PN-ACC-736

Staff Paper

FEB 21 95
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Staff Paper No 95-10 February 95

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Farm productivity in Rwanda: effects of farm size, erosion, and soil conservation investments

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February 1995

We thank USAID/Africa Bureau/Office of Sustainable Development/Productive Sector Growth and Environment/Food Security and Productivity (USAID/AFR/SD/PSGE/FSP) and USAID/Kigali for funding this work under the Food Security II Cooperative Agreement managed by the USAID/Global Bureau, Office of Agriculture and Food Security We thank the Division de Statistiques Agricoles, MINAGRI, Rwanda, for use of the data We thank Dan Clay for comments on earlier versions

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Abstract

This paper examines the effects of farm size, soil erosion, and soil conservation investments on farm land and labor productivity in Rwanda There were four key results (1) There is a strong inverse relationship between farm size and land productivity, and the opposite for labor productivity For smaller farms, the marginal value product of land is far below the rental price of land, implying factor use inefficiency and constraints to land market access, by contrast, for larger farms the value product and rental price are nearly equal The findings for labor were the inverse the marginal value product of labor for smaller farms was well below the market wage, this implies that there are constraints to access to labor market opportunities for the smaller farm households (2) Land productivity on very eroded farms is 21 percent lower than on farms with little erosion, the most extreme case is for farms with a low share of high value cash crops (bananas and coffee) and a low share of cultivated area to which fertilizer or organic matter has been applied the loss of productivity is 36 percent (3) On average, farms with a relatively high level of soil conservation investments have 25 percent greater land productivity than those with few of these investments The biggest gainers from such investments are farms with a high share of low value crops (food crops, annuals) and high erosion, they gain 33 percent (relative to the average) Those that gain the least are those with a high share of perennial cash crops and low erosion (4) A substantial increase in the share of farm output from high value cash crops strongly benefits incomes of smallholders and land productivity increases by 50 percent The yield gains to shifting to cash crops are clearly highest for those with better farm conditions -- with low erosion and high use of fertilizer and organic matter The implications are (1) Getting a strong farm yield and income effect from cash cropping requires that land be less eroded to begin with, and that farmers be able to use substantial quantities of improved inputs (fertilizer and organic matter) (2) Program and policy effort to encourage and enable farmers to make soil conservation investments on farm will have big payoffs in productivity (3) Small farming in Rwanda is hobbled, however, by constraint to use of land rental markets, but tend to use land more efficiently than larger farms This implies that attention to reform of land markets is needed even in situations where the land size distribution is quite unequal but the absolute farm size is still small

Farm productivity in Rwanda: effects of farm size, erosion, and soil conservation investments

The farm-level research on patterns and determinants of productivity in the 1960's and 1970's in Africa focused principally on sample stratification based on farm characteristics -- generally, by one or more of the following farm size, use of animal traction, access to credit, use of new seed varieties, land tenure status, and income (Eicher and Baker, 1982)

Since the 1960s, soils have degraded and erosion has become a major environmental problem in many developing countries, access to land has become increasingly constrained in areas formerly thought land abundant, factor and credit markets have structurally changed and land markets have developed Now most countries have important issues related to land degradation and land productivity and there is the increasing specter of land constraints This issue is particularly under-researched yet important in areas of Africa where land constraints and land degradation have been growing rapidly, such as in Rwanda

This paper explores the determinants of agricultural productivity in a cross-section of farms in Rwanda, using data from the 1991 agricultural year We contribute to productivity determinants research in Africa by combining an enquiry into how farm size affects productivity with enquiry as to what magnitude of productivity reduction is caused by erosion and conversely, what productivity benefits are generated by soil conservation investments

The above strategic research issues give rise to two related hypotheses for Rwanda

(1) Hypothesis Average and marginal land products will rise as size of farm decreases

Empirical productivity research in developing countries in general has focused on the farm size - productivity relationship Most of the work has been in Asia, and very little in Africa

Research in Asia has often indicated an inverse relationship For example, work in India (Bardhan

1973, Deolalikar 1981, Rao and Chotigeat 1981) shows that small farms have higher land productivity but lower labor productivity (they use more labor intensive techniques) This evidence has been important in land reform debate in developing countries, supporting the smallholder whose technique's factor bias uses shrinking land resources more productively

Research in Africa on productivity has often been crop specific, and has often focused on larger commercial farmers Relatively few have analyzed the farm size - productivity relationship in the smallholder sector (Ellis 1993 reviews these studies) Recent studies include Blarel et al (1989), Carter and Wiebe (1990) in Kenya, Barrett (1994) in Madagascar, and Adesina et al (1994) in Cote d'Ivoire The Kenya and Madagascar studies confirm the Asian findings (an inverse relationship) Blarel et al show that the marginal product of capital in maize-beans cultivation in Kenya falls as farm size increases while the marginal product of labor starts low, due to intensive labor application on small farms, and rises with farm size Carter and Wiebe find similar patterns for wheat in Kenya, and attribute them to constraints faced by smallholders in access to capital, and constraints faced by largeholders in access to labor Barrett found an inverse relationship in Madagascar, and noted that differences in households' marketable surplus in an environment of price uncertainty explain the inverse relationship between farm size and productivity if small farms are price risk averse He did not assume labor market imperfections or differences in the quality of land, cropping patterns, or village-level effects

Empirical research has found that the relationship depends, however, on how much non-labor inputs are used by large farmers as a substitute for labor Adesina et al in Northern Cote d'Ivoire find that large rice farms have greater land productivity than small rice farms The difference is attributed to differential technology between small and large farms as a consequence of public policy Large farms were given a preferential access to inputs, credit, and research Asian work finds a similar qualification Rao and Chotigeat (1981) show in India that land and labor have a negative effect on the elasticity of gross value of output per unit of land while capital has a positive effect The net effect depends on which

of the two is greatest Farms employing more hired labor and more fertilizer, high-yielding varieties, improved ploughs and tractors, larger holdings have greater land productivity

Ellis (1993) and Barrett (1994) review four main explanations for the inverse relationship (A) There is a dual labor market, largeholders face the market wage, smallholders face a virtual wage or opportunity cost of labor that is lower than the market wage Small farms apply labor until its marginal value product becomes a fraction of the market wage, the greater labor to land ratio means higher yields (Feder 1984) (B) There may be decreasing returns to scale, although most production studies in developing countries show constant returns to scale (C) Smallholders may crop available land more intensively, whereas large farmers may underuse land, leaving more fallow or planting less densely (D) Zone-specific characteristics such as soil quality or price risk can affect the yield-size relationship perceived in an aggregate sample (covering more than one zone) For example, a zone with better soils might attract more people, giving rise to smaller farms with better yields than in other zones

We expect that one or more of explanations above apply to rural Rwanda, and thus expect the inverse relationship to hold

Using marginal productivity analysis based on production functions we descriptively test (C), and show that smaller farms crop more intensively, and analytically test explanation (A), that marginal value products differ from market factor prices, indicating constraints to access to inputs and hence economic inefficiency Tests of this proposition have been rare in Africa, the exception is Carter and Wiebe (1990), other recent examples of tests of economic efficiency are Adesina et al (1994) for Cote d'Ivoire and Bravo-Ureta and Evenson (1994) for Paraguay

(2) Hypothesis Land degradation importantly reduces land productivity, conversely, soil conservation investments raise land productivity substantially

The direction of the effect is common sense, but the empirical importance of the effect has rarely been examined in developing countries outside of experimental situations, particularly in Africa For

India, Bhalla and Roy (1988) and Bhalla (1988) incorporated the effect of land quality in their analysis of the inverse relationship between farm size and productivity Land quality was proxied by soil type, soil color and soil depth in absence of data on soil fertility

An additional issue, however, is whether one should expect this effect to differ between small and large farms That depends on whether small farms have more degraded soils than large farms If the soils of smaller farms are more degraded, this would offset the potential inverse relationship of farm size and productivity

Our preliminary assumption was that smaller farms indeed have more degraded soils in Rwanda, as one observes that with increasing land constraints (associated with a secular tendency to smaller farms) farmers are increasingly pushing onto the fragile "extensive margins", the hillsides (von Braun et al 1991, Clay 1993) We then analyzed erosion per hectare (measured by methods described in section 2) over farm size terciles (reported in Table 1), and found that erosion does not differ significantly over farm size strata This is at first surprising, but then one notices in Table 1 that smaller farms have also been farmed less time, are much more fragmented into small plots, and have twice as many meters per hectare of soil conservation infrastructure Thus, as these smaller farms age and there is little opportunity to shift cultivation to fallow areas and let cropped areas rest, the short to medium term strategies of soil conservation investment will slow degradation but not fully offset it, and in the longer term one would expect degradation to be more severe on smaller farms (thus mitigating the inverse relationship of farm size and land productivity)

In sum, in the short-medium term, we expect that degradation will not have a differential productivity effect on smaller farms, and the land quality effect will not offset the expected inverse relationship between farm size and land productivity

1 Model

We start with a production function relating output to inputs (labor, land, fertilizer) and other "conditioners" such as land quality

Value of Output = f(Land, Labor, Capital, Conditioners) (1)

From the levels of the variables and the estimated coefficients, we compute marginal (value) products (of inputs), the MVP -- the change in output associated with an incremental change in the use of an input, itself a function which represents the rate of change in the original production function as the use of the factor is varied The MVP in turn is conditioned by the level of use of the input, and the levels of other inputs and conditioners The MVP is used in section 4 for three purposes related to testing our two hypotheses (A) to show how the marginal productivity of land changes over landholding strata, (B) to show how land productivity is conditioned by the degree of degradation of the farm's soil, (C) to examine whether MVP is equal to marginal factor cost (input price) to determine whether use of that input is efficient, or whether there is a constraint its use

2. Data

The data used here derive principally from a nationwide stratified-random sample of 1,240 farm households (operating 6,464 plots) interviewed in 1991 by the Agricultural Statistics Division (DSA) of Rwanda's Ministry of Agriculture Two surveys were conducted (1) the baseline survey, which enumerated production and other activities of the sample every week over the year, (2) the Agroforestry survey, which enumerated soil conservation measures taken by households, the survey was one-shot

retrospective and plot level, administered in June 1991

The baseline survey provides information on outputs and inputs Missing, however, are the following categories of information (1) allocation of own and hired labor to specific crops, and total household labor between cropping and other activities, (2) allocation of purchased inputs (fertilizer, pesticides, lime) to fields or crops The Agroforestry survey provided data on soil characteristics and soil conservation investments, missing however are direct estimates of soil erosion

3 Regression Specification

The regression specification is as follows

OUTPUT = f((LABOR, LAND, FERTSHARE, FRAGMENT, AGEFARM, EROSION, DISTANCE, SHAREHVC, TENURE, NORTHWEST, SOUTHWEST, NORTH-CENTRAL, EAST) (2)

OUTPUT is the aggregate value of production of a farm While our data show allocation of land to specific crops, we lack household observations on labor and fertilizer allocation per crop Moreover, most Rwandan farms allocate an important share of their land to mixed cropping Thus, we specified output as an aggregate (over crops) in cash value terms (the sum of each crop's physical output weighted by the market price prevailing at harvest 1990)

Bardhan (1973) notes, however, that such aggregation overlooks the effect of crop-composition of output and the marginal value product gives more weight than does the marginal physical product to farmers producing crops which have higher prices We address this problem by controlling for crop mix (discussed below)

Variable inputs are LABOR, LAND, and FERTSHARE LABOR is expressed in person-days per hectare, and is an aggregate of hired versus own labor It is considered predetermined because it is mainly own labor which was proxied by household size in adult equivalents

LAND is expressed in hectares (of cultivated land) It is also treated as exogenous because it consists almost entirely of owned land (see section 6) and landholdings are set by traditional land rights and Rwanda lacks a competitive land market for transfer of land

All farms use the hoe and the machete and none use animal traction There is extremely little use of chemical fertilizer, lime, and pesticides (see section 6) Soil fertility is maintained principally by fallow and use of manure Our data set lacks information on quantities of manure used As a rough alternative and with the assumption that parcels are homogeneously fertilized, a proxy variable, FERTSHARE, is used the share of cultivated area on which any of the following are used organic matter, chemical fertilizer, lime, or pesticides

There are several variables that control for farm characteristics FRAGMENT reflects fragmentation -- the number of plots The more plots, the more time the farm spends moving around the farm, and the more inefficient the operation DISTANCE reflects the average (over farm plots) time the farmer travels from the household to the plots, the more distance, the more inefficient the operation

Two variables reflect soil quality (or degradation) AGEFARM is the average (weighted by plot size) of the number of years since cultivation began on currently-farmed plots, older plots are expected to be less fertile

EROSION is the average annual soil loss in tons/ha per farm It is calculated using the Universal Soil Loss Equation, the USLE (Morgan (1986), Hudson (1981)) The USLE provides an estimate of the long-term average annual soil loss from parcels of arable land under various cropping conditions (Hudson 1993) and is specified thus

$$\text{Erosion (observation per plot)} = R \times K \times L \times S \times C \times P \qquad (3)$$

where R is the index of rainfall and runoff, K is the soil erodibility index reflecting the susceptibility of a soil type to erosion, L is the length of the plot (compared to a standard field of 22 6 meters), S is the slope of the plot relative to a standard (9 percent), C is the C-value, the ratio of soil loss on a plot under a standard treatment of cultivated bare fallow compared to the soil loss expected from the crop mix and cropping practice used on the current plot, P is the soil conservation practice factor which is a ratio comparing the soil loss of the plot (given soil conservation measures used thereon) with that from a field with no conservation practice

The following data from the baseline dataset plus secondary data were used to measure the above USLE variables (a) for R, we used rainfall data for the 78 secteurs in which our sample households resided, (b) for S, we used plot slope data, (c) for the C value we used baseline data on crop mix, (d) for L (plot length) we used the square root of the plot area (with the simplifying assumption that the plots are square), (e) for K we used secondary data on the soil types for the 12 zones in which our sample resides, (f) for P (conservation practices) we used DSA Agroforestry data on meters per hectare of soil conservation infrastructure used (grass strips, anti-erosion ditches, hedgerows, and radical terraces)

Land TENURE is the percentage of cultivated area rented per household It reflects effort disincentive because we expect that farmers invest less effort in improving rented plots

Our proxy for crop mix (the need for which is discussed above) is the share of high value crops (SHAREHVC), bananas and coffee, in the gross value of output

Dummy variables are used to capture effects of agroclimatic zone The five zones are NORTHWEST, SOUTHWEST, CENTER-NORTH, CENTER-SOUTH, and EAST, they differ by rainfall, altitude, soil quality, and crop mix and vegetal cover In general, the western zones are rainier and higher altitude, with soils that have been farmed much longer than to the east

4 Functional Form and Estimation Methods

Most production studies in Africa have used linear or log-linear functional forms (Eicher and Baker, 1982), few have used more complex forms Linear and log-linear forms are criticized for being too restrictive as they do not allow analysis of interactions among variables We favor the translog (transcendental logarithmic), a flexible functional form Lau (1975) recommends the translog when there is relatively high substitutability among inputs, Antle and Capalbo (1988) and Nakamura (1984) recommend its use because it is general and flexible, and enables use of few parameters to model behavior without imposing restrictions on the function The general form of the translog production function is

$$\ln y = \beta_o + \Sigma_i\beta_i \ln X_i + \Sigma_j\beta_j Z_j + \Sigma_i\Sigma_j\beta_{ii} \ln X_i \ln X_i + \Sigma_i\Sigma_j\beta_{ij} \ln X_i Z_j + \beta_k D_k \quad (4)$$

where βs are coefficients, i inputs, j conditioning factors, and k dummy variables Applied to our variables this becomes

$$\begin{aligned}\ln(\text{output}) = {} & \beta_o + \beta_1 \ln\text{LABOR} + \beta_2 \ln\text{LAND} + \beta_3\text{FRAGMENT} + \beta_4\text{AGEFARM} \\ & + \beta_5\text{EROSION} + \beta_6\text{FERTSHARE} + \beta_7\text{DISTANCE} + \beta_8\text{SHAREHVC} \\ & + \beta_9\text{TENURE} + \beta_{10}\ln\text{LABOR*lnland} + \beta_{11}\ln\text{LABOR*EAST} \\ & + \beta_{14}\ln\text{LAND*AGEFARM} + \beta_{15}\ln\text{LAND*EROSION} + \beta_{16}\ln\text{LAND*FERTSHARE} \\ & + \beta_{17}\text{NORTHWEST} + \beta_{18}\text{SOUTHWEST} + \beta_{19}\text{CENTER-N} + \beta_{20}\text{EAST} + u \quad (5)\end{aligned}$$

In an initial specification of the model, we had included soil conservation investments as a

regressor, but found they are highly correlated with EROSION, and thus dropped investments, we bring them back into the analysis below by relating MVP of land and labor to levels of soil conservation investments on the farm in section 7

The retained regressors successfully passed the test for exogeneity [1]

5 Patterns

Table 1 shows patterns in output, inputs, conditioning factors, and other household characteristics, compared across terciles of farms grouped according to farm size smallest, averaging 34 ha , middle, 83 ha , largest, 2 38 ha The latter is still far below the Sub-Saharan African average Note the seven-fold difference in landholding between tercile averages, 68 percent of the land is held by the largest tercile, only 10 percent by the smallest The Gini coefficient is 4

Output increases and yield declines as one goes from smallest to largest terciles The overall yield (in value terms) of the average farm in the largest tercile is a third of that of the smallest-farm tercile The yield advantage is mainly due to greater labor use per hectare the smallest apply four times more labor per hectare than the largest tercile

Compared to largest-tercile farms, smallest-tercile farms (A) are four times as fragmented (indicated by number of plots per hectare), (B) have been farmed fewer years, (C) have plots clustered closer to the domicile, (D) have a higher share of land rented (10 percent compared to 6 percent for the largest), with the average sample share of 8 5 percent fairly low, (E) have only slightly less eroded soils, (F) have twice as much soil conservation investment per hectare (measured in meters of own-built infrastructure per hectare), (G) use the same (tiny) amount of chemical fertilizer, (H) have about the same share in value of output of high valued crops (also crops with low erosive impact), coffee and bananas,

[1] We used the procedure set out in Rivers and Vuong (1988)

6 Results and Discussion

Table 2 shows production function regression results Labor and land have positive, significant effects, their full effect can be ascertained, however, only by assessing these sole effects together with the interaction terms, which is done below in our discussion of marginal value products Farm age has a significant negative effect as expected Fragmentation has the expected sign but is insignificant Share of rented land is not significant Erosion's direct effect is unexpectedly positive and barely significant The share of coffee and bananas (high-value crops) have, as expected, a strong effect on the value of aggregate output

Table 3 shows average and marginal value products of land and labor (calculated taking into account direct effects and interaction effects) The average and marginal value products (respectively, AVP, or yield, and MVP) of land decrease as farm size increases, as hypothesized AVP and MVP of labor increase with farm size, again as expected

Nevertheless, Ellis (1993) and Bhalla (1988) note that an observed inverse relationship between land MVP or AVP and farm size can depend on the partition of farms into different strata (i e the definition of stratum cut-off points) To test the robustness of our finding, we specified the following function quadratic in land

$$\text{MVP (land, labor)} = \beta_o + \beta_1\text{LAND} + \beta_2\text{LANDSQUARED} + \beta_3\text{EROSION} + \beta_4\text{FERTSHARE} + \beta_5\text{SHAREHVC} + \beta_6\text{NORTHWEST} + u \qquad (6)$$

Table 4 shows regression results for (5) They confirm strongly the inverse relationship between farm size (LAND) and the MVP of land, and the positive relationship for the MVP of labor The relations are U-shaped EROSION has a strong negative effect especially on land but also on labor

productivity Application of fertilizer and organic matter improves land productivity but not labor's

Table 4 shows MVPs of land and labor, and compares them with factor prices -- the market wage rate and the land rental rate Observe that the smallest farms apply labor until the labor MVP is only a fraction of the market wage -- going from about a third of the wage (for smallest farms) to about two-thirds for the largest farms This implies lower opportunity cost of labor on smallholder farms than that reflected in the agricultural wage probably because of constraints to access to that labor market as well as to nonagricultural employment opportunities

By contrast, the land MVP is much higher for the smaller farms than land rental rates (proxy for market price of land), indicating constraints on access to land The land MVP and the rental rate come near equality These results are similar to those found by Carter et Wiebe (1990) for labor and capital on wheat farms in Kenya

We then controlled for farm size and varied each of several key conditioning variables (holding the others fixed) to see how marginal impacts change The main results are shown in Table 5 part a, various combinations of changes and stratifications are shown in 5 parts b-e

First, when erosion increases from 1 to 8 tons/ha (the average is 4 55 tons/ha), Table 5 a shows the MVP of labor decreases 14 percent The land MVP decreases 21 percent, 5 b shows that as the share of high value crops and FERTSHARE increases from the average, the erosion impact on the land MVP can fall to as low as 19 percent loss, and when there is both a low share of high value crops and low FERTSHARE, the loss from erosion can be as high as 36 percent, these types of farmers have the greatest combination of incentives to invest in erosion control infrastructure As smaller farms do not have more eroded soils on average than larger farms, the erosion effect does not offset the inverse relation between yield and farm size, as hypothesized

Second, increasing soil conservation investment on-farm (here, meters per hectare of soil conservation infrastructure used) from 345 to 673 meters/hectare (the average is 477 meters/ha) increases

the land MVP by 25 percent and the labor MVP by 4 percent Table 5 e shows that when comparing over farms using the criteria of erosion and FERTSHARE (holding all else constant), the farms that benefit most (and logically so) are those with high erosion and low FERTSHARE (with a 26 percent increase in land MVP), those that benefit least are those with low erosion and high FERTSHARE (only 18 percent)

Also in Table 5 e , and comparing by the criteria of share of high value crop in output and FERTSHARE, we find that those with the lowest share of high value crops but low FERTSHARE stand to gain the most -- 30 percent, two forces are at play here, lower value crops provide a lower payoff per extra kilogram produced than do high value crops, but the latter tend to be crops with low C values, hence already protect the soil Hence the lowest payoff is to those with a high share of coffee and bananas and that have already a high FERTSHARE (17 percent) At the bottom of 5 e we find a similar finding that the farms with the greatest impact on land productivity of any farms are those with high erosion and low share of high value crops -- 33 percent

Third, Table 5 a shows that increasing the share of land on which fertilizer or organic matter is applied from 40 percent to 90 percent (the average is 67 percent), the labor MVP increases by 4 percent and the land MVP by 15 percent Table 5 c shows that with high erosion and a high share of high-value crops, the gain to land MVP can be as high as 33 percent -- and thus these types of farmers have the greatest combination of incentives to use fertilizer and organic matter, with low erosion and low share of high value crops, the gain can be as little as 11 percent

Fourth, increasing the share of farm output from high value cash crops (bananas or coffee) from 15 percent to 54 percent (the average is 34 percent), the labor MVP increases by 30 percent and the land MVP by 50 percent These cash crops improve smallholder incomes Table 5 d shows that the gain to shifting to cash crops is clearly highest for those with better farm conditions -- with low erosion and a high FERTSHARE Those gaining least have highly eroded soils and use few improved inputs

7. Conclusions

This paper tested the hypotheses that (1) small farms have better land productivity than larger farms, (2) soil erosion strongly reduces land productivity, and (3) soil conservation investments strongly improve land productivity If smaller farms had more eroded soils than larger farms, (2) would mitigate (1), whereas we find that smaller farms do not have more eroded soils (in the short-medium run at least) than larger farms, because they use more soil conservation measures We found four sets of key results

First, we found a strong inverse relationship between farm size and average and marginal land productivity, and the opposite for labor productivity For smaller farms, the marginal value product of land is far below the rental price of land, implying factor use inefficiency and constraints to land market access, by contrast, for larger farms the value product and rental price are nearly equal The findings for labor were the inverse the marginal value product of labor for smaller farms was well below the market wage, while they are nearly equal for larger farms This implies that there are constraints to access to labor market opportunities for the smaller farm households

Second, land productivity on very eroded farms is 21 percent lower than on farms with little erosion, the most extreme case is for farms with a low share of high value cash crops (bananas and coffee) and a low share of cultivated area to which fertilizer or organic matter has been applied the loss of productivity is 36 percent

Third, on average, farms with a relatively high level of soil conservation investments have 25 percent greater land productivity than those with few of these investments The biggest gainers from such investments are farms with a high share of low value crops (food crops, annuals) and high erosion, they gain 33 percent (relative to the average) Those that gain the least are those with a high share of perennial cash crops and low erosion

Fourth, increasing the share of farm output from high value cash crops (bananas or coffee) from

low to high strongly benefits incomes of smallholders and land productivity increases by 50 percent The yield gains to shifting to cash crops are clearly highest for those with better farm conditions -- with low erosion and high use of fertilizer and organic matter

There appears to be a certain substitutability between perennial cash cropping and soil conservation investment But the catch is that getting a strong farm yield and income effect from cash cropping requires that land be less eroded to begin with, and that farmers be able to use substantial quantities of improved inputs (fertilizer and organic matter)

Many small farms already have quite eroded soils, and this erosion has a very harmful effect on land productivity, reducing yields up to a third Thus, general program and policy effort to encourage and enable farmers to make soil conservation investments on farm will have big payoffs in productivity

Small farming in Rwanda is hobbled, however, by constraint to use of land rental markets, but tend to use land more efficiently than larger farms This implies that attention to reform of land markets is needed even in situations where the land size distribution is quite unequal but the absolute farm size is still small

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Table 1 Farm Characteristics

Farm Size Strata[b]	Smallest	Middle	Largest	Overall	CV
Output (RWF[a])	21 6	34 3	52 6	36 3***	0 9
Yield (RWF/ha)	74 4	42 1	26 1	47 4***	1 1
Labor (days/ha)	1251 0	557 0	271 0	689 0***	1 0
Land (ha)	0 34	0 83	2 38	1 19***	0 8
Plots (#/ha)	13 0	7 0	3 0	8 0***	0 8
Farm age	17 9	18 4	20 8	19 1***	0 7
Erosion (T/ha)	4 3	4 7	4 6	4 5	1 1
Soil Cons (m/ha)	672 8	414 1	344 6	477 2***	1 5
Share land under inputs	68 1	66 2	68 1	67 5	0 4
Fert expend (kg/ha)	0 08	0 07	0 08	0 08**	14
Distance (min)	8 25	9 08	11 65	9 70***	1 1
Rented land (percent)	9 9	10 0	5 60	8 50**	1 9
Share high value crops	0 34	0 32	0 36	0 34**	0 7
Stratum's share land	0 10	0 22	0 68	1 00	
GINI Coefficient land				0 3827	

Table 1 Notes.

[a] 71 RWF = US$ 1 in 1990

[b] Definitions

Strata Bottom Tercile ≤ 58 Ha, Middle Tercile between 58 and 1 45, Top Tercile > 1 45 Ha, No of cases (households) per tercile 373, 374, 376 for first, second and third tercile

CV Coefficient of Variation

Output Value of gross agricultural production in thousands RWF

Yield Value of gross agricultural production per hectare (in thousands of RWF)

Labor Available labor for the household in person-days per hectare (total family labor + labor hired - labor sold) Labor is standardized into adult equivalents (AE) 1 for adults (aged between 16 and 60) and 25 for children (between 6 and 15) and seniors (above 60)

Land Total cultivable land in hectares

Plots (FRAGMENT in regressions) Number of plots

Farm age Average number of years of cultivation of plots

Erosion Average annual soil loss in Tons/hectare

Soil cons Total length of anti-erosion devices for the farm

Share land under inputs FERTSHARE in regressions)
Share of farm area on which organic or chemical inputs are applied

Fertilizer Amount of chemical fertilizers purchased (kg/ha)

Distance Average distance from residence to plot in minutes

Rented Percentage of area that is rented

Share HVC Share of high valued crops (banana and coffee) in total agricultural output value

Proportion of Land per Stratum
Percentage of cumulated land per stratum

[c] Strata means are significantly different at (*) 10 percent, (**) 5 percent and (***) 1 percent

Table 2 Translog Production Function Estimates

Variable	Coeff	Variable	Coeff
(1) LABOR	0 54*** (0 13)	(1)*(8)	- 0 31 (0 15)
(2) LAND	0 36** (0 19)	(1)*NORTH WEST	0 31 (0 09)
(3) FRAGMENT	- 0 002 (0 002)	(2)*(5)	- 0 01 (0 007)
(4) AGEFARM	- 0 003** (0 001)	(2)*(6)	- 0 001*** (0 001)
(5) EROSION	0 04* (0 07)	(2)*(8)	0 07 (0 1)
(6)FERTSHARE	0 007 (0 006)	NORTHWEST	- 1 22** (0 53)
(7)DISTANCE	0 003 (0 002)	SOUTHWEST	- 0 07 (0 06)
(8)SHAREHVC	2 73*** (0 91)	CENTER-N	0 18*** (0 05)
(9) RENTED	0 001 (0 001)	EAST	0 42*** (0 06)
(1)*(2)	0 02 (0 03)	Constant	6 56*** (0 76)
(1)*(5)	- 0 01 (0 01)	Adj R^2	0 53
(1)*(6)	0 001 (0 001)		

Table 2 Notes

The dependent variable is the logarithm of gross value of output in 1990 agricultural production in RWF

a Standard errors are in parentheses

b *** Significant at 1 percent, ** significant at 5 percent, * significant at 10 percent

c Definitions of variables as in Table 1

Table 3 Marginal and Average Factor Products

Farm Strata (terciles)	Labor		Land	
	MVP	AVP	MVP	AVP
Smallest	38 3	64 2	25 2	74 4
Middle	46 8	76 8	20 6	42 1
Largest	67 5	95 7	9 0	26 1
Overall	52 5	81 6	17 5	47 4
Factor Price	100 0		7 5	

Table 3 notes:

Farm size terciles are defined as in earlier tables

The Marginal Value Product (MVP) and the Average Value Product (AVP) of labor are expressed in RWF/person-days

Factor prices (wage of labor and rental price of land) were derived from the data The wage rate is for one day of labor They are median values Land products and land rental price are 1000's of RWF's

Table 4 Regression of Marginal Value Products of Land and Labor on Farm Size and Farm Characteristics

Variables	MVP of LAND	MVP of LABOR
Constant	19225 2*** (2128 9)	14 86 (15 62)
LAND	-10423 1*** (969 5)	19 71*** (7 11)
LAND²	905 4*** (133 2)	- 1 98* (0 98)
EROSION	- 746 5*** (122 5)	- 1 23 (0 90)
FERTSHARE	54 2*** (19 4)	0 04 (0 14)
SHAREHVC	22086 0*** (2901 1)	41 76* (21 28)
NORTHWEST	11082 55*** (1730 9)	37 88*** (12 70)
Adj R^2	0 23	0 02

Table 4 notes:

Standard errors are in parentheses

*** significant at 1 percent, ** significant at 5 percent, * significant at 10 percent

Table 5 Percentage change of Marginal Value Product of Land and Labor

N.B. The ranges (low to high) are defined in the text

5 a Variation of one conditioning factor while holding other variables constant

Moving from	MVP of Labor	MVP of Land
Small Farms to Large Farms	38 percent	- 36 percent
Low Erosion to High Erosion	- 14 percent	- 21 percent
Low to High FERTSHARE	4 percent	15 percent
Low to High Share of High Value Crops	34 percent	49 percent
Low soil conservation investment to high	4 percent	25 percent

Table 5 b **Impact of change from low to high erosion for various farm categories**

Moving from Low to High Erosion	MVP of Labor	MVP of Land
Low SHAREHVC Small FERTSHARE	- 20 percent	- 36 percent
Low SHAREHVC High FERTSHARE	- 22 percent	- 32 percent
High SHAREHVC Low FERTSHARE	- 15 percent	- 22 percent
High SHAREHVC High FERTSHARE	- 14 percent	- 19 percent

Table 5 c **Impact of change from low to high FERTSHARE for various farm categories**

Moving from Low to High FERTSHARE	MVP of Labor	MVP of Land
Low EROSION Low SHAREHVC	3 percent	11 percent
Low EROSION High SHAREHVC	11 percent	27 percent
High EROSION Low SHAREHVC	4 percent	16 percent
High EROSION High SHAREHVC	9 percent	33 percent

Table 5 d **Impact of change from low to high share of high value crops (bananas/coffee) for various farm categories**

Moving from Low to High Share	MVP of Labor	MVP of Land
Low EROSION Low FERTSHARE	39 percent	58 percent
Low EROSION High FERTSHARE	49 percent	92 percent
High EROSION Low FERTSHARE	29 percent	39 percent
High EROSION High FERTSHARE	42 percent	67 percent

Table 5 e **Impact of change from low to high soil conservation investment for various farm categories**

Moving from low to high soil cons investment	MVP of Labor	MVP of Land
Low EROSION Low FERTSHARE	+ 1 3 percent	+ 20 percent
Low EROSION High FERTSHARE	+ 1 2 percent	+ 18 percent
High EROSION Low FERTSHARE	+ 1 5 percent	+ 26 percent
High EROSION High FERTSHARE	+ 1 4 percent	+ 23 percent
Moving from low to high soil cons investment		
Low SHAREHVC High FERTSHARE	+ 1 6 percent	+ 30 percent
Low SHAREHVC High FERTSHARE	+ 1 6 percent	+ 26 percent
High SHAREHVC Low FERTSHARE	+ 1 2 percent	+ 19 percent
High SHAREHVC High FERTSHARE	+ 1 2 percent	+ 17 percent
Moving from low to high soil cons investment		
Low EROSION Low SHAREHVC	+ 1 5 percent	+ 24 percent
Low EROSION High SHAREHVC	+ 1 1 percent	+ 16 percent
High EROSION Low SHAREHVC	+ 1 8 percent	+ 33 percent
High EROSION High SHAREHVC	+ 1 3 percent	+ 20 percent