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Farm productivity and poverty in Kenya: The effect of soil conservation

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Abstract

Soil erosion and land degradation have become major environmental concerns and present a formidable threat to food security and sustainability of agricultural production in Kenya. The biggest challenge currently facing the Kenyan government is how to achieve the triple developmental goals of food sufficiency, better nutrition and poverty reduction without increasing the land devoted to food crops. This paper responds to a paucity of empirical information on the impact of land degradation on farm productivity and poverty in Kenya. The paper builds on the few existing studies in this area and explores the impact of conventional inputs and adoption of soil conservation practices on farm yields per acre controlling for the effects of institutional factors. Panel data collected from farming households is utilized to achieve the study objectives. The paper tests and rejects the hypothesis that adoption of soil conservation practices has no effect on farm productivity or on poverty reduction. We test this hypothesis controlling for impacts of conventional farm inputs and institutional factors notably the property rights regimes. Due to the joint determination of soil conservation practices and productivity, we use the fixed effects – instrumental variables (FE-IV) method to isolate the productivity effects of soil conservation. We further simulate the impact of key policy changes on productivity on one hand and on poverty (head count ratio) on the other. The key finding of the paper (from the FE-IV) is that controlling for unobserved heterogeneity, soil conservation has a large measurable impact on farm productivity and on poverty reduction in the long-run. We also find that well specified property rights are associated with higher farm productivity, a debate that is widely contested in the literature. Policy simulations indicate that privatization of common land and adoption of particular soil conservation practices can play a decisive role in increasing agricultural yields and in reducing poverty in semi-arid areas.

Key words: Productivity, poverty, land conservation, Kenya.

Introduction

In many developing countries, soil erosion and land degradation have become major environmental concerns and present a formidable threat to food security and sustainability of agricultural production. Access to land in Kenya and a number of other African countries has become increasingly constrained in smallholder agricultural areas that were formerly land abundant [10]. For land scarce countries, the long-term growth in food and crop cash production necessarily depends upon increased yields from land already under crops. Production will have to increase in such a way that future production capacity of natural resources is enhanced rather than diminished. The biggest challenge currently facing the Kenyan government is how to enhance food crop production so that food output can keep pace with population growth without increasing the land devoted to food crops, especially maize, and milk [35]. Enhancement of agricultural productivity is essential for a country to achieve the triple developmental goals of food sufficiency, better nutrition and poverty reduction (see Pinstrup-Anderson and Pandya-Lorch [30]).

However, available literature indicates that agricultural production has increased through expansion of farmed acreage rather than via enhancement of productivity per acre. Large areas of forests, wetlands, river valley bottoms, grassland savannas and other marginal lands have been converted into farmlands with serious soil degradation consequences [24]. In other words, livelihoods in many resource poor farming and pastoral systems have been sustained by land-use practices which have tended to perpetuate poverty, soil erosion and other land degradation phenomena. The factors responsible for land degradation include lack of land policies, unavailability of technology for improving the productivity of traditional food crops, unfavorable weather conditions, low levels of physical and human capital and migration. The feedback effects among these factors lead to a vicious circle of low productivity, poverty and land degradation [4, 34, 36].

Although there is increased concern about land degradation in developing countries, there is paucity of empirical information on the impact of land degradation on farm productivity and poverty in fragile agricultural systems in Kenya [16, 17]. We build on the few existing studies in this area and explore the impact of conventional inputs and adoption of soil conservation practices on farm productivity controlling for the effects of institutional factors, notably the property rights in land. We test and fail to reject the hypothesis that secure land rights act as incentives which enhance productivity and the well-being of farmers. The impact of property rights on productivity is through incentives that they create for investment in land improvements, an issue which has been widely debated in the literature [5, 9, 13, 24, 27, 28, 31]. Some of these studies concur that tenure security encourages investment in land improvements, while others argue that tenure security has no effect on investment incentives. The paper simulates the impact of policy changes on farm productivity and poverty reduction, with the aim of shedding light on how policy can effectively address poverty reduction in fragile ecological environments.

Study Site and Data

Kajiado district, the field site for study, is located on the southern part of the Rift Valley province of Kenya and covers an area of 21,105 square kilometers. It spans four agro-ecological zones: a semi-humid climate that supports mixed agriculture, an arable semi-arid climate and an arid climate, favourable mainly for ranching and pastoral activities[*]. Although the district largely supports livestock and wildlife, there is also significant crop farming in the area.

The panel data for the study were collected from a cross section of households in Kajiado district over the period March 1999 to May 2000 in three phases. The first phase corresponded with the long rains March-May 1999, the second phase with the short rains October-December 1999 and the third phase with the long rains March-May 2000. The National Sample Survey and Evaluation Programme of the Central Bureau of Statistics, Ministry of Planning and National Development [35] was used as the sampling frame for the field survey. A self weighting probability sample of 1600 farming households was chosen from the national sampling frame and a detailed questionnaire used to collect the required data. The questionnaire was designed to collect information regarding economic and demographic characteristics of sampled households, on farm yields and soil conservation practices and land use rights, among other covariates of interest.

Table 1. Sample statistics (N=1600).

Variable	Mean	Std. deviation
Revenue per acre (Kshs. 1000)	20.31	63.75
Property right regimes (1 = private, 0 = common)	0.73	0.44
Total land owned (acres)	98.19	145.29
Workers per plot	4.10	4.09
Household size	8.43	5.45
Age of farmer	35.12	13.18
Sex (1 = male, 0 = female)	0.49	0.50
Marital status (1 = married, 0 = not married)	0.69	0.46
Primary school education (1 = yes, 0 = no)	0.31	0.46
Secondary school education (1 = yes, 0 = no)	0.17	0.38
Post secondary education (1 = yes, 0 = no)	0.03	0.18
Price of maize (Kshs/kg)	20.77	6.36
Price of beans (Kshs/kg)	42.58	13.18
Distance to market (Kms)	11.74	9.65
Distance to source of water (Kms)	3.46	4.58
Number of cattle owned	29.41	86.79
Biomass (1000 kg per acre)	2.17	0.77
Farmer engaged in blocking soil erosion outlets (1 = yes, 0 = no)	0.08	0.28
Farmer engaged in land terracing (1 = yes, 0 = no)	0.08	0.27
Farmer engaged in planting land resistant vegetation (1 = yes, 0 = no)	0.19	0.39

The secondary data for the study concerning the quantity of biomass at the village level was obtained from the Department of Resource Surveys and Remote Sensing (DRSRS), Ministry of Natural Resources, Environment and Wildlife. These data are derived from satellite images and vegetation indices collected by the National Oceanic and Atmospheric Administration (a US-government body) and translated into biomass in kilograms per acre of land in village clusters by the DRSRS. We used the data in the same form that we received them from the DRSRS.

The main variables used in the analysis are presented in Table 1. One of the key variables in Table 1 is revenue, the aggregate value of farm output. This is the variable we chose as a measure of productivity because of the usual difficulties of calculating aggregate farm output per acre for different crops. It is the aggregate total value of output of crops grown by farmers in the area which comprised mainly maize, beans and vegetables. As can be seen from the table, the mean revenue per acre was Kenyan Shillings (Kshs.) 20,000 but with a very high variance. It is also evident from the table that 73% of all households in the sample held land under private property arrangements.

Land ownership in the study district is highly unequal (Table 1). The average of plot size is 98 acres with a standard deviation of 145 acres. Since over 70% of the land area in the district is under the private rights regime, it is not surprising that cattle ownership in the district is quite unequal (the mean herd size is 29 heads of cattle, with a standard deviation of 87).

The education dummies indicate that most of the farmers in the sample (31%) have only a primary level of education compared with 17 and 3% of sample farmers with secondary and post schooling respectively. Nearly 49% of the farmers have no formal education, which is indicative of a high level of illiteracy in the study area.

Table 1 further indicates lack of access to markets and water in the study district, which is implied by long distances to markets (12 kilometers) and to the usual sources of water (3.5 kilometers). Long distances to markets and water points reduce the time available for farm activities. The quantity of biomass shown in Table 1 indicates the extent of vegetation cover in a village and is measured in kilograms per acre. A low biomass density is an indicator of reduced vegetation cover at the village level and is suggestive of land degradation resulting from over-cultivation or other uses of land [1, 20, 21]. The average amount of biomass is about 2,000 kilograms of vegetation matter per acre, with a standard deviation of 800 kilograms, which indicates a modest variation in vegetation cover across villages.

The bottom panel of Table 1 details adoption of soil conservation methods. Nearly 39% of sample farmers had undertaken some form of land improving activity. However, the analysis focused on the main type of land improving investment for each household. Three *main* types of land improving practices were identified, namely, planting of drought resistant vegetation (19% of all households), blocking soil erosion outlets (8%) and land terracing (8%).

Conceptual Framework

Specification issues: The existing literature employs the meta production function and the total factor productivity index to analyze the variation in crop yields across plots (see e.g., Bindlish and Evenson [7]). In the meta production function, factors conventionally treated as fixed (background variables) in the farm productivity function, such as technological options and infrastructure, are incorporated directly into the estimating

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[*] The classification of these agro-ecological zones is based on differences in soil quality, rainfall variability, altitude and vegetation. Land in the district spans between arable semi-humid/semi arid to arid climate. We created dummies for the administrative divisions to capture agro-ecological zones as our sample clusters were scattered through out the entire district and thus fell under different agro-ecological zones.

equation. The yield effects of factors of focus in a farm productivity analysis, such as the biomass or the soil conservation practices, are then measured, controlling for influences of background variables. In contrast, in the total factor productivity approach, an aggregate input index whose value depends on quantities of variable and fixed inputs is first constructed. The observed agricultural output is then divided by this aggregate index to obtain total factor productivity, which is conditioned on a vector of determinants such as biomass or soil conservation practices. The choice of either approach in a productivity analysis is dictated by the nature of the data available [6].

We adopt the meta productivity function approach[†] and formulate a simple model that relates average revenue of a given farm household to conventional farm inputs, farm output prices, soil conservation practices, biomass, land rights institutions and village level characteristics of sample households (see Lopez [20, 21], Stevenson [38] and Place and Otsuka [32]). The general form of the model is: $\text{Ln } Y_j = f(X^j, P^j, K^j, R^j, H^j, V^j, C^j, \theta^j, \varepsilon)$ ……………........ (1)[‡] where Y_j is gross average revenue per acre accruing to household j.X^j is a vector of conventional farm inputs (land, capital and labour) employed by household j; P^j is a vector of product prices facing household j; K^j is a vector of soil conservation practices adopted by household j; R^j is property right regime facing household j; H^j is a vector of characteristics for household j; V^j is a vector of village level infrastructure facing household j;C^j is the number of cattle owned by household j; θ^j is amount of biomass available to household j; ε is a stochastic error term for which a distribution is unspecified.

Although the above variables are defined in Table 1, there is need to clarify a few of them. Conventional farm inputs include land, measured by total land acreage owned by a household. Capital comprises variable inputs and machinery. Variable or working capital is measured by the current market value for fertilizers, improved seeds, drugs and so on, while fixed machinery or fixed capital is valued at the purchase price. Labour refers to both hired and family labor. It is expected that the more the capital and laborers a household employ, the higher the farm yield, all other factors held constant. Farm output prices are measured in current market price for maize and beans (the main crops grown in the study district).

Soil conservation practices (K^j) is a vector of dummies capturing the main soil conservation practices adopted by household j. We explore the impact on revenue per acre of three conservation practices by farmers: blocking soil erosion outlets, land terracing and planting resistant vegetation.

Village level characteristics are included to capture the village environment, which affects decision making at the household level, as regards for example, soil conservation practices. For instance, availability of infrastructure such as water and markets facilities is expected to have a favorable impact on farm productivity.

The number of cattle owned by a household is measured by the standardized cattle units, which take into account the age of livestock. The amount of biomass available at village level is a proxy for favourable ecological conditions [1, 20, 21]. Following the Department of Resource Surveys and Remote Sensing (DRSRS), biomass is measured in kilograms per acre. All households in a village or sample cluster face the same level of biomass.

Estimation issues: In estimating the impact of soil conservation practices on productivity, it is important to note a number of issues that arise in this type of analysis. The main issue is the possibility of encountering the problem of endogeneity. The problem is that most variables that influence soil conservation practices also determine productivity. It is difficult to find good identifying variables that determine soil conservation but theoretically do not influence revenue per acre. On the other hand, it is possible to have feed back effects between soil conservation practices and productivity. Under such cases, the appropriate estimation procedures are 2SLS or 3SLS. However, such methods require proper instrumentation in order to deal adequately with the endogeneity problem.

To illustrate the issue at hand, assume that a household adopts a certain soil conservation practice and consider the following system of equations, where Y_1 is dichotomous and Y_2 is an observed continuous variable:

$Y_1 = f(R) + \varepsilon_1$……………………………………................. …..…...(2)

$Y_2 = g(Y_1, M) + \varepsilon_2$ ………….……………......................…..……..…..(3)

where Y_1 represents the adoption of the soil conservation practice and takes a value of 1if the household undertook that practice, otherwise 0. Y_2 represents revenue per acre. R and M are distinct vectors of exogenous variables and ε_1 and ε_2 are uncorrelated residuals in the soil conservation and revenue functions.

The standard procedure for estimating equations (2) and (3) is to derive the reduced forms of these structural equations as in Maddala [22]:

$Y_1^* = \lambda_1 X + \tau Z + v_1$……………………........................………..…..(4)

$Y_2^* = \lambda_2 X + \gamma Y_1^* + v_2$…………………….........................………...(5)

where X includes all the exogenous variables determining soil conservation and revenue per acre, Z is a set of exogenous instruments and v_1 and v_2 are stochastic disturbance terms. The next step is to estimate equations (4) and (5) using appropriate methods. The productivity equation (Y_2) and the soil conservation equation (Y_1) can be properly estimated using instrumental variables (IV) and two stage methods. In the IV procedure, equation (4), which has a dichotomous dependent variable is specified as a linear probability model and estimated using OLS method, which is also used to estimate equation (5). However, in a two-stage procedure, equation (4) is specified as logit (or probit) model and estimated using maximum likelihood methods.

It should be noted that in two-stage least squares, consistency of the second stage estimates is not assured by getting the first stage functional form right. Using a linear regression for the first stage estimates generates consistent estimates even with dummy endogenous variables. Moreover, using non-linear first stage to generate fitted values for the second stage equation does not generate consistent estimates unless the non-linear model happens to be exactly right, which makes the risk of misspecification high [3]. Instead, fitted values from a non-linear model can be used as instruments provided a linear model is used to generate first stage predictions of the practices from the fitted values and all other exogenous covariates in the second stage [22]. In this light, we use the linear probability model to obtain the fitted values of each practice in the first stage regressions and then plug these into the second stage to estimate the

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[†] A meta production function allows gross revenue/profit to be used as a measure of productivity [6].

[‡] In estimation, we transform the continuous variables into logarithmic form. Such a transformation corrects for skewness in the original data and makes the data fit better the classical model assumptions without changing the order of the data and without changing the relative efficiency of the sample means [25].

parameters of the revenue (productivity) equation.

The other aspect of two-stage least squares, which confirms the robustness of this procedure, is to use the instrumental variable method where soil conservation and productivity are determined simultaneously, controlling for endogeneity of conservation through appropriate instrumentation. This method is identical to the two-stage least squares except for the fact that it runs the regression in two stages from one estimation command [3]. Angrist and Krueger [3] show that the two methods provide consistent estimates in the presence of measurement errors in explanatory variables and overcome omitted variable problems in estimates of causal relationships while taking care of simultaneity. This estimation procedure accounts for the simultaneity of the feedback relationship between soil conservation, productivity and poverty.

Another estimation issue in our analysis that is worth mentioning is the possible endogeneity of property rights. Available evidence indicates that farmers are more willing to invest in soil conservation when they have security of land tenure. On the other hand investments in soil conservation could enhance security of tenure, as an individual strengthens claim on a parcel of land once he has made significant land improving investments such as planting trees [5, 9]. Property rights could also be endogenous to productivity as it may be argued that productive land is more likely to be privatized than less productive land [33]. In our sample, however, we assume that land rights may not be endogenous as the decision to privatize land is made at the group level and not at the individual level . For instance, in some of the existing group ranches, members have agitated for subdivision of land for a long period of time, yet this has not been done due to non-cooperation and misappropriation of funds by the management. Exogeneity of land rights has also been supported by empirical evidence, which has shown that property rights may be dependent on one's lineage and the person's status in the lineage [14, 15, 40] (see also Place and Otsuka [31]). Thus we take property rights regimes as exogenous in our estimations.

Results and Discussion

Preliminaries: To test the impact of property rights and soil conservation on revenue per acre, we first test for the endogeneity of the soil conservation practices. The correct estimation procedure here is to first perform the Hausman specification test for exogeneity of practices using the two-stage least squares method [41]. The procedure involves, first, the derivation of residuals from predictions based on linear probability models for various practices, and then using these residuals as regressors together with the observed values of practices in the second stage to explain productivity. If the coefficients on residuals of predicted practices turn out to be statistically significant, the model fails the exogeneity test, and cannot consistently be estimated with the OLS method.

In our analysis, we use the fixed effects two-stage least squares (FE-2SLS) and the fixed effects instrumental variable methods (FE-IV) to control for the effect of endogeneity arising from joint determination of practices and revenue and to account for the endogeneity effect due to unobserved farmer specific factors which are fixed over time and which would otherwise be swept into the error term and be a source of bias and inconsistency of OLS estimates. The FE-2SLS involves obtaining predicted values of the soil conservation practices from the linear probability models for participation, then using these predicted values in the second stage to estimate the impact of the practices on the revenue function. The FE-IV method estimates the participation and revenue models simultaneously using fixed effects instrumental variables procedure in STATA [37]. Except for the standard errors, the FE-IV and FE-2SLS yield identical results so long as the models are correctly specified. We chose the fixed effects estimator rather than the random effects estimator because the Hausman specification test rejected the latter. In our case, the Hausman exogeneity test is inconclusive[§] as to whether practices are endogenous. Thus we use the fixed effects regression in order to control for unobserved heterogeneity that may arise from measurement errors and simultaneity.

Determinants of productivity: This discussion is based on fixed effects results for the full sample (Table 2). The results indicate that the property right regime dummy has the expected positive and significant coefficient, implying that well specified private property rights are associated with higher revenue per acre. This finding supports the literature which argues that well specified private property rights act as incentives for productivity enhancing investments [13, 16, 17, 27, 38]. The result contradicts Migot-Adholla *et al.* [24] who did not detect such an effect from cross-sectional data. Moreover, in contrast to what we find, Pinckney and Kimuyu [29] found that land titling in Kenya and Tanzania did not act as an incentive for undertaking investments that boost farm productivity. Differences between our findings and those from the literature are likely due to differences in data and estimation methods. In particular, we use better data and better methods to measure productivity effects of land right regimes.

Total land has a positive impact on productivity, implying that farmers with larger land holdings are likely to report higher productivity than their small land holding counterparts. An increase in land holding by 1% increases productivity by 0.25%, holding other factors constant. Total hired labour has the expected positive impact on productivity, implying that households with greater access to hired labour report higher productivity per acre. Household size (a proxy for family labour), which is arguably endogenous (but see Kebede [18] for arguments in support of exogeneity of household size) has the expected positive coefficient and indicates that increasing family labour by 1% would increase productivity by 0.77%. This result supports findings by Boserup [8], Tiffen *et al.* [39] and Ahuja [1], and is consistent with the results for the hired labour.

The positive household size elasticities of average revenue may have important policy implications for productivity. Demographic and health surveys indicate that there is a demographic transition with fertility in the district declining as the level of education increases. This implies that in the long run, productivity could fall due to scarcity of labour. To counter such an effect, labour markets in the district need to be made more competitive to ensure that hired labour from other regions could substitute for family labour if there was to be a deficiency in the latter. We do not observe age and gender to be important determinants of productivity though the coefficient for age indicates that productivity declines with age.

[§] The results of the test imply that the decision to block soil erosion outlets may be endogenous but the decisions to terrace and to plant drought resistant vegetation are exogenous. As recommended by one of the reviewers, the results for FE-2SLS, OLS, FE-2SLS-Hausman and FE-IV are not presented but would be available from the authors upon request.

Table 2. Fixed effects regression estimates: Dependent variable is log of revenue per acre.

Variable	Coefficient	Std. error	*t*-statistic
Property right regimes (1 = private, 0 = common)	0.741***	0.168	4.4
Log of total land owned	0.256***	0.042	6.02
Log of workers per plot	0.051***	0.019	2.74
Log of household size	0.774***	0.218	3.55
Log of age of farmer	-0.132	0.176	-0.75
Sex (1=male, 0=female)	-0.027	0.099	-0.27
Marital status (1=married, 0=not married	0.006	0.158	0.04
Primary school education (1=yes, 0=no)	0.027	0.167	0.16
Secondary school education (1=yes, 0=no)	0.142	0.206	0.69
Post secondary education (1=yes, 0=no)	0.277	0.317	0.87
Log of price of maize (Kshs)	0.261	0.381	0.69
Log of price of beans (Kshs)	-0.119	0.343	-0.35
Log of distance to market (Kms)	-0.460	0.499	-0.92
Log of distance to source of water (Kms)	1.034	0.651	1.59
Log number of cattle owned	0.385**	0.066	5.85
Log of biomass (kg/acre)	1.042***	0.320	3.26
Farmer engaged in blocking soil erosion outlets (1=yes, 0=no)	0.434**	0.212	2.04
Farmer engaged in land terracing (1=yes, 0=no)	0.502**	0.243	2.07
Farmer engaged in planting land resistant vegetation (1=yes, 0=no)	0.386**	0.164	2.35
Constant	-3.688	2.942	-1.25
Number of observations			1600
F(19,1354) = 10.43***			
[1] R-squared = 0.1277			

***, ** Significant at 1%, and 5% respectively.

Soil conservation is captured by the three dummy variables, which represent adoption of various land use practices. Controlling for unobserved heterogeneity, all farm level conservation practices exert strong positive effects on productivity. The log of a farmer's revenue increases by 0.4 points if the blocks soil erosion outlets or plants drought resistant vegetation compared with the default practice of doing nothing. The yields effect is slightly stronger for terracing which is 0.5 log points higher.

Controlling for other covariates, biomass exerts a positive and significant effect on productivity. A 1% improvement in biomass increases revenue by 1.04%, implying that the elasticity of revenue per acre with respect to the amount of biomass available in kilograms per acre is about unity. This effect is consistent with results by Lopez [21] and Ahuja [1], who found that environmental conservation through leaving land fallow will increase natural vegetation (biomass) which translates into higher productivity. Our results could also be interpreted as supporting findings obtained by Evenson and Mwabu [11] for Kenya concerning the positive effect of fallow land on farm yields. Goldstein and Udry [14, 15] also report similar results for Ghana, especially on plots cultivated by men, where fallowing is more likely to be practiced. As Boserup [8] emphasizes, fallow land is not idle land but is land used for restoring soil fertility and can therefore be considered as a kind of investment [28]. However, whether or not land is left fallow depends on whether fallow land is subject to expropriation [14, 15, 40].

Policy simulations: In this section, we use our empirical results to simulate effects of various policies on productivity, holding other factors constant. We argue that controlling for other factors, any policy option that increases productivity would be expected to increase the welfare of the household.

Impact of policy changes on revenue per acre: We simulate the impact of policy changes on average revenue using the FE regression results in Table 2 and the means of the relevant variables in Table 1 (for the continuous variables, we use the means of their log transformation as in the estimated equation). We explore the impact of policies that change property rights, the adoption of soil conservation practices and increase availability of biomass at the village level. In each case, we simulate the effect of a 10% change in the variable of interest on farm productivity, approximated by revenue per acre. The results are presented in Table 3.

Our simulation results confirm that clear property rights act as incentives that enhance land investments which increase productivity [13, 27]. Our results show that holding other factors constant, increasing the proportion of land held under private property regimes by 10% would increase productivity by 0.68%. Privatization of common property resources is a way of increasing assets owned by producers, as it facilitates independent decisions on use of land. The low elasticity of average revenue with respect to privatization of land in our sample finds support in Kebede [19] who argues that productivity differentials may not be observed in the short-run if returns to investment resulting from privatization are long-term in nature. In this respect, the impact of privatization is to strengthen security of tenure and reduce the uncertainty related to whoever gets the future returns from farm investment.

Land investment and land use strategies of rural households affect the link between land degradation and poverty [34]. Our results confirm this relationship as we find that soil conservation practices result in higher farm productivity. If an extra 10% of farmers were to plant drought resistant vegetation, productivity would increase by 0.09%. If an additional 10% of farmers were to either terrace their land or block soil erosion outlets, productivity would, in each case, increase by 0.04%. If 10% more farmers were to adopt all the three practices simultaneously, productivity would increase by 0.18%. A 10% increase in biomass per acre would increase productivity by 10%. This last result indicates that policies that conserve biomass such as leaving land fallow should be encouraged [1, 20, 21]. A combination of all these policy changes would increase productivity by 11%.

Compared with other variables, the elasticities of average revenue with respect to adoption of soil conservation practices are quite low. This is however expected given that they are short-run elasticities. The full impact of a conservation practice adopted today will be realized in the future through the gradual improvement in the quality of the soil. In the short run, adoption of a given soil conservation practice could impact negatively on productivity if the farmer has to invest a lot of resources in conservation, yet the benefits of the practice would be realized later leading to large long-run elasticities. Alemu [2] report a similar

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**For all estimates in our analysis, the chow test results indicate that the models fit the data better than the intercept only model, and that the variables are jointly significant in explaining variations in the dependent variable.

Table 3. Simulating impacts of policy changes on average revenue.

Base average log revenue Policies	Policy outcomes	= 7.929 Mean log revenue per acre
1) Increase proportion of land held under private property by 10%	New mean revenue	7.983
	Absolute change	0.054
	Relative change	0.68%
	Elasticity	0.068
2) Increase proportion of farmers terracing their land by 10%	New mean revenue	7.932
	Absolute change	0.003
	Relative change	0.04%
	Elasticity	0.004
3) Increase proportion of farmers planting drought resistant vegetation by 10%	New mean revenue	7.936
	Absolute change	0.007
	Relative change	0.09%
	Elasticity	0.009
4) Increase proportion of farmers blocking soil erosion by 10%	New mean revenue	7.932
	Absolute change	0.003
	Relative change	0.04%
	Elasticity	0.004
5) Policies 2,3 and 4	New mean revenue	7.943
	Absolute change	0.014
	Relative change	0.18%
	Elasticity	0.018
6) Increasing biomass by 10%	New mean revenue	8.722
	Absolute change	0.793
	Relative change	10.00%
	Elasticity	1.0
7) Policies 1,2, 3, 4 and 6	New mean revenue	8.791
	Absolute change	0.793
	Relative change	10.87%
	Elasticity	1.1

finding for Ethiopia, where soil erosion investments have long-term benefits but their short-run benefits are negative. Shiferaw and Holden [36] also show that gains from conservation may be limited especially where there are high input costs. Given data limitations, our study does not estimate long-run elasticities of average revenue with respect to adoption of soil conservation practices.

Impact of policy changes on poverty: To simulate the impact of policy changes on poverty, we use results from Table 3. We argue that any change in policy that raises productivity enhances the welfare of the households. We therefore assess the impact of a change in productivity on the percentage of households below the poverty line [***]. We focus on policies that favour privatization of land, encourage soil conservation and increase availability of biomass at the village level. To do so, we first compute the FGT base poverty line [††] from our sample and find that 21% of the households are below the poverty line.

The simulation results are presented in Table 4. With a head count of 21%, a 10% increase in the proportion of total land held under private property reduces the head count ratio by 2.06%. Other factors held constant, increasing the proportion of farmers adopting any of the three soil conservation practices by 10% would reduce the head count ratio by 1.4%. A combination of all these policy changes would reduce the head count ratio by 2.2%. Increasing the kilograms of biomass per acre by 10% would reduce the head count ratio by 2.5%.

We note that in spite of differences in elasticities of revenue with respect to different policy interventions in Table 3, the changes in head count ratio are not pronounced. This small response of poverty rate to policy changes could be explained by the fact that the simulation methodology does not take into account the distribution of the poor households below the poverty line. This result is consistent with the low elasticities of revenue with respect to soil conservation practices. Adoption of soil conservation practices has only a minimal short-run impact on the base poverty rate. However, in the long run, the poverty reduction effects of these measures can be substantial. Our simulations demonstrate the need to go beyond the signs and magnitudes of regression coefficients in assessing true welfare effects of policies.

Conclusions

This paper explores the determinants of farm productivity in Kenya, using survey data. The paper tests and fails to reject the hypothesis that adoption of soil conservation practices increases productivity and reduces poverty. We study the impact of conventional farm inputs, institutional factors and adoption of soil conservation practices on productivity. We further simulate the impact of policy changes on productivity and the base poverty rate, with the aim of shedding light on how policy can effectively address poverty reduction in fragile ecological environments.

The results indicate that controlling for unobserved heterogeneity, property right regimes and soil conservation are important determinants of farm productivity. Also important is availability of labour and the amount of village level biomass. Our results indicate that failure to control for endogeneity of soil conservation practices tends to overstate the impact of individual practices on productivity. We further show that privatization of

Table 4. Impact of policy changes on the head count ratio (base poverty rate = 21%).

Policy measure	New head count ratio (%)	% Decline in head count ratio
1) Increase proportion of land held under private property rights by 10%	18.94	2.06
2) Increase proportion of farmers terracing their land by 10%	19.56	1.44
3) Increase proportion of farmers planting drought resistant vegetation by 10%	19.55	1.45
4) Increase proportion of farmers blocking soil erosion by 10%	19.56	1.44
5) Policies 1, 2, 3, and 4	18.81	2.19
6) Increase biomass by 10%	18.50	2.50

[***] We use absolute poverty line (Kshs. 825) derived by Mwabu *et al.* [26]. We assume absolute poverty to be fixed over time and space so that we need not adjust the poverty line to reflect the standard of living in the sample period. We note here that our head count ratio is consistent with that reported by Mwabu *et al.* [26] where the cost of basic needs and food energy intake head count ratio ranged from 20.45% to 26.52%.

[††] FGT base poverty rate refers to the head count poverty index calculated on the basis of sample means, which turns out to be 21% (see Foster *et al.* [12]). The purpose of the simulation exercise is to observe how the base poverty rate changes as selected sample means are varied by policy interventions.

common property land and adoption of soil conservation practices are some of the most important policy options for increasing farm productivity and reducing poverty. Efforts towards these policy directions are recommended.

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