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Rural Roads and Natural Resource Management in the Semi-arid Lands of Kenya

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Abstract: This research uses data from a 2000 household survey of smallholder farmers in Kenya's marginal areas to investigate the effects of road infrastructure on farm level soil conservation investments. A logistic regression was used to determine the decision to invest in soil conservation measures. Three Stage Least Squares at the household level was also used for estimating a system of Cobb-Douglas type simultaneous equations. The study findings show clearly that poor road infrastructure reduces soil conservation investments. Improvement of road infrastructure thus creates an incentive to invest in soil conservation measures. However, in the absence of significant investments in road infrastructure due to budgetary constraints, the policy challenge is to involve a number of stakeholders such as the local communities and non-governmental organizations in the provision of rural road infrastructure.

Key words: Road infrastructure, soil conservation, agriculture, marginal, Kenya

INTRODUCTION

Studies on rural road projects in sub-Saharan Africa reveal a strong catalytic effect of rural feeder projects on agricultural development[1-3]. Yet, the road density in Africa is generally much lower than that of Asia[4-6]. In Kenya, rural access and minor roads programmes which are formulated and implemented by the government as central infrastructure strategies for rural development have had positive impacts in providing cheap access to markets for both agricultural outputs and modern inputs.

However, rural roads in Kenya are inadequate and often of poor quality. Rural feeder roads which are prevalent in rural areas and in particular marginal areas are worse. At the end of 1999 up to 85% of the rural roads were estimated to be in poor condition with accessibility limited to dry seasons in most cases[7]. The resultant effects are usually high access costs to the market, high effective farm gate input prices, low farm gate output prices, low traded volumes, low productivity and often poor management of natural resources[8]. In addition, diffusion of technology may be constrained[9]. An inadequate public infrastructure could also result in massive losses to producers[10-12].

Natural resource management in marginal areas consists of investments into soil conservation such as terraces and trees among others. This may be undertaken if sufficient returns are expected in comparison with the situation when no such investments are made. The returns to the household of the investments would critically depend on what the household can do with the crops grown. These returns can be related to outside factors, but may be influenced by the state of existing road infrastructure and the available modes of transport, which subsequently determine the level of access to input and output markets.

The level of accessibility to markets is a function of the mode of transport used, the physical distance and the state of road infrastructure. Consequently, a good measure for accessibility should incorporate these components for it to be adequate. In this study, time to the market is used as a proxy of road infrastructure. In any case, the mode of transport used, the physical distance and the state of road infrastructure all have an influence on the time it takes to reach the market. Such a variable is sufficient to measure the level of accessibility, when the existing stock of road infrastructure cannot be valued.

The condition of road infrastructure to the market will determine the type and quantities of inputs used in agricultural production and also the returns obtained. This will therefore have a profound influence on the investments made in soil conservation. The predominant soil conservation investment in semi-arid areas in Kenya is terrace construction[13,14]. Any reference to soil conservation investments is thus synonymous to terracing. Thus, the poorer the road infrastructure, the less competitive the marketing systems are likely to be and also the less information available is. This should be reflected in differential terrace adoption and terrace density.

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Various studies on the influence of road infrastructure on agriculture have been carried out in Kenya. For example, easier access encourages the adoption of high value crops[15-18] and commercialisation of agriculture[19]. However, studies on rural roads and natural resource management are generally rare and particularly in marginal areas. Most studies in marginal areas focus on benefit-cost analysis[20,21].

Our maintained hypothesis is that markets are important and that people produce for home consumption and also for the market. When there is no access to the market, returns to farm produce tend to be very low. This may be due to the use of traditional low yielding technologies and also due to limited demand for produce emanating from thin or shallow village market(s). As soon as there is access to markets, returns are bound to rise as farmers search for high yielding technologies and favourable prices. This access to the market in rural areas is usually through the road infrastructure. If it is poor, farmers face considerable costs and it therefore follows that the returns even with the market exchange are bound to be low. In such a scenario, there is no sufficient incentive to invest in soil conservation measures.

MATERIALS AND METHODS

In Machakos district, the classified road network in the district covers a distance of 1562.9 km. The road network connects most of the market centres and also provides access to areas of agricultural importance. The distribution network by class and type of surface is given in Table 1.

There are also unclassified roads built and maintained by local communities. Despite the extensive network, the distribution is not even and the condition of the roads is not good throughout the year. The tarmac road network is linked by gravel and earth roads, most of them are impassable during the rainy seasons. The hilly terrain in Kangundo, Ndithini and Kalama Divisions has some of the worst roads. Due to the extensive nature of the district and also to the steep and rocky hill masses, the conditions of the roads deteriorate very fast. Kangundo, Kalama and Ndithini are the divisions greatly affected by the poor road network.

With Kitui district (Table 1), there are 3373.1 km of classified and unclassified roads. These are international trunk road (A), national trunk road (B), secondary roads and motorable trucks (C). This road network covers only a small portion of the district. Central and Kabati divisions are fairly well covered by reasonable road network.

Modelling strategy

Modelling adoption and investment levels: The decision to invest or not in soil conservation measures is a binary decision. The adoption of a particular soil conservation measure can therefore be analysed with binary choice models.

The conceptual framework is to build a model that will allow the prediction of how a farmer in marginal lands with given attributes will decide. In other words, the objective of the model is to determine the probability of a farmer making one choice rather than the alternative. Three types of models have been used in the economic literature for estimating binary choice models: the linear probability, logit and probit models. Feder *et al.*[24] provide a useful survey of empirical studies of adoption using these types of models.

The linear probability model has a number of shortcomings[25]. First the disturbance term is heteroscedastic depending on β. Secondly without some ad hoc tinkering with the disturbances, one is not assured that the predictions from this model will look like probabilities. The β'x cannot be constrained to the 0-1 interval. Such a model produces both nonsense probabilities and negative variances.

The Logit and the Probit models are still the most common frameworks used in econometric applications. Which one to use is dependent on practical reasons and in some cases on mathematical convenience.

However, it is difficult to justify the choice of one distribution or another on theoretical grounds. It seems

Table 1: Classified road network in Machakos and Kitui Districts in kilometers

	Road type				Road type			
Class	Machakos Bitumen	Gravel	Earth	Total	Kitui Bitumen	Gravel	Earth	Total
A	108.6			108.6	48.8		94.2	143.0
B	35.5			35.5	6.5	147.6	9.6	163.7
C	151.9	82.7		234.6	25.5	110.7	74.3	210.5
D		207.3	69.8	277.1	4.2	871.9	162.1	1038.2
E	44.7	107.5	519.6	671.8	1.0	63.2	1182.6	1246.8
Rural access	4.1	2.3	12.7	19.1	0.0	537.1	30.4	567.5
GOK Access		216.2		216.2	2.2		1.2	3.4
Total	344.8	616.0	602.1	1562.9	88.2	1730.5	1554.4	3373.1

Source: GoK[22,23]

therefore, that in most applications, there is no much difference[25]. For this study, the logistic regression was used due to its computational simplicity. The purpose of the Logit was to identify the important factors explaining adoption of soil conservation measures.

The impact of crop productivity on terracing intensity and vice-versa may or may not be direct. Alternatively, some factors may simultaneously affect both productivity and the intensity of terracing. In which case we are dealing with simultaneous equations model in that two or more endogenous variables are determined jointly within the model, as a function of exogenous variables, pre-determined variables and error terms. This simultaneity induces correlation between the regressors and error terms of each equation in the systems, thus causing OLS to be inconsistent in estimating parameters.

As a result, the main estimating techniques are indirect least squares (ILS), two stage least squares (2SLS), limited-information maximum likelihood (LIML), three-stage least squares (3SLS) and full-information maximum likelihood (FIML). ILS, 2SLS and LIML are essentially single-equation methods in which attention is focused on one equation at a time without using all the information contained in the detailed specification of the rest of the model. In principle, information on the complete structure, if correct, will yield estimators with greater asymptotic efficiency than that attainable by limited-information methods. FIML is computationally more expensive as it involves the solution of non-linear equations, leaving 3SLS as the best estimation technique[25].

Model specification: Two types of models were estimated in this study. A logit model was used to estimate the determinants of the decision to construct terraces on crop fields. A three-stage-least square full-system method, in which all parameters that appear in the model are jointly estimated, was used to determine the impact of level of infrastructure on crop productivity. A system of five equations was estimated simultaneously.

The models are specified as follows:

The general function for the household level decision analysis for individual responses is:

PROB(TERACING) = f (ACCESST, WEALTH, DISTH, AGE, POPPRE, HHS, SELFHG, SLOPE, TENURE, LOCATION, FARMORE, INC, EDUC)

Three-Stage-Least squares system equations:

1. *TERACE= f (ACCESST, WEALTH, DISTH, AGE, POPPRE, HHS, SELFHG, SLOPE, TENURE, LOCATION, FARMORE, INC, EDUC, SEX, LCROPAC)*
2. *CROPAC= f (LAB, MAN, FERT, TERACE, LOCATION)*
3. *LAB= f (ACCESST, WEALTH, DISTH, AGE, POPPRE, TENURE, LOCATION, INC, EDUC, LCROPAC)*
4. *MAN= f (ACCESST, WEALTH, DISTH, AGE, POPPRE, SLOPE, TENURE, LOCATION, INC, EDUC, SEX, LCROPAC)*
5. *FERT= f (ACCESST, WEALTH, DISTH, AGE, POPPRE, SLOPE, TENURE, LOCATION, INC, EDUC, LCROPAC)*

The description and measurements units of the variables that are used in the various models presented above is as follows: *TERACE* is the length of terraces in metres per acre; *ACCESST* is the time taken in minutes to the district main market, which is a proxy for the road infrastructure; *HHS* is household size; *POPPRE* is the number of people per unit area; *EDUC*, *SEX* and *AGE* are characteristics of principal household member; *SELFHG* is whether a household participates in self-help group activities or not and takes a value of 1 or 0; *DISTH* is distance, in metres, from the particular crop fields to the homestead; *SLOPE*, *TENURE* are characteristics of the fields; *FARMORE* is the degree of farm-orientation calculated as a fraction of farm income in the total household income; *INC* is household income in Kenya shilling (Ksh) ; *LOCATION* is a dummy indicating whether household is in Machakos or Kitui District; *CROPAC* is aggregate crop output in Ksh per acre; L*CROPAC* is the lagged aggregate crop output in Ksh per acre; *LAB* is the labour use in man-days per acre; *MAN* is manure use in Kgs per acre; *FERT* is the fertiliser use in Kgs per acre; and *WEALTH* is wealth of the household proxed by number of rooms of the main house in the homestead. The local people often build very good houses rendering the type of house as a poor indicator of wealth.

Data: The data used in this study comes from a survey of rural households in Machakos and Kitui districts during 1999-2000 cropping season. Four sub-locations were chosen in each district on the basis of condition of population density and distance to Nairobi. Two sub-locations with high population density but far and near Nairobi were selected in each district. Likewise, two sub-locations with low population density but far and near Nairobi were also selected. A village was then selected from each of the sub-locations that showed recent signs of transition to sustainable agriculture. The villages selected in Machakos district were Kisaki, Musoka, Ngalalia and Ngumo; while in Kitui district these were Mwanyani, Kitungati, Utwiini and Kyondoni. The survey involved 105 households in each district with about 25 households in each village.

The study areas were in agro-ecological zone 4[26]. This zone is a transition between semi-arid and semi-humid, depending on altitude. It is characterised by having between 115 and 145 growing days (medium to medium/short growing season) and annual mean temperature between 15 and 18°C in the Lower Highland zone. The Upper Midland zone has between 75-104 growing days (short to very short growing season) and a mean annual temperature of between 21 and 24°C. Cattle and sheep keeping and the growing of barley are recommended in the Lower Highland zone, while sunflower and maize are recommended in the Upper Midland zone.

RESULTS AND DISCUSSION

Determinants of the decision to invest: This was analyzed at the household level as it is where final decisions are made about land use, crop and technology choice [27]. Most of the variables were transformed into natural logs with the exception of membership to self-help group and location. The results are shown in Table 2 below and were estimated using Statistical Package for Social Science (SPSS).

We find that access time, location and distance to the fields from the homestead are negative and significant. These factors reduce the probability of undertaking soil conservation investments. The analysis at the household level confirms that homestead to fields "kind of infrastructure" (i.e. distance to the fields) is important. The implication is that the further the fields are, the difficult it is to supervise, monitor and control. Hence the less likely the odds of undertaking investments in soil conservation measures. The vice-versa is true. Access time to the district trading centre has the right expected sign and significant at the 1% level. This means that when the access time is high, given that farmers are price takers, farm returns reduce significantly thus depressing the incentive to invest in soil conservation measures. In other words, when the road infrastructure is poor, farmers are less likely to undertake terrace investments.

This means that farmers' behavior is influenced by the expected profitability of any investment made. The returns to terrace investments are the crops grown after the investments have been undertaken. With poor road infrastructure, which implies high costs of access to the market, the net returns to the farmers are low, depressing the incentive for further terracing. Prior to making any investments in soil conservation measures, the farmers appear to have a clear understanding of the costs of access to the market. This implies that the decision to invest is arrived after taking into account access costs.

Location is found to be significant, pointing that there are significant differences between Machakos and Kitui districts regarding soil conservation investments. It strongly suggests that Machakos has perhaps unique factors from that of Kitui that are location specific[28,29].

Table 2: Decision to invest in soil conservation measures in Kitui and Machakos Districts, Kenya, 2000

	Coefficient	Exp. (B)
ln *ACCESST*	-3.21 (7.75)***	0.040
ln *WEALTH*	0.88 (2.71)*	2.42
ln *DISTH*	-0.20 (3.47)*	0.81
ln *AGE*	-0.95 (0.78)	0.38
ln *POPPRE*	-0.22 (0.36)	0.79
ln *HHS*	0.50 (0.48)	1.66
SELFHG	0.08 (0.02)	1.08
ln *SLOPE*	-1.18 (2.66)	0.30
ln *TENURE*	-0.02 (0.00)	0.97
LOCATION	-2.36 (9.14)***	0.09
ln *FARMORE*	-0.13 (0.10)	0.87
ln *INC*	0.23 (0.62)	1.26
ln *EDUC*	-0.42 (0.41)	0.65
(CONSTANT)	21.65 (5.83)**	-
% Correctly predicted	85.12	
-2log likelihood	113.68	
N	172	

* significant at $P<0.10$, ** significant at $P<0.05$, *** significant at $P<0.01$
Figures in parentheses are Wald statistics
Source: Estimates from field survey, 2000

Wealth is found to be positive and significant. Our considered inference is that wealth is conspicuous and that there is prestige for having well laid down terraces. The results also suggest financial constraint as a result of imperfect credit markets[30,31].

Slope and tenure have unexpected signs. However, they are not significant. Household size is found to be positive, although it is not significant. Nevertheless, it has the second highest effect on increasing the odds of making a decision to invest (1.66). This is an endowment for labour, which is likely to be used in terracing and also for crop production. This type of labour (own or family labour) faces very low transaction costs and most farmers fall back on it when transaction costs of outside labour are considerably high. Hired labour is expensive due to hiring, monitoring and has serious incentive problems. Moreover, this labour has a tendency to shirk[32]. However, where opportunity costs of family labour are high especially when there is plenty of well paying off-farm jobs in close proximity, the trade-off becomes complex. This is particularly true with better-educated household members, making their time have high opportunity costs.

Table 3: Level of investment (meters per acre) in Machakos and Kitui Districts, Kenya, 2000

Variable	Equation				
DEPENDENT VARIABLE	1 (TERACE)	2 (CROPAC)	3 (LAB)	4 (MAN)	5 (FERT)
(CONSTANT)	8.51	1.75	2.46	6.42	-4.49
	(1.81)**	(1.87)**	(1.62)*	(1.19)	(-1.87)**
ln *ACCESST*	-1.26		-0.13	-0.51	0.10
	(-2.38)***		(-0.69)	(-0.80)	(0.35)
ln *WEALTH*	0.92		0.17	0.57	-0.77E-01
	(2.87)***		(1.47)*	(1.46)*	(-0.44)
ln *DISTH*	-0.78E-01		-0.47E-01	-0.38E-01	0.66E-01
	(-1.26)		(-2.17)**	(-0.51)	(1.97)**
ln *AGE*	-1.83E-01		-0.29	-0.95	0.62
	(-0.12)		(-1.34)*	(-1.23)	(1.82)**
ln *POPPRE*	0.28		0.37	-0.45	-0.15
	(1.23)		(5.37)***	(-1.93)**	(-1.48)
ln *HHS*	-0.73E-01				
	(-0.18)				
SELFHG	0.43E-01				
	(0.15)				
SLOPE	-0.26E-01			0.81E-01	-0.51E-01
	(-.92E-01)			(0.22)	(-0.31)
TENURE	0.53		0.31E-01	0.11	0.28
	(0.52)		(0.91E-01)	(0.93E-01)	(0.51)
LOCATION	-1.36	0.16	0.95E-01	-0.49	-0.74
	(-3.17)***	(0.67)	(0.60)	(-0.94)	(-3.18)***
ln *FARMORE*	-0.27				
	(-1.27)				
ln *INC*	-0.48E-01		0.10	0.42	0.12
	(-0.27)		(2.30)**	(2.68)***	(1.74)**
EDUC	-0.46		-0.43	-1.13	0.64
	(-1.05)		(-2.96)***	(-2.15)**	(2.99)***
SEX	0.10			0.84	
	(0.19)			(1.33)*	
ln *LCROPAC*	0.20		0.13	-0.18	0.53E-01
	(1.61)**		(2.72)***	(-1.16)	(0.74)
ln *LAB*		2.22			
		(10.74)***			
ln *MAN*		0.43			
		(3.90)***			
ln *FERT*		0.93			
		(3.20)***			
ln *TERACE*		-0.66			
		(-3.11)***			
N	163	163	163	163	163

* significant at P<0.10, ** significant at P<0.05, *** significant at P<0.01
Figures in parentheses are t-statistics for the probabilities that respective coefficients are zero
Source: Field survey, 2000

It is also that household income is positive as expected but not significant. This is not surprising considering that returns to investment in agriculture compared to other enterprises are generally low. It does suggest that household income is not a prerequisite (i.e. driving force) for soil conservation investments but rather is facilitative. This explains some peculiar observations of rich households that have not yet terraced their farms.

Membership in a self-help group is positive although not significant. Not withstanding, self-help groups are very important in investment decisions and indeed represent social capital. This is some form of peer group pressure, which can be very helpful in investments in soil conservation. Moreover, we posit that this self-group involvement makes labour sourcing and supervision rather cheap for both terracing and crop production. This is because the owner of the farm is part of the group and is ever present. Since there are other benefits from social interaction such as risk sharing and pooling, self-help labour has less opportunistic tendencies (i.e. less incentive to shirk).

Determinants of the level of soil conservation investments: The 3SLS system of equations was estimated using Shazam Econometric Package (Table 3). The variables that directly affect terracing intensity are access time, wealth, location and lagged crop output. The indirect effect of access time through labour, manure and fertilizer use is weak. Perhaps this is linked to the low input use by many farmers and the fact that most of the labour used is family labour.

The dummy variable for location indicates that Machakos district has high level of soil conservation investment compared to that of Kitui. This shows that locational associated factors are crucial in soil conservation. The road infrastructure variable shows that a unit increase in time to the market as a result of deterioration of roads will decrease terrace investment by a factor of 1.26. This implies in effect that with the improvement of road infrastructure, we expect significant investments in soil conservation and thereby make land use in semi-arid areas sustainable. As Zaal and Oostendorp[33] argue, policy needs to consider infrastructure development that would enhance investments in the quality of land by small farmers.

Those variables that have a strong indirect effect on terracing are wealth, distance to the crop fields, population pressure, household income, education, sex and lagged crop output.

The coefficient for road infrastructure though elastic is quite close to one. This might be explained by the fact some investments may be made with the purpose of meeting subsistence requirements. This kind of investment (i.e. autonomous investment) may not be very much responsive to costs of access. Logically then, investment above the autonomous level becomes responsive to access costs (i.e. we theoretically expect elasticity of costs of access with respect to investment to be elastic above the threshold; and inelastic below the threshold). This may point that road infrastructure which is felt in the form of low prices for farm produce becomes a decision variable once the autonomous or subsistence terrace investment threshold has been reached.

Household income is found to have a weak direct effect on terracing. The strong influence is the indirect one through manure, fertilizer and labour use. The significance of household income through input use suggests the existence of imperfect credit markets[30].

The results also show that lagged crop out put directly increase terracing intensity. Indirectly, the strong effect is through manure use. Crop output which has a powerful direct and indirect feed back effect on soil conservation investments is also influenced by the state of rural roads.

Road infrastructure is thus an important factor in explaining the level of investment. Since we do not have purely subsistence production nowadays, farmers do invest with an objective of meeting household consumption requirements and for sale to obtain money to meet some other household expenditure requirements. Thus the poor the road infrastructure faced, the lower the expected returns and thus low investment in soil conservation.

Any improvements on road infrastructure can raise incomes of the poor through diverse mechanisms. Agricultural output, especially where bulky, low-value crops are involved, would benefit from the reduction in the time spent on water and firewood collection, particularly by women. Trucks can be hired to move bulk produce and fertilizer can be moved to villages and stored close to where it is needed. Improved tracks and foot paths facilitate the movement of hired farm labour to the fields. In isolated rural areas where there is great difficult in marketing produce, crops can be moved in smaller quantities by non-moterized transport if roads or paths are in good condition. Improving roads will result in better access to social services, including health clinics and increase non-agricultural, income-generating activities and travel from peri-urban to urban locations to work in services and construction in the informal sector.

Conclusions and policy implications: The results of this study show that poor and inadequate rural roads impose significant constraints towards soil conservation investments by smallholder farmers in the study region and, elsewhere in Kenya and in other parts of Africa where similar conditions prevail. Farmers faced with high farm-to-market access time invest less in soil conservation measures. An obvious policy implication is that governments in countries like Kenya whose agricultural sectors are dominated by smallholders should invest in improved rural infrastructure. However, such governments are constrained by sluggish growth, dwindling budgets and weak human and institutional capacity to afford the high costs of major rural infrastructural investments. Moreover, private sector participation may not possible with rural access roads[7].

The policy challenge therefore under high costs of provision of rural roads is to identify and catalyse innovations or measures of various kinds. Some of the measures are essentially institutional procedures that aim to reduce a range of transaction costs (e.g., enforcement, coordination and handling costs), increase financial liquidity, increase social capital and reduce risk.

Some of these measures include formation of farmers' associations[34]; trader associations[35]; industry associations comprising a number of stakeholders such as farmers, traders, manufacturers and scientists[36]; and organizations that link farm input supply with information dissemination[37]. In all these measures, active support and participation should be encouraged.

Given the high returns from improved market access in the rural areas of developing countries[17,38,39], cost-effective methods can be introduced to ensure that the existing road network is improved or even expanded. For instance, with support from government institutions and non-government organizations, rural communities can be mobilized to grade or upgrade and maintain rural access roads. Communally upgraded and maintained roads will improve farmers' marketing margins and thus higher returns in soil conservation investments. Moreover, involving communities themselves in planning local transport interventions is likely to increase the effectiveness of the services by allowing an accurate identification of bottlenecks and ensuring regular maintenance[7].

Improvement in roads and paths, especially in rural areas, have the potential to improve the position of the poor[40], although they have to be provided as part of a package of measures that include credit, extension services and investments in areas such as irrigation and water.

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