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A Binomial Logit Analysis of Factors Affecting Adoption of Soil Conservation Structures in Kericho County, Kenya

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Abstract
Kericho is one of the forty-seven counties of Kenya and one that is characterized with steep areas prone to soil erosion. A number of organizations have for a long time promoted soil conservation technologies in soil erosion prone parts of Kenya. The paper provides findings of a study carried out to analyze the factors affecting adoption of the various soil conservation technologies by farmers. Cross sectional data was collected from respondents who were selected using multistage sampling procedure. Data was collected from a random sample of 115 farmers in Kericho County. Questionnaires were used to collect primary data from selected households. The binomial logit models were used to analyze the factors believed to affect adoption of the selected soil conservation technologies. Most of the variables postulated to affect the promoted soil conservation practices were found to be statistically significant in determining adoption of the promoted soil conservation technologies. Based on the study findings, it can be said that economic, social and cultural factors are important in soil conservation promotion strategies and should be considered in implementation and sustainable use of soil conservation technology. Soil conservation and other environmental conservation efforts are controversial issues that politicians rarely talk about in political rallies. Since politicians hold a high position in the eyes of farmers, they should be encouraged to support environmental conservation through championing soil conservation support efforts.
Keywords: Binomial Logit, Factors, Adoption, Soil Conservation.
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1.0 Introduction

Agriculture is considered the backbone of Kenya's economy contributing about 26% of GDP, and another 27% of GDP is indirectly through linkage with other sectors. The sector employs 40% of total population and more than 70% of Kenya's rural population (UNEP, 2015; Barmao & Tarus, 2019; FAO, 2021). Soil erosion is a threat to sustainable food production in agriculture-based poor economies (Hijbeek et al., 2021; Pimentel & Burgess, 2013). This is because it is prevalent in high agricultural potential areas. The high agricultural potential areas are associated with factors contributing to soil erosion that include steep rugged terrain and high rainfall regimes. The most important on-farm effect of soil erosion is loss in agricultural productivity. Off farm effects of soil erosion include deposition of infertile sediments on productive land, downstream flooding, water pollution and siltation of waterways. Loss of hydroelectric power generation capacity is associated with water ways sedimentation.

The need for soil conservation in Kenya was recognized in 1930. Soil conservation during the colonial period (1930 to 1963) was achieved by coercion but most farmers did not understand the need for soil conservation as few of them related it to improvement in crop yields. Coercive implementation of soil conservation practices has for a long time been considered as a symbol of Kenya's colonial legacy and oppression (Branch, 2010). Currently adoption of soil conservation technologies is low calling for the need to study the factors affecting adoption of the promoted technologies.

The study was carried out in Kericho County. Kericho slopes to the west with many rivers and streams flowing westwards. The climate is highland sub-tropical with high and well distributed (except for the short dry season in January and February) rainfall. The mean annual rainfall in the County ranged between 1000 mm and 1600 mm. West Mau Forest, Kipkelion and Londiani received highest mean annual rainfall of 1660, 1390 and 1250 mm respectively. The County's agro- Ecological Zones consist of four main agro-ecological zones; Upper Highland Zone, Lower Highland Zone; Upper Midland Zone and Lower Midland Zone. Kericho is a major agricultural zone producing both subsistence and cash crops (tea, coffee, pyrethrum, maize and sugarcane). It contributed to pollution of waterways because of its rugged terrain thus soil erosion. It was also associated with high agrochemicals use mainly in production of cash crops. The downstream effect of degradation in water quality was evident in Lake Victoria where the emergence of water hyacinth gave an indication of eutrophication.

Soil conservation technologies promoted in the area included contour plowing, minimum tillage, grass and unplowed strips, strip cropping, agroforestry, vegetative barriers and physical structures such as terraces, drainage ditches, river bank dykes, plain ridging, gabions weirs and stone lines. Organizations like LBDA, KEFRI, KARI, ICRISAT, SIDA, LVEMP and CREPP had done a lot of research and generated a wealth of information on various aspects of soil and water conservation in the study area. Government of Kenya (GoK) complemented research efforts with trained agricultural extension service providers that gave the support needed in the promotion of soil conservation technologies in farmers' fields.

Reviewed literature on soil conservation in Kericho indicated that experience and technical knowledge to provide technical solutions to soil degradation in the study area was available but adoption of soil conservation was low. The study aimed at determining and analyzing factors that affect farmers' choice of soil conservation technologies in the study area. The objective of the study was to determine the effect of farm, farmer and technology characteristics on adoption of soil conservation practices in the study area. The study was restricted to four technologies namely: terracing; unploughed strips; grass strips and; stone lines due to the prevalence of the technologies in the study area. The null hypothesis tested in this study was: farm, farmer and technology characteristics; socio-economic; cultural and; biophysical factors had no significant effects on adoption of the selected promoted soil conservation technologies in the study area.

2.0 Methodology

2.1 Sample Frame

The sample frame was that of selected farmers who lived in the selected divisions where soil conservation was promoted due to being soil erosion prone. The sample frame also consisted of farmers who lived and owned land in soil conservation catchment areas.

2.2 Sampling Procedure

Simple random sampling was used to identify study respondents. Numbers were assigned to farmers in selected soil erosion prone divisions. Random numbers were used to select farmers from each division. Farmers were randomly selected to provide data needed to analyze factors affecting decisions to adopt soil conservation practices.

2.3 Sample Size

A total of 115 respondents were selected for the study. The randomly selected farmers provided data needed for analysis of factors affecting adoption of the selected soil conservation technologies.

2.4 Data Collection Tools

Questionnaires used to collect data were pre-tested with a random sample of 12 farmers in Ainamoi Division, Kericho County. Trained enumerators conversant with farmers' local language and customs orally obtained data from respondents and filled the questionnaires.

2.5 Types and Sources Data Collected

Primary data was obtained from respondents and included whether or not a farmer was adopter of studied technology, access to credit, frequency of extension visits, household income, availability of labor, age, education level and sex of head of household, farm size, security of tenure, cultural factors like attitude towards protection of cultural sites, resource endowments (physical assets, human, financial and social capital), land tenure system, group membership, social capital and biophysical features of the farm.

According to Nelson et al. (2014), Saeedifar & Asgari (2015), Van Meijl et al. (2018) and Gill et al. (2018) biophysical features include climate, biological, physical and chemical features of soil, topography, altitude, temperature and biodiversity. The variable biophysical features took a value of "3" if erosion problem was severe and if unique features of the farm existed, "2" if erosion problem was moderate and "1" if erosion was not a problem. Adesina *et al*. (2002) used severity of erosion problem as proxies for biophysical features to study the effect of biophysical features on adoption of alley cropping. Their classification was "1" for high erosion, "2" for minor and "3" for no erosion problem.

2.6 Data Analysis

The dependent variable in Binomial Logit model is log odds of making a choice and the estimation procedure is the Maximum Likelihood Estimation (MLE). MLE of a parameter (a) is the value of estimate ($\hat{a}$) for which observed probability of the sample data (Y_i) takes its greatest value. For a particular sampling model the sample data is substituted into the probability function and the probability is considered a function of the unknown parameter value a. The probability is defined for all the potential values of a, namely the values between 0 and 1 and the probability first choice is made equal to one minus probability second choice is made (Cameron & Trivedi, 2005; Nkamleu & Manyong, 2005; Withers, 2009). The likelihood function is specified as:

$L = \text{Prob.}(Y_1)\ \text{Prob.}(Y_2)\ \text{Prob.}(Y_3) \ldots \text{Prob.}(Y_n)$.

Y is a dummy variable indicating the critical cut off value that translates the underlying index into a decision equal to 1 when first category is chosen and 0 when second category is chosen. Variance of logistic distribution is given as $\prod^2/3$ (Ghosh, 1991). In this study the choice is binary (technology adoption that will take value of 1 and non-adoption which will take value of 0). Data was analyzed using regression of Binomial Logit models and was computed using Statistical Package for Social Sciences (SPSS) software.

Multicollinearity in the pairs of explanatory variables in the Logit models was assessed by computing Pearson correlation test of coefficients. Multicollinearity was considered serious when Pearson correlation was at least 0.5. A backward stepwise elimination procedure was used in determining variables to be retained in the binomial Logit models. Initially 15 variables were entered into the Logit models. Moderate multicollinearity was detected between some independent variables and the variables were placed and replaced in turns. At each step, the model was evaluated using goodness of fit measures and the log likelihood predictions. After the elimination procedure, 10 exogenous variables were retained and their effects on adoption analyzed in the binomial Logit models.

3.0 Results and Discussions

Presented below are the results of the regressions of Binomial Logit models of factors hypothesized to affect adoption of the four selected soil conservation technologies.

Table 1: Presentation of the Binomial Logit Regression Analyses Summary Results

Variable	**Regression Coefficients and Test Statistics for Analyzed Technologies**			
	Grass Strips	Terracing	Unploughed Strips	Stone Lines
Age of Decision-Maker	-0.04 (0.03) [0.17]	-0.05** (0.02) [0.04]	0.03 (0.03) [0.36]	-0.31 (0.67) [0.65]
Decision maker's level of education	0.14 (0.82) [0.86]	0.03 (0.18) [0.87]	2.70*** (0.67) [0.01]	0.88** (0.46) [0.03]
Farm size	-1.93** (0.60) [0.02]	-1.03** (0.40) [0.03]	-1.23** (0.82) [0.17]	-0.87 (0.66) [0.19]
Income of household	0.28 (0.52) [0.43]	0.67** (0.34) [0.05]	0.32 (0.53) [0.54]	1.89** (0.88) [0.03]
Size of household	0.04 (0.24) [0.87]	0.38 (0.49) [0.44]	0.08 (0.23) [0.73]	0.01 (0.03) [0.74]
Sex of head of household	1.11 (0.89) [0.21]	0.22 (0.70) [0.75]	-2.37** (1.11) [0.03]	1.73* (0.93) [0.09]
Frequency of extension visits	0.19** (0.61) [0.02]	1.87** (0.87) [0.03]	-1.66* (0.93) [0.07]	0.18 (0.90) [0.84]
Biophysical features of the farm	1.42* (0.74) [0.06]	1.73* (0.93) [0.06]	2.28*** (0.91) [0.01]	1.11* (0.64) [0.08]
Security of Tenure	0.15 (0.36) [0.68]	3.26 (0.60) [0.70]	0.08 (0.23) [0.73]	0.89 (0.50) [0.17]
Perception of profitability of technology	0.14 (0.70) [0.84]	1.72* (0.98) [0.08]	2.27*** (0.69) [0.00]	0.18 (0.90) [0.84]
Constant	-2.71 (2.05) [0.20]	2.29 (1.67) [0.19]	5.04** (2.39) [0.04]	-1.52 (1.93) [0.43]

* Significant at 10% , ** Significant at 5%, *** Significant at 1% levels of significance

-Brackets () contain standard errors, [] parenthesis show coefficient levels of significance

As shown in table above the effects of age, number of extension visits and farm size on adoption of terracing were significant at 5% level. Perception of profitability and farm biophysical features were significant at 10% level. The effects of perception about profitability, biophysical features of farm and education level of household decision-maker on adoption of unploughed strips were significant at 1% level while effects of sex of decision maker and frequency of extension visits on adoption of unploughed strips were significant at 5% and 10% respectively. Effect of frequency of extension visits and farm size on adoption of grass strips were significant at 5%. The effect of biophysical features of farm on adoption of stone lines was significant at 10% level. Effects of income and education level of decision-maker were significant at 5% level.

Age of decision maker negatively affected adoption of terracing, grass strips and stone lines and positively affected adoption of unploughed strips. The effect of age was significant at 95% level for only terracing whose high labor demands tended to exclude most of the older decision makers. The negative effect of age on adoption of grass strips, terracing, and stone lines could be because of the fact that younger farmers other than being energetic better understood the need for conservation than older decision makers who tended to be less innovative and had shorter planning horizons and higher risk aversion arising from fearing the uncertain old age futures.

The effect level of formal education of decision-maker on adoption of all analyzed soil conservation technologies was positive. The effect was significant at 99% level for unploughed strips and 95% level for stone lines. The effect can be explained by fact that it takes educated farmers to consider using the two technologies to control soil erosion. This is because education increases the ability to decode, understand, learn from experience Asafu-Adjaye (2008) Udayakumara et al. (2010) and Takahashi et al. (2020) and plays the critical role of changing farmers' perception and awareness of erosion problems and improves farmers' decision-making capabilities. Education positively correlated with adoption as education raised awareness on need to conserve soil. Educated farmers most likely incorporated soil conservation into their farm operations as they understood that soil conservation reduced the rate of soil and plant nutrient loss arising from soil erosion. Non- adopters recognized erosion symptoms but associated them to factors such as high rainfall and steep slopes and not to their own land use and farm management practices. Some farmers could not recognize the negative impacts of soil erosion while others saw no role they could play to reduce soil erosion as they viewed land degradation as an act of God.

Farm Size negatively affected adoption of all analyzed technologies. The effect was however not significant at 95% level for stone lines. As farms become smaller and intensification occurs, there is more incentive to conserve declining resource base by adopting more of the recommended soil conservation practices. Due to high population pressure in the study area there was land fragmentation and farm sizes averaged 1.5 ha/ household. The effect of farm size on adoption of grass strips, terracing and unploughed strips was significant probably because of features of the soil conservation measures. Eroded soil trapped in terraces needs to be removed while grass strips need weeding and annual maintenance. Unploughed strips are likely to be adopted by farmers who are not land constrained as the opportunity cost of land that was left as unploughed strip was likely to be higher for farmers who have smaller parcels of land.

Income positively affected adoption of all considered technologies. The effect was significant at 95% level for adoption of only terracing and stone lines probably because income increased farmers' ability to employ the labor intensive technologies. Relatively poor land owners had a tendency to neglect conservation practices as they lacked the capital to establish and maintain the technologies, mainly terracing and stone lines. Economic constraints or factor endowment model assumes that distribution of resources among potential users in an area determines the pattern of adoption of any technology. Income have the potential of increasing household liquidity, freeing up some resources for soil conservation investment. Since credit markets are not efficient in Kenya, adoption of conservation measures was limited by farmers' ability to finance the required investments. Household income was thus important as sustainable soil conservation technologies such as terracing and stones lines were considered highly labor and capital intensive.

Male headed households tended to adopt stone lines, grass strips and terracing while female decision-makers tended to adopt unploughed strips. The effect was only significant at 95% level for unploughed strips. Most household in the study area were headed by males. Conservation activities conflicted with women's family chores. Men and youths were more active in soil conservation. Cultural practices dictated the technologies adopted by women and were more likely to be those that are less labor intensive, sustainable and cheaper to set up. Men headed households adopted labor intensive technologies such as "*fanya juu*" and "*fanya chini*" terraces.

Frequency of extension visits positively affected adoption of stone lines, grass strips and terracing while frequency of extension visits negatively affected adoption of unploughed strips. The effect was significant at 95% level for only grass strips and terracing. Extension visits, though usually associated with positive effect on adoption of new technologies, did not have the same effect on adoption of unploughed strips in this study. This could be explained by the fact that adoption of unploughed strips did not need a lot of skill. The positive correlation between frequency of extension visits and adoption of terracing, stone lines and grass strips was expected because agricultural extension is known to be a traditional way of transmitting new information and technology to relevant users, especially in agriculture. Apart from providing farmers with information on how to set up soil conservation structures, agricultural extension agents played a big role in decision-making on types of conservation measures to establish in farmer's fields. The extent of farmers' participation in conservation activities was dependent on quality and frequency of extension services provided to the farmers. The low extension agent to farmer ratio in the area could explain the fact that frequency of extension visits was not significant as the low number limited the number of visits to farmer's fields. Past and present support of conservation effort has developed a "dependency syndrome" among farmers and farmers felt it was the duty of government to provide soil conservation tools and equipment and to finance soil conservation.

The effect of biophysical features of the farm on adoption of all the targeted soil conservation technologies was positive but only significant at 99% unploughed strips. Stone lines were concentrated in rocky areas of the study area. This was because stones were used as stone lines construction materials. Farmers whose farms were on steep slopes more likely identified the need for soil conservation than farmers whose farms were on gentle slopes. If factors markets were perfect, steep slopes of land would be expected to lead to greater investment in conservation. Farmers on steep terrain were more involved in soil conservation than those on gentle slopes. Choice of appropriate and effective area specific sustainable structural and agro-techniques depended on slope, soil type, land use type and climate among other factors. Land use changes in the study area had greatly affected soil biophysical features. The changes included the conversion of large scale farms to small scale farms and shifts in crop production from one enterprise to another. Enterprise shifts have been motivated by changes in crop performance and profitability. Government forestlands had also been converted into farmlands and homesteads, as either official settlements or encroachments. This was particularly apparent in Kipkelion area of Kericho County. The Government however has continued to repossess encroached lands via the presidential decree to repossess illegally allocated government properties passed in 2003.

Farmers' perception of the profitability of adoption of technology positively affected adoption of all the analyzed technologies. The effect was only significant at 99% level for unploughed strips. Technologies perceived to result in high yield responses were perceived to be profitable and wer preferred by farmers. The effect of soil conservation on yields was considered a function of cumulative conservation efforts. As long as the cost of maintaining the technologies was within the ability of the farmers, farmers' perception of profitability depended on the ability of the technology to improve crop yields. The cost of use of new technologies was not given much consideration as most farmers did not calculate profitability of farm enterprises. Enterprise selection and perception of profitability were based on crop yields, output prices, farmers' attitudes, cultural and social considerations. Farmers who had adopted soil conservation for a long time were aware of yield increases due to soil conservation. Data obtained from such farmers showed that it was possible to realize up to 150% yield increases by conserving soil.

Secure tenure and size of household positively affected adoption of soil conservation technologies. The effects however were not statistically significant. This could probably be because most farmers had secure land tenure and family sizes were on average 8 in number. Large families as expected were associated with labor needed for soil conservation. Majority (94.7%) of the sampled household in the study area had private ownership rights and only 2.6% of land was communally owned. Soil conservation was associated with long term payback periods so that secure land tenure assured farmers of reaping investment benefits. Farmers do not undertake capital intensive long-term investments associated with long pay back periods in land that was not secure. With land ownership rights, there is usually restricted access to private property. Restricted access provided the incentive to invest and this resulted in reduced land degradation. This is mainly because the cost of resource degradation was internalized by the household that owns the land. Property rights are usually related to farmers' relative risk aversion. The individualization and subsequent subdivision of land to family members has led to most farmers intensifying their farming systems from subsistence to semi-commercial system.

4.0 Conclusions and Recommendations

The results of the binomial logit analyses resulted in the rejection of the null hypothesis that farm, farmer, technology and biophysical characteristics had no statistically significant effects on adoption of selected soil conservation technologies among selected households in the study area.

It is recommended that government efforts be focused towards soil conservation in the study area. Land use planning policy should be enforced in Kenya to ensure proper management of forests, steep lands and wetlands. This will solve the persistent problem of soil erosion, downstream flooding, and sedimentation and water pollution. There is need to study the effect of indigenous knowledge and skills on adoption of environmental conservation practices. Practices like conservation of shade and medicinal trees, shifting cultivation and shifting of cattle shed to spread farmyard manure was used for soil and water conservation. River bank cultivation was traditionally prohibited resulting in riverbank conservation. Some forests were considered sacred and had not been affected by deforestration.

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