DETERMINANTS OF FARM-LEVEL CONSERVATION INVESTMENTS IN RWANDA

by

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ABSTRACT: This paper analyzes the determinants of conservation investments at the farm level in Rwanda. The following tend to be important promoters of investment: (1) own-sources of liquidity, especially from off-farm employment, (2) smaller landholdings, (3) household labor, and, under certain circumstances, (4) conservation knowledge (possibly from extension). But insecurity of land tenure (reflected in the share of rented land) tends to decrease investment. The policy implications are: (1) projects and policies aimed at developing off-farm enterprises by farm families can also indirectly promote soil conservation on-farm; this should be important to the Rwanda government and to external donors that are actively pursuing both to promote rural food security; (2) extension service's emphasis on conservation measures has clear payoffs at the farm level, and also increases the compatibility of conservation and income diversification; (3) the nature of the land market and land tenure policy affect conservation investments.

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I. INTRODUCTION

Declining productivity of farmland due to soil degradation poses an immediate threat to the livelihoods of farm families in Rwanda. Steep slopes, abundant rainfall, and intense demographic pressure have raised the specter of food insecurity and have driven the country's smallholders to cultivate marginal lands once held in pasture and long fallow. Like many other highland countries in Africa, Asia, and Latin America, the problem of land degradation has for Rwanda become a matter of national concern. Rwanda's National Agricultural Commission now estimates that half the country's farmland suffers from moderate to severe erosion (Commission Nationale d'Agriculture, 1992); farmers report that the productivity of nearly half their holdings has declined in recent years from degradation (Clay 1993).

The focus of Rwanda's national strategy to control soil erosion and restore productivity is the promotion of farm-level investments in soil conservation, notably: grass strips, anti-erosion ditches, hedgerows, and radical terraces. These investments require substantial household outlays of labor time and cash.

Conservation investments are crucial to the long-run interests of the country, as well as the individual farm household; they are found in varying degrees in no less than three-fourths of Rwanda's cultivable holdings. This paper examines the determinants of farmer investments in soil conservation. Specifically, we ask how economic incentives (e.g., risk due to insecurity of land tenure, and relative regional profitability of agriculture), household characteristics (e.g., nonfarm income, wealth, human capital, and knowledge of conservation practices), and ecological attributes of farmers' operational holdings (e.g., steepness of slope, distance from the family compound) affect the investments that farmers make to ensure the continuing productivity of their land.

Though fundamental to the formulation of policies to promote conservation investments, there exists little empirical literature on these questions in developing countries, particularly those of Sub-Saharan Africa. Recent exceptions include Ehui *et al.* on land use determinants in Nigeria, and the impact of land tenure on land improvements in Rwanda, among other places (Blarel 1989; Place and Hazell 1993). Research on the determinants of farm asset investments, e.g., Collier and Deepak (1980) in Kenya and Christensen (1989) in Burkina Faso, has been only slightly more prevalent.

To contribute to this nascent literature in Africa, we pursue two objectives in this paper. The first is to describe the nature and extent of conservation investments in Rwanda; the second is to explain inter-household variations in conservation investments as a function of selected parcel, household, and regional variables. The paper proceeds as follows: Section II discusses the context. Section III discusses the theory and the model. Section IV discusses the data. Section V presents regression results. Section IV concludes with a summary of findings and a review of policy implications.

II. CONTEXT

Ninety-three percent of Rwanda's population lives in rural areas and nearly all rural households farm. 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). Pulses, roots and tubers, and grains are the main food staples, and coffee and tea are important cash crops. Farming is labor intensive. 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.

Table 1 shows characteristics of the farm household sample. There is great variation over farm households in the degree to which they invest in soil conservation measures: grass strips are most common, followed by anti-erosion ditches, then hedgerows. Almost all operable land is either cropped or in woodlot. Little land is kept under fallow. Fields tend to be on slopes, and annual rainfall is high. These factors provide strong incentive for farmers to take appropriate measures aimed at controlling soil loss.

Nonfarm income (wages from hired agricultural and non-agricultural work plus own-business income) is constitutes on average about one third of total income, and about two-thirds of households earn some nonfarm income. Operational holdings are very small, and are fragmented into many smaller plots. The vast majority of landholdings are owner-operated; only 9 percent are rented. Most households own a few small ruminants; less than a quarter own cattle. There is strong variation over households in their (self-reported) degree of knowledge of various soil conservation and productivity-enhancing practices. Agricultural profitability as well as price variability vary considerably over prefectures.

III. THEORY and MODEL

Economic theory suggests conflicting hypotheses with respect to the determinants of conservation investments by smallholders in rural contexts such as Rwanda's. On the one hand, a declining land base and weak credit markets (to insulate the household from food shortages) compels households to husband carefully their declining resource base, through conservation investments *inter alia* (Boserup; Ehui *et al.*).

On the other hand, risk (from price and rainfall instability, or from insecurity of land tenure hence risk of appropriation of capital) is inimical to investment for risk-averse farmers (Newbery and Stiglitz). Rather than narrowly focusing on their land base, farmers diversify their asset portfolios and

incomes (Binswanger; Robison and Barry). Yet both from theory and empirical evidence for farm asset investment, off-farm income as a liquidity source would be critical to on-farm investments where there is failure of, or constraints in, the credit market (Reardon *et al.*). Moreover, Reardon and Vosti contend that where credit markets are underdeveloped, the least likely investments to receive credit are conservation measures.

Hence, there are competing forces (mirrored in competing theoretical hypotheses) encouraging and discouraging households from making these investments. But practical development policy choices depend on empirical evidence concerning these determinants in specific contexts. The model and hypotheses presented below are intended to address these practical needs.

Based on firm-level investment theory (see Christensen for review), we model farm-level conservation investments as a function of four sets of variables: (a) financial returns (incentives/disincentives) to investment, (b) physical returns to investment, (c) riskiness of investment, and (d) capacity to invest (human and physical capital, liquidity sources).

Following are the hypotheses related to each set of the above general determinants. The specific variables that comprise each group are listed in Table 1 along with their summary statistics.

Financial incentives to invest: Agricultural profitability is expected to have a positive effect on conservation investments. The relative return to nonfarm work, however, will have an ambiguous effect: better returns to nonfarm investment mean competition with on-farm investment, but they may also raise the absolute amount of cash available to invest on the farm. In the presence of credit constraints, the latter (own liquidity) is critical.

Physical incentives to invest: Greater steepness of slope increases the incentive to invest in soil protection as these slopes tend to be more susceptible to erosion. Farmers with greater holdings in fallow will be less likely to invest as their reliance on presently-cultivated land is not as great. As fields become more dispersed and grow smaller, there is less incentive to build and maintain bunds or apply fertility

supplements because of higher travel/transaction costs. More erosive forms of land use (high C-values) will be associated with greater conservation investment; less erosive uses such as pasture, fallow and perennial crops will need, and receive, fewer investments.[1]

Riskiness of investment: Holdings operated under lease rights (hence greater risk of appropriation of land conservation investments by owners of rented land), and those in areas of price and rainfall instability, will receive fewer investments than those for which the level of risk is lower. Though Blarel (1989) found no significant relationship between risk and conservation investments in Rwanda, we believe this to be due to the methodological and analytical limitations of that study.[2]

Physical and human capital, and own-liquidity sources: With perfectly functioning credit markets and perfect information, household wealth and liquidity sources, such as cash crop sales and nonfarm income, should not affect investment. Yet we suspect that gross imperfections in Rwanda's credit and information markets exist, and therefore hypothesize these own-liquidity sources to be crucial to investment. However, as noted earlier, nonfarm income diversification is conceptually a 'two-edged sword,' providing liquidity for on-farm investments but also potentially competing (as a destination for such income) with these investments.

The installation and maintenance of conservation measures can be a very labor intensive endeavor, and will thus vary along with the availability of household labor. Larger households, *ceteris paribus,* will be more likely than smaller households to adopt conservation practices of all types. In addition to the amount of labor available, the quality of human capital can also make a difference. Higher levels of

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[1]A well-known measure that reflects the protective quality of crops is the C-value. The C-value 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," (Wischmeier and Smith 1978). For any given field, the crop cover, canopy, and tillage practices can vary throughout the year. The C-value represents the average soil loss ratio resulting from these factors over the growing season.

[2]Blarel's study was limited to just three of Rwanda's ten prefectures, and the analysis of tenure status and investments was conducted exclusively at the bivariate level.

education and knowledge of conservation practices, particularly among household heads, should alert farm families to the long run hazards of declining productivity, while also providing more information on specific countermeasures. These factors will exert a positive effect on conservation investments.

IV. DATA

A reason for the dearth of empirical work on the determinants of conservation investments in Africa is the difficult data requirements. On one hand, such research requires data on the extent of farmers' conservation investments, implying either the physical measurement of terraces, for example, or on cash and labor time required to build them, or both. On the other hand, a broader set of data is needed 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 multi-level 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 parcels) interviewed in 1991 by the Agricultural Statistics Division (DSA) of Rwanda's Ministry of Agriculture.[3] Interviews with heads of households and/or their spouses were conducted over a six-week period beginning in June 1991. The survey instrument treated both household-level variables (such as nonfarm income) and parcel-level variables (such soil conservation investments, land tenure, and steepness of slope). To complete the dataset for our purposes, we integrated these data with those on farm and livestock enterprise management from the Ministry's ongoing national longitudinal survey on the same sample of households.

[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.

V. REGRESSION RESULTS

Ordinary Least Squares regressions on soil conservation investments are estimated using the variables described in section III, and the results are reported in Table 2. The results of these regressions are discussed below for each of the variable sets in our model. Because the OLS estimates are run at the parcel level, all estimates are weighted according to parcel size, as well as for the household's probability of selection.

Monetary incentive: Agricultural profitability provides farmers with strong incentive to invest in both grass strips and ditches, but it appears to be a disincentive for planting hedgerows. Non-agricultural wage rates, as expected, exert a negative effect on conservation investment, though only significant for grass strips and ditches.

Physical incentive: More erosive forms of land use (high C-values), notably annual crops, are associated with greater conservation investment, though this relationship is not significant for anti-erosion ditches. Farmers are more likely to make investments in soil conservation if their holdings are closer to the family compound and if they are located higher on the slope. Historically, erosion has been the most severe on these upper slopes where farmers tend to grow beans and other important annual crops.

Holdings on steep slopes receive fewer investments in grass strips and ditches, but relatively greater investment in hedgerows. This seems paradoxical at first, but is likely a reflection of three factors: (i) Farmers tend to place these steep slopes under pasture, woodlot, and perennial crops because of their high susceptibility to erosion. Of the three types of investments examined here only hedgerows are commonly found in wooded parcels. Grass strips and ditches are almost always used in fields containing annual crops. (ii) It is very costly to maintain investments on these slopes. (iii) Population growth and land scarcity have pushed Rwandan farmers to occupy the very steep mid slopes where erosion problems are particularly common. The characteristic lightness and thinness of these soils make them especially prone to erosion; these characteristics also keep yields low and diminish returns to

investments in soil conservation. Thus a downward spiral of low production and low investment is easily set into motion (Pingali and Binswanger, 1984) as these marginal lands are taken out of their traditional uses (forest, long fallow, rangeland, etc.) and put under more intensive cultivation.

Risk of investment: As anticipated, for all forms of conservation investment, lands that are rented-in provide farmers with less incentive to invest, as the risk of appropriation is greater. This finding contradicts Blarel's conclusion, based on a smaller sample and bivariate analysis, that no such relationship exists. Price variation exerts a significant negative influence on the planting of hedgerows, yet, like agricultural profitability, there is a positive effect on the installation of anti-erosion ditches.

Wealth and liquidity: Larger farms tend to invest less per hectare. This may confirm that credit (with land as collateral) is not important to these investments. Large holders also have more land under fallow and thus may feel less pressured to protect the soils of their operational holdings. It may also be that larger holders are not compelled to take conservation measures to meet daily food and cash needs. Many small holders, on the other hand, appear to recognize that such investments are vital to their livelihoods, even in the short run.

Wealth in livestock does not have a strong effect on conservation investments, as it might have in countries where livestock play a larger part in the farm economy. Consistent with our expectations, nonfarm income as a liquidity source for investments (hiring labor, buying materials) exerts a positive effect on investments in grass strips and hedgerows. However nonfarm income exerts no significant effect on the installation of anti-erosion ditches.

Human capital: Household labor exerts a modest, positive effect on all three types of investment, suggesting the possibility of labor market constraints. Knowledge of conservation and productivity-enhancing technologies emerges as a positive and significant determinant of investments in hedgerows, but not of other conservation investments. 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.

VI. CONCLUSIONS AND POLICY IMPLICATIONS

The empirical analysis of conservation investments described in this paper provides us with five general conclusions. First, own sources of liquidity, especially from nonfarm employment, are important determinants of capacity to invest in conservation measures. That nonfarm cash sources are important is probably linked to failure of the credit market for cash outlays for labor and equipment. Yet increases in returns to nonfarm employment, controlling for agricultural profitability, dampens the incentive to invest. Hence nonfarm opportunities have a dual character of enabling but also sometimes competing with on-farm conservation investments.

Second, risk of appropriation of the investment (because of uncertain land use rights) decreases investment in conservation measures. This finding is inconsistent with those of Blarel and of Place and Hazell who conclude that land tenure status does not affect land improvements.

Third, smaller farms are more likely to invest in conservation measures, which makes sense given their dependence on the fertility of the small plots they intensively farm. Under conditions of rapid population increase, it is likely that the trend toward farm miniaturization will continue; our results suggest that this will not necessarily lead to unsustainable intensification.

Fourth, households with a greater supply of labor are more likely to take conservation measures than those with less household labor. An absence of household labor, coupled with low nonfarm earnings (with which to hire labor), means that conservation investments will be few.

Fifth, conservation extension emerges as an important determinant of certain types of household conservation investment, notably those which have not yet been broadly disseminated and adopted among

the farm population. Once techniques have become universally known and widely practiced, the impact of continuing extension appears to be negligible.

Several important policy implications emerge from these results. First, the Rwandan government seeks to achieve the following policy goals: to improve food security through increased farm productivity and profitability, to combat soil degradation, and to diversify rural household incomes (Commission Nationale d'Agriculture, 1992). We believe that the above results lend empirical support to the mutually-reenforcing nature of these aims. This conclusion should also be important to external donor programming, as it implies that under certain circumstances, projects aimed at developing nonfarm enterprises by farm families can indirectly promote soil conservation on-farm.

Second, increasing the extension service's emphasis on new and appropriate conservation measures has clear payoffs at the farm level, and also increases the compatibility of the above policy goals.

Third, the nature of land transactions and land tenure policy affect conservation investments.

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Table 1
CONSERVATION INVESTMENTS MODEL VARIABLES

Model Variables	Overall Mean	Coefficient of Variation	Level of Observation HH = 1,240 Pref = 10
1. Conservation Investments			
A. Grass Strips *(m/ha)*	198	1.40	Parcel
B. Anti-erosion Ditches *(m/ha)*	157	1.72	Parcel
C. Hedgerows *(m/ha)*	55	3.02	Parcel
2. Independent Variables			
A. Monetary Incentive to Invest			
Agricultural profitability index	1.00	0.31	Prefecture
Mean agricultural wage *(140FRW = 1$US)*	100	0.09	Prefecture
Mean non-agric. wage *(140FRW = 1$US)*	206	0.35	Prefecture
B. Physical Incentive to Invest			
Erosivity of Land Use (C-value index)	0.13	0.46	Parcel
Share of operational holdings under fallow *(ha)*	0.17	1.47	Parcel
Slope *(degrees)*	16.92	0.64	Parcel
Location on slope (1=highest, 5=lowest)	3.11	0.33	Parcel
Distance from residence *(min. on foot)*	7.61	2.14	Parcel
Size of parcel *(ha)*	.77	1.03	Parcel
Mean annual rainfall *(mm)*	1,214	0.14	Prefecture
C. Risk of Investment			
Ownership rights (1=own, 2=lease)	1.08	0.25	Parcel
Price variation *(CV of ag prices, 1986-92)*	0.25	0.20	Prefecture
D. Wealth and Liquidity Sources			
Landholdings owned *(ha)*	.83	0.95	Household
Value of livestock *(140FRW = 1$US)*	10,768	1.81	Household
Non-farm income *(140FRW = 1$US)*	11,120	3.24	Household
Value of agri. production *(140FRW = 1$US)*	22,150	0.83	Household
E. Other Household Characteristics			
Number of adults *(aged 15-65)*	2.64	0.54	Household
Dependency ratio *(econ inactive/econ active)*	121	0.74	Household
Number of literate household members	2.28	0.82	Household
Knowledge of conserv/prod techniques	3.59	.55	Household
Age of head of household *(years)*	45	0.33	Household

Table 2
OLS REGRESSIONS — CONSERVATION INVESTMENTS MODEL

Independent Variables	Conservation Investment: Grass Strips (m/ha)	Anti-erosion Ditches (m/ha)	Hedge-rows (m/ha)
A. Monetary Incentive to Invest			
Agricultural profitability index	.18**	.11**	-.07**
Mean agricultural wage in prefecture	-.02	.12**	.05**
Mean non-agricultural wage in pref.	-.20**	-.08**	.01
B. Physical Incentive to Invest			
Erosivity of Land use (C-value index)	.12**	.01	.07**
Share of operational holdings under fallow	-.02	-.02	.02
Slope (degrees)	-.06**	-.06**	.06**
Location on slope (1=lowest, 5=highest)	-.16**	-.11**	-.09**
Distance from residence	-.07**	-.04**	.02
Size of parcel	-.00	.10**	.00
Mean annual rainfall	.07**	-.01	.11**
C. Risk of Investment			
Ownership rights (1=own, 2=lease)	-.07**	-.03*	-.07**
Price variation (1986-92)	.00	.08**	-.07**
D. Wealth and Liquidity Sources			
Landholdings owned	-.15**	-.17**	-.15**
Value of livestock	.02	.04*	-.01
Non-farm income	.08**	-.01	.04**
Value of agricultural production	-.01	.04**	.04**
E. Other Household Characteristics			
Number of adults (aged 15-65)	.09**	.08**	.05
Dependency ratio *(econ inactive/econ active)*	.03	.05	.01
Number of literate household members	-.06**	-.03	-.02
Knowledge of conserv/prod techniques	-.05**	.01	.08**
Age of head of household (years)	.02	-.01	-.01
R^2	.13	.10	.06

*Sig T ≤.05 **Sig T ≤.01