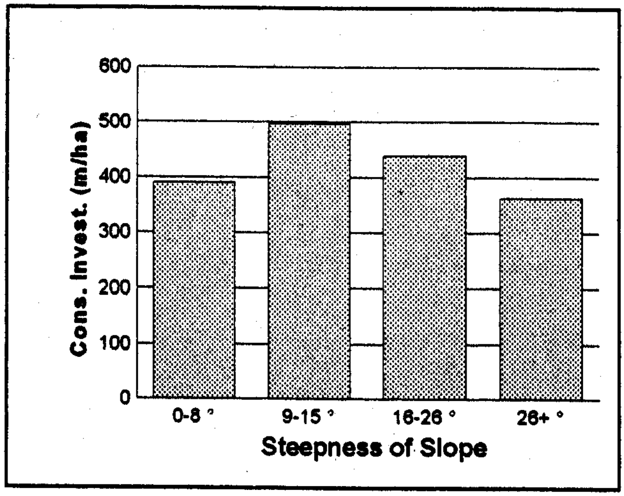

FIG. 2.—Conservation investments by slope

tions discussed below. This may be because most crops are not marketed. Higher returns to agriculture do not significantly affect land conservation investments. Crop prices also do not affect these investments.

Second, plot and farm characteristics (ecological and organizational) play an important role in the investment decision. Farmers are more likely to make investments in land conservation if their holdings are located higher on the hillside, are closer to the residence, and are owned (not rented). Historically, erosion has been most severe on upper hillsides, where farmers tend to grow beans and other important annual crops. Fragmentation (reflected in the Simpson index) has the expected negative sign.

Moreover, the relationship between conservation investments and field slope is complex. Though the regressions in table 2 show no significant association, closer examination of the relationship between slope and conservation investments (see fig. 2) shows that farmers invest most heavily in slopes of medium steepness—those steep enough to need conservation investments, but not so steep as to discourage investment—for the following reasons: (1) traditionally, farmers placed their steepest slopes under pasture, woodlot, and perennial crops because these slopes easily erode; (2) it is very costly to maintain land protection infrastructure on steep slopes; and (3) the lightness and thinness of these soils make them prone to erosion, keep yields low, and lower long-term returns to investments. Thus a downward spiral of low production and low investment is set into motion as these marginal lands are taken out of their traditional uses (forest, long fallow, rangeland, and so on) and put under more intensive cultivation.

Wealth. Four sets of results are significant. First, noncropping income as a liquidity source for investments (hiring labor, buying materials) exerts a positive effect on conservation investments. Second, larger farmers tend to make fewer conservation investments than do smaller farmers. This may confirm that credit (with land as collateral) is not important to these investments. Larger farmers also have more land under fallow and thus may feel less pressured to protect their land. It may also be that larger holders are not compelled to take conservation measures to meet daily food and cash needs. Many smallholders, on the other hand, appear to recognize that such investments are vital to their livelihood, even in the short run.

Third, knowledge of sustainable production practices (gained from extension visits) appears to have little effect on conservation investments when measured as an aggregate of all four types of investment, as we do here. However, Clay and Reardon, using the same data but disaggregating types of land conservation practices, show that some conservation practices are positively affected by this knowledge, while others are not.[45] In particular, farmers who have had greater exposure to conservation and fertility-enhancing technologies are more apt to plant hedgerows than are other farmers. However, this is not true for other investments. The difference may emerge because, unlike grass strips and ditches, the use of hedgerows to control soil loss is a relatively new technology for Rwandan farmers, and its application is less widespread. As the extension service is an important vehicle for dissemination of this technology, it is perhaps for this reason that the positive effects of farmer knowledge are greater for hedgerows than for other, more traditional conservation investments.[46]

Sector-level variables. As expected, the local-area (sector) prevalence of land conservation investment encourages farm-level investment. This effect reflects the local-level promotion of conservation investments and the tendency of farmers to adopt the practices of their neighbors.

Determinants of use of organic inputs and chemical inputs. We estimated two separate regressions for organic inputs and chemical inputs because of their different agronomic effects, labor requirements (organic inputs require collection and distribution), and cash requirements (chemical inputs are purchased). But for comparison we discuss the two sets of (significant) results side-by-side. The explanatory power of the regressions and the number of significant variables were much greater for the organic inputs regressions. This is probably because so few farmers use chemical inputs.

Monetary incentives. Better returns to agriculture do not significantly affect the use of organic or chemical inputs. Moreover, there is an inverse relationship between distance to a paved road and use of both types of inputs. This suggests that the marketability of output reinforces the desire to enhance soil fertility. Second, as expected, a higher nonagri-

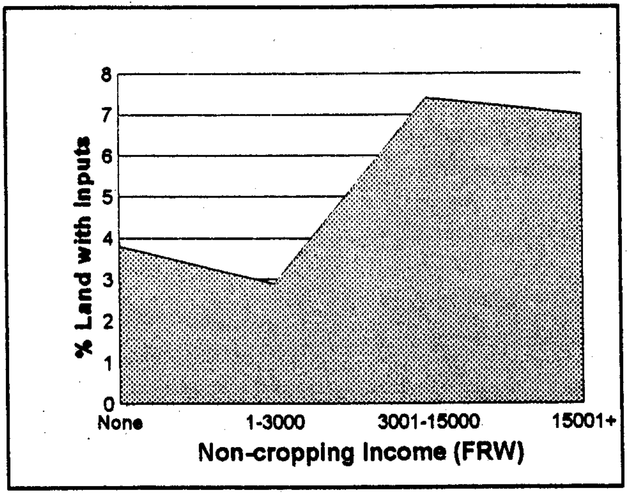

FIG. 3.—Use of chemical inputs by level of non-cropping income

cultural wage reduces the use of organic matter. The effect on chemical inputs has the expected sign but is not significant.

Physical incentives. Fields higher on the hillside are more likely to receive both organic and chemical inputs. Steeper slopes are less likely to receive inputs because of runoff. Older plots receive more organic matter, presumably to restore soil fertility as older plots are more eroded. Older plots receive fewer chemical inputs, perhaps because the effects are judged to be less effective on more eroded soils. Plots farther from the residence receive fewer organic inputs (because of higher transaction costs) and more chemical inputs (because fertilizer is easy to transport and because the annual crops on which fertilizer is used are produced farther from the residence). Farms with more land under fallow, woodlot, and pasture, use less of both types of inputs. This makes particularly good sense in the case of organic inputs, which are agronomic substitutes for the effects of fallow.

Risk. As hypothesized, lands that are rented-in provide farmers with less incentive to use organic inputs and chemical inputs. Moreover, price variation (short-term risk) discourages the use of both organic and chemical inputs, but the effect is significant only for organic inputs.

Wealth. More organic inputs are used by households with (1) more noncropping income, (2) smaller farms, (3) more livestock (source of manure), and (4) greater knowledge of sustainable production practices learned from the extension service.

None of the wealth variables significantly affects the use of chemical inputs. However, despite low overall use rates for chemical fertilizer, lime, and pesticides, figure 3 shows that farms in the higher-nonfarm-income categories are about twice a likely as the lower-nonfarm-income groups to use these inputs.

Sector-level variables. Local area use of organic matter affects its plot-level use, and sector-level use of fertilizer affects its plot-level use. In addition, sector-level use of chemical inputs increases plot-level use of organic inputs, a complementarity suggested above.

Determinants of Land Use

Monetary incentives. These variables were, in general, not significant. This implies that profitability—at least in a cross-section study—is not nearly as important as are agroclimate and farm characteristics in determining land use. This result may not hold if tested in a time-series context.

Physical incentives. Farmers are choosing more protective land uses (especially bananas and other perennials) for hillside cultivation. In part this is because households prefer to locate bananas close to their home compounds, which for historical and cultural reasons are more often located on the moderately steep hilltops than in the valleys. The relationship between erosivity (C-value) and slope is inverse, showing that farmers choose protective crops for the slopes.

Risk. Consistent with Cook and Grut's observation discussed earlier, land use rights also affect the use of trees and shrubs. Rwandan households are far less likely to grow protective crops (bananas, coffee, and other perennials) on land they rent than on land they own. This may be because they feel more confident that they and their families will reap the benefits of the investments they make in perennial crops or simply because they have had more time to make such investments.

Wealth. Having cash crop (banana, coffee, white potato) income reduces the erosivity of land use because the cash crops in Rwanda are mainly perennials. Moreover, greater landholdings, holding constant family size and share of land in noncropping uses, means more erosive land use, as larger farmers are under less livelihood pressure to husband their land. By contrast, greater family size and share of children in the family, controlling for farm size (hence greater population pressure on the land), translates into more erosive land uses (annual food crops).

The above paragraph paints an ambiguous picture concerning the relationship between land scarcity and the erosivity of land use. To shed light on the inconclusiveness of these results, J. Kangasniemi and Reardon explored in greater detail the differences in C-values of smaller and larger farms.[47] They take into account (by adjusting the C-values accordingly) that small farmers (1) crop more densely (mixed cropping and intercropping), with efforts such as densely planted banana groves, and (2) grow more trees per hectare. They show that land use practices among the most land-scarce quartile of households do not appear to be any more erosive than those among higher quartiles. In other words, al-though the current patterns of land use threaten the long-term sustainability of Rwandan agriculture, small farmer strategies in the short to medium run have, overall, offset the inevitable impacts of population growth on the land. Data from the DSA for 1984 and 1990 also show a major expansion in the allocation of land to protective perennials. Land planted in bananas and coffee has expanded by one-fourth. Land in tubers, which provide modest protection against erosion, has also increased, largely at the expense of maize and sorghum, which provide only minimal protection against erosion. How crops are managed is equally important to erosivity. For instance, the effectiveness of coffee depends in large measure on mulching, and our observations in the field show that many coffee fields were without mulch in the early 1990s, in contrast to the nearly universal mulching before that time.[48] In the case of bananas, the outlook is better, since, in contrast to coffee, bananas produce their own mulch.

VII. Conclusions

This research contributes to the debate concerning what are referred to here as the labor-led and capital-led paths to sustainable agricultural intensification. We address the questions of whether and why particular types of farm households situated in a given agroclimatic and policy context, and facing similar incentives to intensify, take the capital-led intensification path (either a full version or a partial version of this path). Specifically, using a nationwide sample of Rwandan farm households, we explore the determinants of smallholder investments in three forms of land protection and improvement (land conservation and use of organic inputs and chemical fertilizer) as well as the determinants of land use.

The setting in the East African highland tropics is characterized by rapid population growth and land degradation. In rural areas of Rwanda, only a small fraction of the farmers fall into extreme categories, making either none (0.7%) or all (7.8%) of the three types of improvements. The vast majority of the farmers are ranged between the two extremes of the labor-led and the capital-led intensification paths in their pure forms. We found, in general, that where farms are positioned along this continuum is influenced by factors linked to agroclimate and farm structure, as well as by factors affected by policy. The results are summarized below.

Our analysis of survey data from a nationwide sample of farm households in Rwanda provides empirical confirmation of four sets of conclusions that have implications for national policy makers, external donor programming, and for the broader ''relief-to-development'' trajectory that the international donor community envisions for postcrisis Rwanda.

First, the structure of landholding is an important conditioning link between population pressure and the intensification paths taken by farmers. Land tenure; slope; fragmentation; years of cultivation; share of holdings under fallow, woodlot, and pasture; and size of holdings (controlling for family size) are important determinants of farmer investment strategies. In general, investments in land conservation and fertility are greater on land owned (not rented) by farmers, where slopes are of medium steepness, where land is less fragmented and is cultivated for a shorter time, and among smaller farmers and those with little land in fallow, woodlot, and pasture. Thus, apart from the obvious need for political stability in this war-torn country, our work shows that farmers need confidence in the longer term through secure land tenure. This means reducing the risk of appropriation—which in the past 2 years has been extremely high—and the ensuing right to transact land. Enhancing farmer access to the land market will require reform of existing and antiquated land laws.

Second, household-level intersectoral links—specifically, reverse linkages, where nonfarm income affects farm investment—enhance the capacity of households to follow the capital-led intensification path. Nonfarm income as an important source of own liquidity, in this setting of underdeveloped credit markets, is important for households in order to buy materials, animals, and labor, all of which are needed for sustainable intensification. It can also provide a buffer by allowing farmers breathing space to make long-term investments in higher-yielding and cash-earning perennials. Nonfarm activities also increase the demand for crops through downstream production linkages. And as an alternative source of income, such activities can reduce pressure on the land, enabling households to meet food needs through market access rather than subsistence. Livestock husbandry is also important for organic matter use, and it is important to enhance livestock holdings via intensification of husbandry.

Third, short-term relative economic profitability of cropping, commercialization, lower price risk, and more accessible infrastructure promote the use of organic and chemical inputs to enhance soil fertility. Inputs such as chemical fertilizer and manure, however, are expensive and often unavailable; policies and programs to increase access to these inputs are crucial.[49] Cash cropping (in the Rwandan case, of food and beverage crops) is especially important. Far from being a villain with respect to sustainable agriculture and the environment, cash cropping is an important prerequisite for capital-led intensification. This is because it provides farmers with the incentive and capacity to make substantial investments.

Fourth, public investments in extension and roads promote sustainable intensification. We found that the knowledge farmers gained from extension encouraged sustainable production practices, specifically the use of organic matter and the building of terraces. Investment in roads results in improved marketing of crops, which, consequently, encourages land improvement.

Notes

* We thank the Division des Statistiques Agricoles (DSA) of the Rwandan Ministry of Agriculture (MINAGRI) for provision of the data. We thank USAID/AFR/SD/PSGE (FSP and NRM), USAID/Kigali, and AID/Global Bureau, Office of Agriculture and Food Security, for funding via the Food Security II Cooperative Agreement, and Akin Adesina, Sara Scherr, David Tardif-Douglin, and two anonymous reviewers for very useful comments on earlier versions.

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18. See, e.g., Place and Hazell; see also Clay (n. 2 above).

19. For this literature, see, e.g., G. Christensen, "Determinants of Private Investment in Rural Burkina Faso" (Ph.D. diss., Cornell University, 1989); G. Feder, L. J. Lau, J. Y. Lin, and X. Luo, "The Determinants of Farm Investment and Residential Construction in Post-reform China," *Economic Development and Cultural Change* 41, no. 1 (1992): 1–26; and G. Feder, R. E. Just, and D. Zilberman, "Adoption of Agricultural Innovations in Developing Countries: A Survey," *Economic Development and Cultural Change* 33, no. 2 (1985): 255–98.

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21. Erosivity of land use is measured using C-values. The C-value index is a well-known measure that reflects the overall protective quality of crops. It is defined as "the ratio of soil loss from an area with a specific cover and tillage practice to that from an identical area in tilled continuous fallow" (W. H. Wischmeier and D. D. Smith, "Predicting Rainfall Erosion Losses: A Guide to Conservation Planning," *Agricultural Handbook No. 537* [Washington, D.C.: USDA, 1978], pp. 1–58). For any given field, the crop cover, canopy, and tillage practices can vary throughout the year. C-values represent the average soil loss ratio resulting from these factors over the growing season. They must be obtained empirically, as planting and tillage strategies of specific crops vary over farming systems. For this reason, the use of the standard published C-values, based largely on farming practices in the United States, should not be used in Third World countries without first being evaluated. We use region-specific C-values, based on fieldwork undertaken in the Kiambu and Nurang'a districts of the Kenya highlands (Lawrence A. Lewis, "Assessing Soil Loss in Kiambu and Nurang'a Districts, Kenya," *Geografiska Annaler* 67, pt. A [1985]: 273–84) and a pilot study of soil loss in Rwanda (Lawrence A. Lewis, "Measurement and Assessment of Soil Loss in Rwanda," *Catena Supplement* 12 [1988]: 151–65). Among crops commonly grown in Rwanda, C-values vary from .02 and .04 for coffee and bananas, to .35 and .40 for maize and sorghum. In general, perennial crops, pasture, fallow, and woodlot have low, less erosive, C-values. Annual crops, particularly grains, have high, more erosive, C-values. Tubers and leguminous crops tend to have values in the middle range. The average C-value for cultivated holdings in Rwanda is .16, a composite of many forms of land use and crop mix. Given the calibrated C-value estimates from these studies in the region, one only has to know the crops planted on the plot to know the C-value of that plot. Hence, we used our data on crop and cropped area per plot to calculate C-values.

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26. This expectation is supported by empirical evidence from field surveys in the Ruhengeri zone; see Ford (n. 6 above); and Ndiaye and Sofranko (see n. 17 above).

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39. Ford (n. 6 above) notes that the administration of campaigns and regulations concerning soil conservation can have important effects locally. We expect these to vary greatly over geographic sectors and households within a given sector (as our data show).

40. See Clay et al. (n. 10 above) for details.

41. Only .08 kilograms/hectare of fertilizer are used in rural Rwanda; this is substantially less than is used in cash-cropping areas of highland Kenya and Uganda. See F. U. Byiringiro, ''Determinants of Farm Productivity and the Size-Productivity Relationship under Land Constraints: The Case of Rwanda'' (M.S. thesis, Department of Agricultural Economics, Michigan State University, 1995).

42. We used share of farmland rather than share of households because many households use inputs on only a small share of their land and it would be misleading to classify them as following capital-led intensification.

43. The random effects model (REM) using GLS was used to account for household-level random effects because we use multiple plot-level observations per household. For each regression, the appropriateness of using the model was tested using the Breusch and Pagan Lagrangian multiplier test for random effects. In every case the REM was strongly justified, at $P = .0000$. We also estimated the models using ordinary least squares (OLS) for conservation investments and land use, and logit for the two input-use equations. The results were close to those found in the REM GLS regressions. Moreover, because the equations are estimated using plot-level observations, estimates are weighted according to parcel size, as well as for the household's probability of selection.

44. Ndiaye and Sofranko (n. 17 above), e.g., find that farmers in Ruhengeri were unwilling to use inputs where runoff caused by steep slopes was a problem.

45. C. Clay and T. Reardon, ''Determinants of Farm-Level Conservation Investments in Rwanda,'' in *Issues in Agricultural Competitiveness: Markets and Policies,* ed. R. Rose, C. Tanner, and M. A. Bellamy, IAAE Occasional Paper no. 7 (paper presented at twenty-second Congress of International Association of Agricultural Economists, Harare, August 1994), pp. 210–21.

46. We expected labor to have a positive effect on investments; the coefficient is positive but not significant, probably because measuring labor as family size is not a good fit.

47. J. Kangasniemi and T. Reardon, ''Demographic Pressure and the Sustainability of Land Use in Rwanda,'' in *Issues in Agricultural Competitiveness: Markets and Policies,* ed. R. Rose, C. Tanner, and M. A. Bellamy, IAAE Occasional Paper no. 7 (paper presented at twenty-second Congress of International Association of Agricultural Economists, Harare, August 1994), pp. 23–31.

48. Some observers of Rwandan agriculture predicted more than a decade ago that, as the availability of organic matter from previously uncultivated valley bottoms and other areas declines, mulching will decrease. On the other hand, mulching of coffee is mandatory and was rigorously enforced until the early 1990s. The decline in mulching in recent years may have more to do with the low coffee prices that led farmers to neglect their coffee trees and the reduced government control that allowed this neglect than with any decline in the availability of mulch.

49. This conclusion coincides with one for the Ruhengeri zone noted in Ndiaye and Sofranko, who observed that farmers found these inputs too expensive and inaccessible.