NEIGHBORS' SOIL CONSERVATION AND CROP PRODUCTION IN KENYA

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Abstract

This paper looks at the extent to which neighborhood soil conservation efforts affect crop output in smallholder farms in Kenya. Neighborhood soil conservation efforts are proxied by fertilizer application, grass stripping and soil ridging by neighboring farmers, all measured at the village level. Regression method was applied to primary data collected from Nyeri, a rural district in Kenya, to estimate crop production effects of neighbors' soil conservation efforts on individual plots. The results indicate that neighborhood fertilizer usage significantly increases crop production in smallholder agriculture.

Keywords: Neighborhood, externalities, soil conservation, smallholder farms

1.0 Introduction[1]

Agriculture is an important economic activity employing nearly 70 percent of the labor force and contributing about 25 percent of the gross domestic product (GDP) in Kenya, valuation problems of subsistence output notwithstanding (Republic of Kenya, 2006; 2007a; 2010). Much of the farming takes place in only 20 percent of Kenya's landmass (approximately 116,528 sq. km.), which is classified as of medium-to-high agricultural potential. In this area also lives 75 percent (over 28 million people) of the country's population. Majority of the farms are small-sized, measuring less than 5 acres in medium-to-high potential areas and less than 50 acres in low agricultural potential zones.

Most of these farms grow food crops exclusively, and only a few farms have a mix of food and cash crops (Senga, 1976). A majority of smallholder farmers rear livestock, the most common types of which are chicken, goats, sheep and cattle.

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Population growth in medium- to high- potential highland zones is quite high. According to some school of thought, population pressure can drive households to use resources available to them more prudently and to embrace innovative technologies so that output and productivity increase rather than decrease. Boserup belongs to this school. She postulates that as population increases and access to markets improve, people are encouraged to invest in new technologies including conservation that improve land productivity (Boserup, 1965; 1976).

Potent as the argument may be, Kenya's population growth has exerted great pressure on the country's natural resources particularly land, water and forests. It has occasioned land uses that disregard land potential or carrying capacities. Population spillovers have encroached into marginal areas accelerating soil degradation and loss of biodiversity. Population pressure has also caused farms to suffer continuous fragmentation into smaller units, some of which are uneconomical (Republic of Kenya, 2007b; 2010).

Nonetheless, farms in the highlands could realize high to average returns to investments but they are intensely cultivated without soil conservation measures to replenish lost nutrients. Libecap and Hansen (2002) observe that farm size and land use practices contribute to soil erosion particularly by wind more than does natural geologic and climatic conditions.

The use of fertilizer, animal manure, soil terracing and ridging, tree planting among other soil conservation measures have the potential to improve productivity in smallholder agriculture, but these inputs usually fall below optimal application levels. This is partly because the concept of soil conservation is misunderstood by farmers. Many of them interpret it to mean 'stopping erosion' rather than the wider view of protecting and preserving soil nutrients and prudent management to restore any lost nutrients. Without proper interpretation of the concept, smallholder farmers hardly appreciate the link between soil conservation and farm productivity (Kabubo-Mariara, 2010).

Low agricultural productivity in smallholder farms undermines not only household food security but also the ability of smallholder farmers to earn decent livelihoods out of agriculture. Without substantive earnings, farmers' ability to invest in soil conservation is reduced thereby increasing the risk of erosion. They remain trapped in first part of environmental Kuznet's curve causing damage to the environment. Soil degradation and poverty feed into each other deepening poverty further.

The damaging effects of erosion spread to neighbors, their erosion control measures notwithstanding. With such cross-cutting damages, non-conserving farmers send negative externalities to other farmers (Nyangena and Kohlin, 2008).

One of the most important inputs in land resource management is fertilizer. Fertilizer is a productivity-enhancing input as well as an instrument for soil fertility replenishment. Combined with improved land husbandry practices, fertilizer has the potential to contribute to various goals (see Kelly, 2005). With declining land holdings and productivity in smallholder agriculture, farmers can gain a lot by using inputs that are known to raise output, a prime example being fertilizer.

Many smallholder farmers have only weak property rights and lack security of tenure. This situation denies smallholder farmers the incentive to invest in soil and environmental conservation (Kabubo-Mariara *et al*., 2010). Although security in tenure rights does not in itself result in greater conservation since the rights do not entail explicit obligation to conserve soil and other natural resources, absence of tenure rights has been noted to contribute to soil degradation in Kenya.

Property rights establish “the legal owner of a resource and specify the ways in which a resource may be used” (Nicholson, 1985). Each property rights regime has implications on the type of agriculture and technology-mix that can be practiced on a farm. Property rights regimes that offer security of tenure induce better management decisions that lead to higher output on average (Kabubo-Mariara *et al*., 2010). In land matters, tenure refers to the "terms and conditions under which rights to land and land-based resources are acquired, retained, used, disposed of, or transmitted" (Republic of Kenya, 2007b).

If the prevalent land tenure in a neighborhood is weak, it may, under certain assumptions suggest that farmers in that neighborhood have no incentive to practice good farming techniques or to invest in conservation (Demsetz, 1967; Fenske, 2010; Kabubo-Mariara *et al.*, 2010). Subsequently, soil quality declines giving rise to poor harvests and low returns to inputs.

Farmers in a neighborhood with weak land tenure can be expected to exchange spillovers in form of negative externalities arising from soil erosion and poor land management practices. For a given level of inputs, productivity in any one farm can be expected to be lower due to the presence of negative externalities. This further undermines farmers’ ability to invest in new technologies, e.g., fertilizers and other soil conservation practices.

On the other hand, farmers with strong land tenure rights are expected to exchange positive externalities. Although title deeds bestow property rights on land owners without a corresponding and explicit obligation on the land owner to conserve the land resource, a title deed can be an incentive for conservation. Gathiaka (2012) observes that farmers with secure property rights apply animal manure in their farms even when the work is laborious. Manure encourages growth of beneficial soil organisms particularly earthworms and bacteria. Earthworms promote macronutrient availability in the soil, and through burrowing they also create soil porosity channels that enhance aeration and drainage. Bacteria fix nitrogen in the soil (Mollison 1988).

From this perspective we see that a farmer’s crop output is a function of inputs used, property rights as well as neighborhood variables. Our interest in this paper is with neighborhood variables and the externalities that they produce affecting production activities of neighboring farmers.

Externalities could be informational or technological. They are non-quantifiable costs or benefits that exist outside the price system. They can also be viewed as third party, spillover or external effects for which no compensation is paid. They occur in virtually all areas of economic activity, yet they are not reflected in market prices (Nicholson, 1985).

In spite of the negative influence of their characteristics on profitability, smallholder farms remain the most common mode of farming in Kenya. In Nyeri district, for instance, 80 percent of the farms are small-sized. The district is of medium- to high- agricultural potential and exhibits the characteristics portrayed above.

Previous studies in Kenya, as well as in many other places, have not taken into account the neighborhood effects of soil conservation in smallholder agricultural production (see for example, Nyangena and Kohlin, 2008; Kabubo-Mariara, 2010; Kabubo-Mariara *et al*., 2010; Pitt, 1983; Singh *et al*, 1986). This paper addresses this research gap using cross sectional data from Nyeri.

The rest of the paper is organized as follows: The second part discusses the analytical issues essential for understanding neighborhood effects in smallholder agriculture. The third part presents data collection method and a short profile of the study area. The fourth part presents econometric results of crop output in smallholder farms accounting for neighborhood variables of soil conservation. The fifth summarizes the paper and draws its policy implications.

2.0 Methodology

Since neighborhood variables are non-quantifiable their data were not available, and we used their proxies. The means of fertilizer usage and conservation efforts of soil ridging and grass stripping in a village were used as the proxies for neighborhood conservation efforts. Each of the neighborhood variables was measured excluding the observation of the farmer of interest.

Crop output in the presence of neighborhood variables was estimated using the linear-in-means model. Following Halliday and Kwak (2007), Gaviria and Raphael (2001) and Fletcher (2010), the linear-in-means model was modified to show crop output of farmer *i* in village *s* as follows:

$$Y_{is} = a_0 + a_1 X_i + a_2 \bar{Y}_{is} + a_4 F_i + a_4 W_i + a_5 V_i + \square_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where,

Y_{is} = crop output of farmer *i* in village *s*

X_i = endogenous input used by farmer *i* (e.g., fertilizer)

$\bar{Y}_{is}$ = vector of neighborhood variables in village *s* when farmer *i* is excluded

F_i = vector of farmer *i*'s observable characteristics or observed heterogeneity

W_i = vector of other covariates of inputs demanded by farmer *i*

V_s = village *s* fixed effects

a_i = parameters (i=0,1,…)

$\square_i$ = error term.

$\bar{Y}_{is}$ is a vector of neighborhood variables of soil conservation. We also considered property rights regime in a village because they affect demand for inputs including conservation efforts.

Besides neighborhood considerations, some of the inputs used are simultaneously determined with crop output and therefore endogenous. Fertilizer and conservation efforts are endogenous inputs in a crop production function. To assess their impact on crop output without the problem of endogeneity, each endogenous input was instrumented. An instrument has the property that it affects demand for the endogenous input without influencing farm output. A good instrument is uncorrelated with the error term and only partially correlated with the endogenous input once other exogenous variables are netted out (Green, 1997; Wooldridge, 2002; Terza, 2007).

To estimate equation (1) without the problem of endogeneity, X_i was instrumented. Instrumentation required that demand for say, fertilizer, be predicted and the actual fertilizer variable in equation (1) be replaced with the predicted fertilizer demand (see Gathiaka, 2012). In this model, C_{di}, the distance from a household to the nearest cooperative society was the instrument for fertilizer. The predicted fertilizer demand was a reduced form of actual fertilizer demand and was expressed as:

$X_{is} = b_0 + b_1\bar{X}_{is} + b_2F_i + b_3W_i + b_4C_d + b_5V_{is} + \square_{fi}$ ……………………………(2)

where,

X_{is} = amount of fertilizer used by farmer *i* in village *s*

$\bar{X}_{is}$ = mean fertilizer used by farmer *i*'s neighbors in village *s* when farmer *i*'s fertilizer usage was excluded

$\bar{Y}_{is}$ = vector of other neighborhood variables in village *s* when farmer *i* was excluded

F_i = vector of farmer *i*'s observable characteristics

W_i = vector of other covariates of inputs demanded by farmer *i*

V_s = village *s* fixed effects

C_{di} = distance to the cooperative society nearest to farmer *i*

b_i = parameters to be estimated (i=0,1…)

$\square_{fi}$ = error term

The reduced form fertilizer demand, X_{is}, replaced X_i in estimating parameters of equation (1). The two-step procedure is behind the logic of IV-2SLS and it was done simultaneously in Stata.

2.1 Data And Study Area

The data from which this paper was developed were collected from Nyeri County of Central Province in Kenya in face-to-face interviews with 423 farmers. Sample selection was guided by the National Population and Household Survey framework of the Kenya National Bureau of Statistics (KNBS), Nyeri. The data was collected between July and September 2007.

Nyeri County is in the eastern highlands of Kenya. A majority of the residents are engaged in small scale farming and the activity occupies 80% of the district's total land area (Republic of Kenya, 1997). Farm size in the county has been falling steadily as a result of land subdivision. Currently, the farms measure on average less than 0.6 ha in the high potential zones, and about 0.88 ha in low potential zones (Republic of Kenya, 2002).

Maize and beans are the most widely grown crops. Maize was found to be grown by 91% of the farmers while beans were grown by 81%. The two crops were mostly inter-cropped and they constituted the staple foods in the county. Potatoes were also widely grown (56%) and consumed. In cash crops, coffee was the most widely grown, but by only 41% of the farmers. However, its prevalence exceeded by a wide margin that of horticultural crops and tea each of which were grown by 15% of farmers.

Table 1 shows the proportion of households in the study area that were investing in soil conservation and the prevalence of the various conservation practices. The conservation methods are either in the nature of preventing or preserving soil nutrients, or adding lost nutrients.

Table 1: Proportion of households investing in soil conservation

Variable	Mean	Std Dev.
Plots with some conservation	0.60	0.49
Erosion control practices		
Terraces	0.03	0.17
Planted tres	0.03	0.16
Ridging	0.19	0.39
Grass strips	0.28	0.45
Other practices (e.g., mulch, fallow)	0.07	0.25
Nature of the practices		
Short term investments	0.46	0.50
Long term investments	0.54	0.50
Mineral addition practices		
Fertilizer use	0.17	0.37
Manure use	0.17	0.38

Source: Field data

The data indicates that 60 percent of the plots practiced some form of soil conservation. Grass stripping was the most common erosion control practice at 28 percent. In addition to erosion control practices, some farmers used fertilizers and manure to increase soil fertility on their plots.

3.0 Results And Discussions

First stage regression of the model gives parameter estimates of demand for fertilizer. These are presented in Table 2. The characteristics of the household head and factor inputs are the control variables. The effect of distance on fertilizer demand is assumed to be non-linear, which is the reason for inclusion of the square of distance in demand equation (see Thori and Mehlum, 2010).

Table 2: First stage regression – Demand for fertilizer (*t*-statistics in parentheses)

Variables	*OLS Parameter Estimates*		
Factor Inputs			
Capital, index	2.664(1.36)	2.081(1.03)	1.804(0.89)
Labor, person days	.043(2.25)	.034(1.71)	.034(1.69)
Land, hectares	.268(0.23)	-.451(0.38)	.200(0.17)
Farmer and Neighborhood Characteristics			
Age, years	.526(0.33)	-.203(0.12)	-.303(0.18)
Age^2	.034(0.23)	-.735(0.00)	.001(0.03)
Education, level	3.632(0.76)	3.362(0.69)	3.167(0.64)
Mean fertilizer usage in a village, kilograms	.675(5.42)	-	-
Mean of soil ridging efforts (1= ridging)	-	55.781(2.30)	-
Mean of grass stripping practices (1=stripping)	-	-	31.474(1.37)
Exclusion Restrictions (instrumental variables excluded from the production functions)			
Distance to a cooperative society	-3.603(3.75)	-3.396(3.41)	-3.570(3.58)
Distance to a cooperative society squared	.097(4.55)	.095(4.35)	.098(4.45)
Constant	28.389(0.67)	45.529(1.04)	0.896(1.16)
R^2	.125	0.0739	0.066
F-statistic [*p*-value]	6.550[0.000]	3.65[0.000]	3.25[0.001]
Root MSE	68.619	70.644	70.933
Observations	423	423	423

The estimates in Table 2 indicate that labor and neighborhood variables represented by means of fertilizer usage, soil conservation efforts and distance to the nearest cooperative society are the main determinants of fertilizer demand. A person-day increase in labor use is associated with an increase in fertilizer application on a plot by 0.043 kilograms. Similarly, when neighbors increase fertilizer usage by one kilogram on average, a farmer within the locality will tend to increase his own fertilizer usage by close to 0.7 kilograms. This is an indicator of positive externalities within farming villages.

Likewise, if soil ridging efforts in a village were to increase by a unit, fertilizer application in farming household would rise by 56 kilograms annually. This suggests that when farmers in a neighborhood become conscious and engage in conservation efforts of one kind, there are multiplier effects to other types of conservation. These findings are indicative of social learning and positive externalities in soil conservation.

An increase in distance to the nearest cooperative society, and an increase in property rights in a village towards private ownership are shown to reduce demand for fertilizer. For every kilometer increase in distance to a cooperative society, a farmer reduces his annual demand for fertilizer by 3 kilograms. Long distances to cooperative societies discourage fertilizer usage.

The endogenous soil conservation efforts (Cn) were estimated similarly controlling for endogeneity, but the results were insignificant. The instruments for soil conservation efforts were the costs of undertaking these investments, including distances to market centers and cooperative societies where conservation materials are purchased (Kabubo-Mariara, 2010).

In Table 3 second stage regression results are presented. The parameters show estimates of returns to farm inputs. The dependent variable is log of crop output in kilograms.

Table 3: Crop production in smallholder farms (*t*- statistics in parentheses)

Variables	*(Dependent Variable is Log Crop Output)*		
Factor Inputs			
Capital, index	.046(2.39)	.046(2.40)	.038(2.12)
Labor*10^{-2}, person day	.02(1.00)	.016(0.84)	.028(1.50)
Land	.022(2.04)	.019(1.78)	.013(1.23)
Fertilizer*10^{-1}, kg	.040(1.93)	.039(1.90)	.029(1.53)

Farmer and Neighborhood Characteristics			
Age, years	-.010(0.65)	-.008(0.55)	-.009(0.60)
Age^2*10^{-3}	.1(0.71)	.083(0.59)	.097(0.73)
Education	-.006(0.13)	-.008(0.18)	.008(0.19)
Mean fertilizer usage by neighbors, Kg	.003(2.00)	-	-
Mean of soil ridging effort by neighbors	-	.431(1.74)	-
Mean of grass stripping efforts by neighbors	-	-	-.958(4.78)
Constant	9.017(22.53)	9.059(22.43)	9.407(24.43)
R^2	.	.	0.080
F-statistic [*p*-value]	6.09[0.000]	4.380[0.000]	6.080[0. 000]
Root MSE	.652	.652	.619
Observations	423	423	423

Village level soil conservation efforts had mixed effects on returns. Fertilizer usage at the village level was found to influence individual farmer's demand for fertilizer and this in turn influenced his crop output. The quantities of fertilizer used in Africa, particularly on food crops, are below optimum (Kelly, 2005; Akwasi, 2010). When farmers observe neighbors apply more fertilizer on plots with noticeable good results, they follow suit and realize higher yields too. The estimates showed that when neighboring farmers increased fertilizer usage by an average of one kilogram, crop output in a household within the village increased by .003 kilograms per annum. Thus neighborhood fertilizer usage had positive externalities on crop production in a farm.

Similarly, soil ridging efforts in a village were found to be positively associated with crop production in a household. Soil ridging by neighbor farmers effectively checked soil erosion leading to positive externalities to non-conserving farmers and raising plot level productivity. A 10 percentage increase in the proportion of farmers engaged in this practice was associated with an increase in crop output of 5.39 percent. The result suggested that there were positive production effects in a village stemming from farmers that practice soil ridging.

These findings contrasted with the case of grass stripping where estimates showed that when grass stripping efforts by neighbors increased, crop output on individual plots declined. Grass strips may not be very effective in controlling soil erosion on their own, particularly when they are young and the rains are heavy. Depending on how they are constructed, grass strips may not be effective in controlling soil erosion, and erosion downstream during heavy rains may occur in spite of their presence. The erosion that ensues may lead to decline in crop output. Over time, the strips become thicker and wider thus increasing their ability to control soil erosion.

Further, if a farmer observed his neighbors' grass strips and planted the same in his farm, the strips may compete for space with crops and reduce yields. This however might be a short-run result because in the long run, the grass strips control erosion and crop output may increase. Existing studies show that soil conservation is a boost to crop production (Kabubo-Mariara, 2010; Kabubo-Mariara *et al*., 2010)

Since yield response affects agricultural production, a clear understanding of the relevant elasticities is crucial. Table 4 shows the estimated elasticities of crop output with respect to factor inputs and village level variables.

Table 4: Absolute elasticities of crop output with respect to factor inputs and village level variables (*t*-statistics in parentheses)

Variable	Elasticity
Capital*10^{-5}	0.081(2.550)
Labor	0.048(1.180)
Land	0.060(2.260)
Fertilizer	0.206(2.270)
Mean fertilizer used by neighbors within a village	0.131(1.680)
Mean of grass stripping efforts by neighbors within a village	0.272(4.760)
Mean of soil ridging efforts by neighbors within a village	0.078(1.710)
Bundles of property rights held by neighbors in a village	0.508(2.360)

According to parameter estimates in Table 4, crop output was inelastic with respect to variations in neighborhood variables and factor inputs. This had implications on demand for inputs at the farm level. The results suggested that soil conservation efforts in the studied area were low due to a myriad of factors, including the farming technology. In smallholder agriculture in the study area, traditional farming methods dominate. The quantities of fertilizer used particularly on food crops are below optimum (Kelly, 2005; Akwasi, 2010). But as to how smallholder farmers could adopt modern technologies remains an issue of major policy concern (Mwabu *et al*., 2008; Nafula *et al*., 2005).

Nevertheless, the estimates in Table 4 indicated positive crop response to factor inputs as well as neighborhood variables. In smallholder agriculture, as land becomes scarce, and as the price of fertilizer relative to price of land continues to decline, the use of fertilizer and other soil conservation practices must increase. Factor substitution can be expected along the isoquant of a meta-production function as happened in Japan (see Hayami, 1969).

With a fixed supply of land, opportunities for higher yields from land lie in combining it with factors that push up crop production functions. This is a prudent farming strategy because crop elasticity with respect to investments in soil conservation efforts is positive. Crop expansion also responds strongly to property rights that give farmers complete control of their plots.

4.0 Conclusion

In smallholder farming activities neighborhood effects of soil conservation should not be ignored in considerations of land resource management at the farm level. The neighborhood influence has been found to be largely positive.

Usage of fertilizer at the plot level is positively correlated with mean village level usage of fertilizer, soil ridging efforts and grass stripping efforts. It is negatively correlated with property rights in a village. If soil fertility at the farm is to increase, attention has to be paid what is happening in the neighborhood. The gains from increasing fertilizer usage in a neighborhood go beyond increasing crop output and farm revenue. Rising farm revenues reduce poverty and enable farmers to invest in soil conservation methods thereby increasing the value of the land resource.

Smallholder agriculture could become important in Kenya's development process if farmers could nurture the natural resource base. Poverty reduction in smallholder agriculture through adoption of technologies that enhance farm yields while enriching the soils would be a big step in the achievement of the Millennium Development Goals. At the policy level, the challenge is how to make farmers adopt these technologies. To boost soil conservation efforts at both the plot and village levels, several options can be explored.

The first option is to increase the number of demonstration farms. The farms can serve as nodal points for technological and information externalities. Since agricultural extension service in Kenya has died, demonstration farms can fill an important gap of technology transfer in a localized context.

The second option is to popularize soil conservation practices through cooperative societies. Cooperative societies could be used as possible sources of funds to finance investments in soil conservation, and to market agricultural inputs such as fertilizer. It is also informative to note that during cooperative societies' meetings farmers exchange ideas on farming and such forums can boost uptake of soil conservation measures in a village.

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