Factors influencing adoption of soil conservation technologies in Tanzania: a case study in Gairo

H.M.M. Kalineza[1], N.S.Y. Mdoe[2] and M.R.S. Mlozi[1]
[1]Department of Agricultural Education and Extension
[2]Department of Agricultural Economics and Agribusiness
Sokoine University of Agriculture

Abstract

Factors that influence smallholder farmers' decision to adopt soil conservation practices were analysed using descriptive statistics and logistic regression model. Data for the study were collected from 114 randomly selected households from four villages in Gairo division. The results of descriptive analysis suggest that technology related factors such as labour requirement and perceived technology benefits influence the adoption of soil conservation practices. Results of the logistic analysis suggest that farmers who obtained knowledge on soil conservation through extension/training seminars as well as those with secure land ownership are likely to adopt soil conservation technologies. Two broad policy implications emerge from the findings of this study. The first implication is that there is a need to provide extension education that demonstrates relative benefits of various land conservation technologies to stimulate their adoption. The second implication which emerge from the significance of land ownership in adoption of soil conservation practices is the need for a clear land policy that provides rights of owning land among smallholder farmers. Secure land rights will promote investments on land such as adoption of soil conservation practices.

Keywords: Adoption, soil conservation technologies, logistic, socio-economic characteristics

Introduction

Environmental problems related to agricultural and rural development have been a major concern in Tanzania and elsewhere in developing countries. One major issue is soil erosion in smallholder farms. Since 1940s, a number of policy instruments have been used in an attempt to control or mitigate soil erosion in rural areas. On the Uluguru

Mountains, the colonial government declared about 277 square Kilometres as a reserve forest in 1909 (Temple, 1977a cited by Magayane, 1994). In the 1930s the problem of soil erosion was not an issue limited to Uluguru Mountains only but to the entire territory (Kauzeni *et al.*, 1987). Among the areas noted to have problems were also the drier parts of Ugogo, Unyaturu and South Eastern Usukuma (Gillman, 1930, cited by Kauzeni *et al.*, 1987). In 1931, a committee on soil erosion under the chairmanship of the Director of Amani Research Station estimated that about one thirtieth of the area of Tanganyika Territory was being threatened by soil erosion (Jacks and Whyte, 1939). Due to inadequate funds for large-scale soil conservation work, the committee recommended the use of coercive measures and demonstration of methods and approaches of arresting soil erosion. The major soil conservation measures applied in the 1940s were ridges, contours, banking of cultivated land, gully control, rotational grazing and re-afforestation. During this period, several reasons contributed to the failure of soil conservation measures. First, the authorities capitalized on using rules towards natives only and this, made people develop negative attitude towards their

Second, soil conservation activities were sometimes carried out as punishment for disobeying local chiefs or poll tax evasion, thereby making them unpopular. Third, the colonial administrators did not appreciate the fact that some groups had adapted their own agricultural systems which controlled soil erosion (Mbegu and Mlenge, 1983 cited by Lundgren *et al.*, 1993; Reij, 1991).

After independence, many soil conservation measures were abandoned. This led to serious land degradation reaching advanced stage in the first decade after independence (Kauzeni *et al.*, 1987). In the 1970s soil conservation resumed under the auspices of the government and international aid agencies (Lundgren *et al.*, 1993). In the 1970s through 1980s various projects with soil conservation components were established in different parts of the country. Notable examples include Hifadhi Ardhi Dodoma (HADO), Soil Erosion Control and Agroforestry Project (SECAP) in Lushoto, Hifadhi Mazingira (HIMA) in Njombe, Iringa and Makete Districts and Hifadhi Ardhi Shinyanga (HASHI) in Shinyanga, Soil Conservation and Agroforestry Project Arusha (SCAPA) in Arusha, and Gairo Agroforestry and Land Use Project (GALUP).

This study is concerned with soil conservation issues in Gairo division. Apart from GALUP other organizations have been involved in one way or another in soil conservation in Gairo division. These include; Sokoine University of Agriculture (SUA), Agriculture and Livestock Research Institutes under the Ministry of Agriculture and Cooperatives (MAC) and the Anglican Church. However, GALUP played a major role in terms of area of coverage, number of staff involved, funding and duration. The project became operational in 1991 with funding from the Irish Government and operated under Kilosa District Council (KDC). The overall aim of the project was to develop capacity at the village level for smallholder farmers to manage their resources sustainably and in a sound manner (Mndeme, 1997). The project activities were centred in parts of the division with severe land degradation as evidenced by degree of soil erosion and absence of dense vegetation particularly large trees. GALUP has been phased out and its activities taken over by Kilosa Environmental Project (KEP) which covers the whole of Kilosa District.

Given the seriousness of soil erosion problem in Gairo and elsewhere in Tanzania as well as lessons learned from failure of conservation measures during the colonial period, soil conservation strategies should aim at achieving widespread tangible results. In this regard there is an obvious need to understand the relative importance of factors which may influence an individual farmer to adopt conservation practices. Findings of the few adoption studies carried out in some parts of Tanzania emphasize the importance of understanding socio-economic characteristic of smallholder farmers in influencing adoption of soil and water conservation measures in the country (Kangalawe, 1995;; Ryoba, 1996; Robberstad, 1997; Semgalawe, 1998; Senkondo et al., 1998).

The objective of this paper is to identify socio-economic factors which influence adoption of soil conservation techniques geared towards increasing agricultural productivity in Gairo division of Morogoro region, Tanzania. The specific techniques investigated in this study are the use of contour ridges, tree planting practices and use of cow dung manure.

Methodology

Analytical framework

The decision to adopt or not to adopt a particular soil conservation measure is a binary decision that can be analysed using binary choice models. The conceptual framework is to build a model that allows

the prediction of how a particular economic agent with given attributes will decide. The objective of such a model is to determine the probability of the economic agent making one choice rather than the alternative. In this study the assumption is that the individual smallholder farmer is considered either to adopt a particular soil conservation practice or not. Three types of models have been proposed in econometric literature for estimating binary choice models: probit, logit and linear probability models. Feder *et al.* (1982) provides a comprehensive review of empirical studies of adoption using these types of models. Several applications of qualitative choice models have also been reported in the literature (Polson and Spencer, 1991; Adesina and Zinnah, 1993; Adesina and Baidu-Forson, 1995). Of the three choice models, probit and logit models usually give similar results for most problems and it is difficult to distinguish them statistically (Amemiya, 1981). The basic difference between the two models is that logit assumes that the dependent variable follows a logistic distribution while the probit model assumes a cumulative normal distribution. Thus, the choice between probit and logit model comes down to convenience (Hanushek and Jackson, 1977; Maddala, 1989)

In this study a logistic regression procedure using maximum likelihood estimation was used to estimate the probability of a soil conservation practice being used (Kmenta, 1986). The Statistical Package for Social Sciences (SPSS) was used in the estimation of the model (Norusis, 1993). The estimated model is expressed as follows:

$$\text{Ln}\,(P/(1-P)) = \beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_2X_4+\beta_5X_5+\beta_6X_6+\beta_7X_7+\beta_8X_8+e$$

Where:
X_1 = Age of household head (years)
X_2 = level of formal education of household head (years)
X_3 = Number of adults in the household available for farm work
X_4 = Farm size (acres)
X_5 = extension education, dummy variable.
X_6 = Ownership of land, dummy variable
X_7 = Number of cattle owned
e = disturbance term
β_i = coefficients of the independent variables in the adoption equation

The dependent variable is the natural log of the probability of adopting a soil conservation measure (p) divided by the probability of not adopting (1-P). The dependent variable takes the value 1 for adopting and 0 for not adopting.

The model was estimated for three most common soil conservation practices recommended by GALUP: contour ridges, tree planting and use of farm yard manure. These three soil conservation practices were separately used as dependent variables. The first six independent variables were included in all three adoption equations but the seventh variable, number of cattle owned was only included in the use of manure adoption equation.

The formation of the three adoption models was influenced by a number of working hypotheses. Farmers' age can increase as well as decrease the probability of adoption of technologies. Older farmers may have more experience that allows them to adopt improved technologies, while young farmers might be less risk-averse and therefore more willing to adopt improved technologies. Shiferaw and Holden (1998) contend that young farmers may have little experience in farming to be aware of a soil erosion problem, but they are more likely to adopt conservation practices once they perceive the problem. Age, therefore, may positively or negatively influence adoption of soil conservation technologies. Formal education is expected to increase farmers' ability to obtain, process, and use information relevant to the adoption of

conservation technologies. Hence, formal education is hypothesised to positively influence the decision of farmers to adopt improved soil conservation technologies.

The number of adults who can work in the farm is an indication of the availability of labour for conservation works and is therefore hypothesised to positively influence adoption of improved conservation practices. Farm size may positively or negatively influence adoption of soil conservation practices. Farmers with small farm sizes are likely to adopt soil conservation measures as a means of preventing soil erosion from reducing their area of operation. Farmers are also likely to adopt soil conservation measures only where they perceive a higher soil erosion problem. The larger the area of holding where they perceive a soil erosion problem, the higher the likelihood that they would adopt soil conservation practices. Availability of information through extension/training seminars is necessary for a farmer to be aware of the new technologies as well as how to use them. Extension education is therefore hypothesised to positively influence the decision of farmers to adopt recommended soil conservation practices. Land tenure has been found by other researchers to have significant influence on farmers' decisions to adopt soil conservation measures (Siden and King, 1990). Farmers with secure land ownership are more likely to adopt soil conservation measures than farmers with insecure land tenure arrangement.

Data collection

Field survey was conducted in Gairo division from March to May1 999. The survey covered 114 farmers randomly selected from 4 purposively selected villages covered by the Gairo Agroforestry and Land Use Project (GALUP). Data from the farmers were collected using structured questionnaire by soliciting information on socio-economic characteristics of the farmers, land tenure, livestock ownership, extension advice received, training seminars attended, soil conservation measures practised, labour demand and costs incurred in the conservation practises.

Results and Discussion

The average age of household heads was 41 years with a minimum of 18 years and a maximum of 76 years. Sample households had on average about three adults who were able to work on the farm. Adults were defined as members in the household with an age of 16 years and above. Average household size was six persons per household with a minimum of one person and a maximum of 22 persons (Table 1). On average adult members working on the farm comprise of 47% of the total household members. Almost 77% of the household heads had elementary formal education (up to seven years of schooling) while 22% of the household heads had no formal education. On average the household heads had about 4 years of education. Land owned by most of the surveyed households (64%) was inherited from their ancestors while 32% rented land. Mean farm size was 7.3 acres with a minimum of one acre and a maximum of 22 acres. Forty one percent of the households owned livestock (cattle, goats or sheep). Mean number of cattle and small stock (goats and sheep) per household was 2.3 and 1.9, respectively (Table 1). Off-farm activities are also an important source of income with 66% of the surveyed households obtaining off-farm income in 1998. Major off-farm activities were petty trade, wage employment and sale of forest products such as honey and timber.

Table 1 Socio-economic characteristics of surveyed households

	Average	Minimum	Maximum	Standard deviation
Age of Household head (years)	41.5	18.0	76.0	12.6
No. of adult members working on the farm (persons)	3.0	1.0	10.0	1.7
Household size (persons)	6.4	1.0	22.0	3.0
Education (years)	4.3	0.0	12.0	2.7
Farm size (acres)	7.3	1.0	42.0	5.8
No. of cattle owned	2.3	0.0	40.0	5.7
No. of small stock owned (goat & sheep)	1.9	0.0	30.0	2.6

The socio-economic characteristics of the households discussed above have important implications for agricultural production in the study area, particularly for the adoption of technologies that require human, financial and other physical resources necessary for increasing agricultural productivity.

Soil conservation measures promoted by the Gairo Agroforestry and Land Use Project (GALUP) to sustain land productivity include establishment of contour ridges on steep slopes, tree planting and other environmental friendly crop and livestock management practices such as use of farmyard manure. Table 2 shows the percentage of the surveyed farmers who adopted contour ridges, tree planting and use of manure in their farms.

Table 2 Distribution of surveyed farmers by soil conservation practice

Soil conservation practice	Number practising	% practising
Contour ridges	14	12.3
Tree planting	52	45.6
Use of farmyard manure	27	23.7

Contour ridges traditionally known as *makinga maji* seem to be the least popular soil conservation practice. Almost all the surveyed farmers with farms on flat land did not establish contour ridges. These are useful on hilly land to control run off and soil erosion. About 50% of the surveyed farmers who had farms on hilly land did establish contour ridges. Those who did not have contour ridges on hilly land indicated that the practice was relatively high labour demanding.

Tree planting was the most popular soil and water conservation practice in the study area. Farmers planted trees around their homesteads, on farm boundary and on cropland. Trees considered contributing to soil and water conservation were those planted on farm boundary and on cropland. Most farmers who planted trees on cropland for the purpose of controlling soil erosion planted them as contour vegetation strips. Apart from soil and water conservation trees are used for fuelwood and building poles. Use of farmyard manure has been promoted by GALUP in order to restore soil fertility and improve soil structure. Soil with firmly bound soil particles is less erodible than soil with loosely bound particles.

Twenty four percent of the surveyed farmers applied farmyard manure in their farms. Those who did not use farmyard manure in their farms cited long distance to travel to their farms and difficulties in terms of handling. Some respondents associated use of farmyard manure with rapid weed growth and higher incidence of cut worms (*Agrotis sp*) in the

Rapid weed growth increases farm labour requirements for weeding.

The results of the three logistic models of the decision to practice the three soil conservation practices are presented in Table 3. In each case the goodness-of-fit statistics for the models with all the independent variables are adequate. The high likelihood of the observed results indicates that the models are reliable and the classification results show that overall, 87.72%, 81.40% and 86.32% of the cases were correctly classified in the contour ridges, tree planting and farmyard manure adoption models respectively, suggesting that the models fit the data well.

Two out of the seven variables hypothesized to influence adoption of soil conservation practices recommended by GALUP have significant coefficients. These are extension education and land tenure. Extension education has significant coefficients in all the three adoption models whereas land ownership has significant coefficients in two models (Table 3). Extension education is expected to create awareness and enhance diffusion of information on available technological options for soil conservation. The Ministry of Agriculture and Co-operatives offers extension education to smallholder farmers through village extension officers. GALUP also conducted training seminars on soil conservation techniques, which also create awareness among smallholder farmers in the study area. The results of this study suggest that extension education have significant effect on the adoption of soil conservation practices. As expected, extension education positively influenced adoption of the soil conservation practices. This finding is similar to the finding in Western Pare Lowlands of Tanzania that the extent of knowledge in rain water harvesting has a positive significant effect on the probability of adoption of rain water harvesting technologies (Senkondo et al., 1998). Other researchers elsewhere in developing countries have also provided evidence on the significance of extension education on the probability of adoption of improved agricultural technologies (Jaminson and Moock, 1984, Baidu-Forson, 1999). This evidence supports the innovation diffusion model as pointed out in earlier works of Rodgers (1983), that information about the technology is the key factor in determining adoption.

Land ownership significantly influences the probability of adoption of contour ridges and use of farmyard manure This supports the research finding that availability of

Table 3 Parameter estimates of logistic models of factors influencing the decision to adopt soil conservation practices in Gairo

Explanatory variable	Contour ridges Parameter estimate β (Wald-statistic)	Tree planting Parameter estimate β (Wald-statistic)	Farmyard manure Parameter estimate β (Wald-statistic)
Constant	-6.29 (4.62)**	-1.02 (0.45)	-1.95 (0.75)
Age of household head (years)	0.06 (2.48)	0.01 (0.46)	0.01 (0.12)
Education of household head (years)	0.28 (2.33)	0.07 (0.65)	0.24 (1.57)
Number of adults able to work	0.23 (0.88)	0.22 (2.10)	0.23 (1.8)
Farm size (acres)	0.04 (0.51)	0.02 (0.14)	0.05 (1.51)
Ownership of land	0.81 (3.87)***	0.12 (0.68)	0.33 (3.06)***
Awareness of soil degradation and conservation measures	1.50 (5.16)**	1.26 (4.25)**	1.15 (3.57)***
Livestock ownership	-	-	0.53 (1.02)
-2 log likelihood	70.99	143.11	104.81
Model Chi-square	13.94***	14.05***	20.00*
Overall cases correctly predicted	87.72	81.40	86.32
Sample size (n)	114	114	114

Note *** = significant at p<0.1 ** = significant at p<0.05 * = significant at p<0.01

security of land tenure increases the adoption of land improvement practices (Feder and Onchan, 1987). However, the results in Table 3 show that land ownership does not significantly influence the probability of planting trees. The implication of this finding is that land tenure is less important to smallholder farmers in Gairo in their decision to plant trees for conserving soil. This may be partly due to the fact that trees planted for conservation purposes can be cut for fuelwood and building poles.

Factors such as age, formal education, number of adults able to work, farm size and off-farm income do not appear to be significant determinants of the adoption of any of the three conservation practices. Ownership of cattle, which is only included in the farmyard manure adoption model, also has no significance in explaining variation in use of manure. Although the sign of coefficients of these variables are as expected, the fact that they are insignificant seem to suggest that household characteristics (age, formal education, number of adults able to work, off-farm income, ownership of livestock) and land characteristics (farm size) have little effect on farmers decision to adopt soil conservation practices.

Conclusions

Results of descriptive analyses suggest that technology related factors such as labour requirement have an influence in the adoption of soil conservation practices. Tree planting was the most popular soil conservation practice not only because of relatively low labour demand but also because trees have multipurpose use. This suggests that soil conservation technologies with greater benefits as perceived by farmers are more likely to be adopted. The results of the logistic analysis suggest that farmers with knowledge on soil conservation through extension education as well as those with secure land tenure are likely to adopt soil conservation technologies. Two broad implications emerge from these findings. The first broad implication is that is a need to provide extension education support to promote adoption of improved soil conservation technologies through the provision of knowledge and skills to smallholder farmers. The second broad implication is the need for clear land policy that provides rights of owning land among smallholder farmers. Secure land rights will promote investments on land such as adoption of soil conservation practices. The new land act of 1999, which is yet to be implemented, is a positive move towards that direction.

Acknowledgements

The authors gratefully acknowledge financial support for data collection provided by the National Extension Programme (NAEP II) of the Ministry of Agriculture and Farm- Level Applied Research Methods in Eastern and Southern Africa (FARMESA) of FAO and SIDA.

References

Adesina, A A. and Baidu-Forson, J. 1995. Farmer perceptions and adoption of new agricultural technology: Evidence for analysis in Burkina Faso and Guinea, West Africa. Agricultural Economics, 13: 1-9.

Adesina, A.A and Zinnah, M.M. 1993. Technology characteristics,farmer perceptions and adoption decisions: A tobit model application in Sierra Leone. Agricultural Economics 9: 297-311.

Amemiya, T .1981. Qualitative response models: a survey. Journal of Economic Literature 19: 1483-1536.

Baidu-Forson, J. 1999. Factors influencing adoption of land-enhancing technology in Sahel: Lesson from a case study in Niger. Agricultural Economics20 ( ): 231-139.

Feder, G; Just, R.E and Ziberman, D.1982. Adoption of improved innovations in developing countries: A survey. Economic Development and Cultural Change., 33: 255-298.

Hanushek, E.A and Jackson, J.E . 1977.Statistical Methods for Social Scientists. Academic Press, New York.

Jaminson, D. and Moock, P.R. 1984. Farmer education and fertilizer use efficiency in Nepal: The role of schooling, extension services and cognitive skills. World Development 12: 67-86.

Jacks, G.V. and Whyte, R.O. 1939. *The Rape of the Earth* Faber and Faber Ltd. London. pp. 312.

Kangalawe, R. 1995. Fighting Soil Degradation in the KEA, Kondoa District, Tanzania: Socio-Economic Attributes, Farmer Perception and Nutrient Balance Assessment. MSc Thesis Agricultural University of Norway. pp 128.

Kmenta, J. 1986. Elements of econometrics (2nd edition). Macmillan, New York.

Kauzeni, A.S. Kikula, I.S. and Shishira, E.K. 1987. Developments inSoil Conservation in Tanzania, In: *History of Soil Conservation in the SADCC Region.* Soil and Water Conservation and Land Utilization Programme Report No. 8 March, 1987. Maseru, Lesotho. pp 22.Lundgren, L. Taylor, G. and Ingevball, A.1993. *From Soil Conservation to Land Husbandry* Guidelines Based SIDA's Experience. SIDANairobi. pp 58.

Maddala, G.S. 1989. Introduction to Econometrics. MacMillan Publishing Company, New York.

Magayane, F.T. 1995. Farmers' Adaptive Effort to Soil Erosion and Land Productivity Decline: The Case of UluguruMountains, Tanzania PhD Thesis. University of IllinoisatUrbana-Champaign. 1995pp139.Mndeme, A.H. 1997. A Multidisciplinary Approach toExtension Services: The GALUP Experience. In: *Proceedings of a Workshop forExtension Officers* (Edited by Isinika, A.C., Kawa, I.H. and Neke, S.M.). 14-15 August,1997. Morogoro, Tanzania.

Norusis, M.J. 1993. SPSS for Windows: Advanced Statistics, Release 6.0. SPSS Inc., Chicago, III.

Polson, R.A and Spencer, D.S.C.1991.The technology adoption process in subsistence agriculture: The case of cassavain Southwestern Nigeria. Agricultural Systems, 2: 65-78.

Robberstad, B. 1997. Time, toil and soil: A study of time preferences and soil conservation in KaratuNorth Tanzania. MSc, Thesis,Agricultural University of Norway. pp. 215

Rodgers, E.M. 1983. Diffusion of innovations. Free Press, Glencoe.

Ryoba, Z.M. 1996. An Assessment onthe Use of Indigenous Soil and Water ManagementTechnologies in Semi-Arid Areas: The Case of Mwanga-District in Tanzania. MSc thesis Sokoine University of Agriculture. pp 174.

Semgalawe, Z.M. 1997. Household adoption behaviour and agricultural sustainability in the Northern Mountains of Tanzania: The case of soil conservation in the North Pare and West Usambara Mountains. PhD. thesis, Wageningen Agricultural University. pp. 189.

Senkondo, E.M.M.; Mdoe, N.S.Y.; Hatibu, N.; Mahoo, H. and Gowing, J. 1998. Factors affecting the adoption of rain-water harvesting technologies in Weatern Pare lowlands of Tanzania. Tanzania Journal of Agricultural Sciences, 1 (1): 81-89.

Siden, J. and King, D.A. 1990. Adoption of soil conservation measures in Manila Shire, New South Wales. Review of Marketing and Agricultural Economics 58: 179-192.

United Republic of Tanzania (URT). 1999. Land Act (No. 4 of 1999). Gazette of the United Republic of Tanzania Vol.