Adoption of Soil Conservation Technologies and Crop Productivity in West Usambara Highlands, Tanzania

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ABSTRACT: Soil erosion has continued to be an alarming problem in the West Usambara highlands, Tanzania. This paper established the level of adoption of Soil Conservation Technologies and crop productivity in the West Usambara highlands following intensive campaigns on soil and water conservation from the early 1980s. A total of 98 randomly selected households from four villages responded to the survey. During data collection, a structured questionnaire survey, interviews, focus group discussions and observation method were used. Multiple linear regression, Paired-samples t-test, and Chi-square were used for analysis in addition to descriptive statistics. Based on the variation of adoption, the Composite Index of Adoption was 0.512±0.156 out of maximum 1. The maximum and minimum Index adoption was 0.86 and 0.14 respectively. This indicates that each farming household managed to adopt at least one among the Soil Conservation Technologies (SCTs). Hence, the overall level of technology adoption was moderate. Grass strip, multipurpose trees and bench terraces were found to be the dominant technologies used by the majority of farmers in an integrated pattern. The average household farm plot under soil conservation intervention in the hillside was 0.54±0.45 acre. However, the paper found overall significant association ($\chi^2_{(3)}$ =55. 237; p<0.001) of crop productivity between the two periods (before and after adoption of SCTs). Using t-test, the study also found a significant increase (p<0.001) in crop productivity before and after the adoption of SCTs. Therefore, it is concluded that the adoption of SCTs had a contribution on farm plot productivity in hillsides. The paper recommends that there should be holistic, integrative and multisectoral intensive soil conservation campaigns in areas with high soil erosion rates.

Key words: *Grass strip, multipurpose trees, fanya juu, fanya chini*

1.0 BACKGROUND INFORMATION

Soil erosion is one of the most important and challenging problems facing farmers and natural resource managers worldwide as farmers are losing an estimated 24 billion tonnes of topsoil each year (Lal, 1995; Pimentel, 1995). In developing countries erosion rates per acre are twice as high as the standard, partly because of population pressure which forces the land to be more intensively farmed (Mowo *et al.*, 2002; Kassie *et al.*, 2011). For instance, in the Philippine uplands, soil erosion is widely regarded as the country's most serious environmental problem since it affects about 63 to76 percent of the country's total land area (Paningbatan, 1990). Soil fertility depletion is considered the main biophysical limiting factor for increasing per capita food production for most smallholder farmers in Africa (Smaling *et al.,* 1997). Ethiopia being among the African country has become increasingly dependent on food aid particularly in most parts of the densely populated highlands where cereal yields average reported to be less than 1 metric ton per hectare following land degradation (Pender and Gebremedhin, 2007).

The continued decline of soil fertility led by land degradation, low and poorly distributed rainfall, poor resource endowments, and lack of or inadequate institutions has been reported to be among the major causes of low and decreasing performance of sub-Saharan Africa's agricultural sector (Ajayi, 2007; Misiko and Ramisch, 2007). Meeting the food demand of a global population is expected to reach 9.1 billion in 2050 and over 10 billion by the end of the century will require major changes in agricultural production systems. Improving cropland management is a key to increasing crop productivity without further degrading soil and water resources (Branca *et al.*, 2011). It is estimated that, by the year 2020, yield reduction due to soil erosion may be as much as 16.5% of the African continent and about 14.5% for sub-Saharan Africa (Lal, 1995).

Like many sub-Saharan African countries, Tanzania also faces a serious soil erosion problem. Soil erosion has been one of the major threats to agricultural production (Kaihura *et al.,* 1999). Because of soil erosion, vast areas of once fertile lands have been left unproductive. The west Usambara highlands are among the areas which are adversely affected by soil erosion in Tanzania although soil and water conservation has a long history in the area. The highlands reported to have a very high rate of soil erosion reaching about 100t/ha/year (Vigiak, 2005; Mwihomeke and Chamshama, 2001; Minderhoud, 2011). Population pressure has increased demand for food, fuelwood, construction materials and other socio-economic needs and hence, forests have been cleared and agriculture has expanded into marginal areas with steep slopes in order to meet these demands. Farmers cultivate on hillslopes approximately 18% to 60% repeatedly, clearing and burning vegetation. Therefore, this leaves the top soil open or with very little ground cover. It is estimated that about 84% of the original forest in the West Usambara highlands has been cleared (Johnson, 2001).

The adoption and diffusion of specific Sustainable Agricultural Practices (SAPs) have become an important issue in the development policy agenda for sub-Saharan Africa in addressing the consequences of land degradation (Scoones and Toulmin, 1999; Ajayi, 2007). In the West Usambara highlands, various soil conservation interventions were introduced to farmers by the government of Tanzania in collaboration with Germany government through GTZ and other partners to steer the conservation process (Mowo *et al.*, 2002). Similar conservation intervention was also implemented by the Ethiopian government in curbing environmental degradation and poverty, increasing agricultural productivity as well as food security enhancement (Kassie *et al.*, 2011).

Major conservation projects introduced in the West Usambara highlands. These projects came with seven major soil conservation technologies disseminated to farmers for adoption. The technologies were bench terraces, "*fanya juu*" ("throw (earth) upwards"), grass strips, mulching, cut-off drains, multipurpose trees and contour ridges which were experimented in the West Usambara highlands and confirmed to be more effective in curbing soil erosion when properly used (Tenge, 2005).

Despite the efforts which have been undertaken by the government and other conservation partner organizations in curbing soil erosion, soil erosion continues to be a major problem contributing to the loss of fertile topsoil in the West Usambara highlands (Tenge, 2005). The consequences of this erosion are; reduced crop yields, food deficiency, silting up of waterways, damage of various structures, and loss of land value (Meliyo, 2002).

1.1 Problem Statement

Although soil conservation technologies have high dissemination and promotion of adoption in the West Usambara highlands, soil erosion continues to be a major problem contributing at large in the reduction of household crop production on the hillside farm plots. Understanding on how far the previous and prevailing soil conservation initiatives have been achieved in controlling soil erosion problem in the West Usambara highlands is essential.

Although studies done by Semgalawe (1998) and Tenge (2005) focused on the adoption of soil conservation technologies in the West Usambara highlands, none of them focused on the level of soil conservation technology adoption and its contribution to crop production on the hillsides farm plots. Instead, authors studied the incidence of technology adoption few years after Soil Erosion Conservation and Agroforestry Project (SECAP) to wind up its activities in the West Usambara highlands in 1990s. Therefore, the paper has provided knowledge to bridge the information gap by assessing the level of soil conservation technology adoption and it contribution to increasing crop productivity.

2.0 METHODOLOGY

2.1 Description of the Study Area

The West Usambara highlands are located in the North Eastern part of Tanzania and constitute a portion of the Eastern Arc Mountains. About 80% of the population of Lushoto district in Tanga Region is found in the West Usambara highlands (Mwihomeke and Chamshama, 2001). West Usambara has been selected for this research because; the area is prone to serve erosion as it is characterized by undulating geographical features. Lushoto District lies between latitudes 4° 05' and 5° 00' and longitudes 38° 05' and 38° 40' with altitudes ranging from 600 to 2300 meters above sea level (Minderhoud, 2011). The district is characterized by the hill slope ranging from 18% to 60% while annual rainfall ranges between 800mm and 1400mm (Mowo *et al.*, 2002; Minderhoud, 2011).

Lushoto District has a population of 492 444 people in which 230 236 are males and 262 205 are females (URT, 2013). The famous tribes found in Lushoto District are Sambaa, Pare and Mbugu. The major soil types in the Lushoto District are reddish-brown soils such as Humic, Haplic and Chromic Acrisols, Luvisols and Lixisols in the mountainous uplands and Fluvisols and Gleysols in the valley bottoms (Meliyo *et al.*, 2002). Agriculture is the main economic activities of people in Lushoto District where horticultural activities are carried out mainly in valley bottoms while paddy production is dominant in plain land areas. The major horticultural crops grown include Irish potatoes (*Solanum tuberosum*), cabbage, carrots, tomatoes as well as other varieties of fruits.

2.2 Study Design, Sampling Procedure and Sample Size

On the basis of the nature of the study objectives, a cross-sectional study design was opted. The study design used allows data to be collected at one point in time and generates data for description and determination of relationships between variables. Smallholder farmer's households formed a sampling frame for this study. A household was, therefore, used as a unit of analysis in which 98 households were chosen by the study as convenient sample size. Maas and Joop (2005) noted that the sample size of at least 30 respondents chosen at random is reasonably large in social science research studies to ensure normal distribution of the sample mean.

The sampling procedure involved three consecutive stages to obtain the representative sample. By starting, two wards namely; Sunga and Rangwi which are in Lushoto District were purposively selected using the criteria of their location on hillsides. In the second stage, from the two selected wards two villages from each ward were chosen by simple random sampling.

Therefore, four villages which are Mambo, Tema, Nkelei and Emao were involved in the survey. Households selected randomly from the villages were as follows: Mambo (25), Tema (25), Nkelei (24) and Emao (24).

2.3 Data Collection

The study collected qualitative and quantitative primary data by using qualitative and quantitative methods. The qualitative methods used were personal interviews, key informant interviews, focus group discussions and direct observation while a questionnaire survey was used for gathering quantitative data. Direct observation, personal interviews, focus group discussions and key informant interviews were used in collecting information concerning the relevance and preferences of integrating different soil conservation technologies on the hillside farm plot. This aimed at ascertaining whether farmers recognized the need for integrating different soil conservation technologies in their farm plots as an effective way of curbing the erosion problem and improving crop productivity.

Quantitative data were collected using a structured questionnaire comprised of both open and closed ended questions administered to household respondents. Quantitative data involved information pertaining to the type and number of soil conservation technologies adopted by farming household, plot size under conservation intervention and crop productivity.

2.4 Data Analysis

Both qualitative and quantitative data were subjected to analysis process. Qualitative data from observation, personal interviews and key informants pertaining to the relevance and preference of farmers on integrating different soil conservation technologies in a farm plot were analyzed by using content analysis. On the other side, quantitative data were analyzed through the application of SPSS computer software in which descriptive and inferential statistics were determined. Descriptive statistics including percentages, means, minimum and maximum, standard deviations and frequencies were employed and presented in tables and figures. The inferential statistics as well were presented in tables and figures.

The variation of adoption of soil conservation technology was determined using the Indices of Adoption (IA). In this regard, **Composite Index of Adoption (CIA)** as well as maximum and minimum index of adoption were computed. According to Yila and Thapa (2008), the Indices of adoption reflect the range of technologies adopted but not the intensity of their use. With reference to Barungi and Maonga (2011), the composite index of adoption (CIA) is computed as follows:

$$CIA = \frac{IA_1 + IA_2 + \ldots\ldots\ldots\ldots\ldots IA_{100}}{N}$$

$$IA_i = T_i / T$$

Where:

IA_i denotes the Index of Adoption of SCTs for i^{th} household

T_i denotes the total number of SCTs adopted by the i^{th} household

T denotes the total number of SCTs available for adoption

N is the sample size

The expression (T_i /T) represents the index of adoption for i^{th} household

Inferential analyses were carried out by using Chi-square and Paired-Samples t-test. The Paired-samples t-test used in the study to identify if there had been a significant difference in the average crop productivity from the same cultivated hillside farm plot before and after adoption of soil conservation technologies. The Chi-square used in identifying associations between respondent's education level and extension visit, farmer's age and years' farming as well as a relationship of crop productivity before and after adoption of SCTs.

3.0 RESULTS AND DISCUSSION

3.1 Background Information of the Respondents

Based on age distribution of respondents, it was found that the average age was 47.52±13.972 years, while the maximum and minimum age was 78 and 22 years respectively. The age of respondents is important in the adoption process of soil conservation technologies in the study area (Boyd *et al.* 2000; Mengstie, 2009).

The study involved a total of 44 females and 54 males. Married respondents constituted the majority (89.8%) and the remaining (10.2%) were widowed. Among other factors, the marital status of a household head can determine the level of adoption of soil conservation technologies in the study area since it can be associated with agricultural land ownership. The study by Leavens and Anderson (2011) found out that the marital status of the farmer has an implication on land ownership since widows and unmarried females often suffer the consequences of land ownership and technology information.

In this study, it was found that the household size ranged from 1 to 14 members while the average household size was 5.84±2.162 members. The household size of 6-10 members constituted the majority (52%) of respondents. Based on respondent's education, majority (87.8%) of the respondents had primary school education while 4.1% had secondary school education. However, 8.2% of the respondents had no formal education. Farmers with higher level of education have higher level of adoption of soil conservation technologies than those with low level of education. Enujeke and Ofuoku (2012), similarly, noted that formal education is important to enhance adoption of soil conservation technologies and innovation of agricultural technologies.

Household Level of Adoption of Soil Conservation Technologies (CSTs) in the West Usambara Highlands

Under household level of adoption of soil conservation technologies, types of technologies used by farmers and variation of adoption were studied. The types of SCTs which were used by farmers based on the seven disseminated SCTs in the area. It was observed that at least each technology was used in the West Usambara (Figure 1).

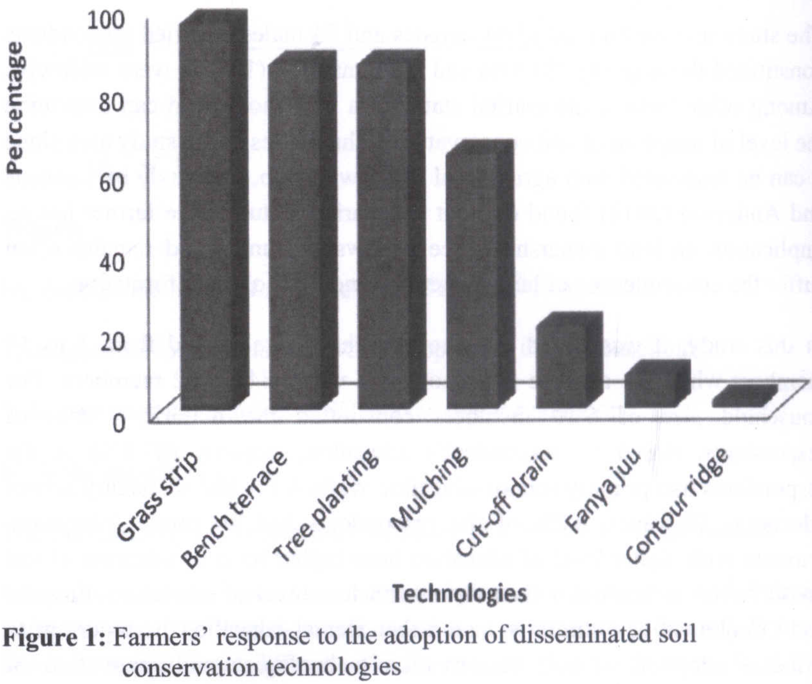

Figure 1: Farmers' response to the adoption of disseminated soil conservation technologies

As shown in Figure 1, grass strip technology dominated by Guatemala and Napier grass was the most popular (95.9%) soil conservation technology followed by multipurpose tree (85.7%) (*Grevillea robusta* (Grevillea), *Pinus patula* (Pines), *Musa spp*. (Banana tree) and *Persia Americana* (Avocado). Also bench terrace stabilized by grass strips and trees was used by the majority of farmers (85.7%) in the study area. One-fifth and three-fifths of the surveyed farming households used cut-off drain and mulching respectively in integration with other soil conservation technologies. On the other hand, it was found that contour ridges and *fanya juu* were the least used soil conservation technologies in the study area. However, through interviews, farmers appreciated soil conservation technologies as being relevant in their farm plots because they demonstrated effectiveness in soil erosion control by improving crop productivity. During focus group discussions, farmers explained that bench terraces were very effective in controlling soil erosion and therefore once bench terraces were invested by the farmer, the need for other mechanical methods such as *fanya juu* and cut-off drains become less important.

It is pointed out by various studies that adoption of soil conservation technologies depends much on farmer's preference (e.g. Mutuma *et al*., 2010; Barungi and Maonga (2011). Therefore, technology use differed among farmers in the area. Similar findings were reported by Mutuma *et al.*, (2010) in Kenya that bench terraces were the most popular used soil conservation technologies while the findings are contrary to those reported by Barungi and Maonga (2011) in the highlands of Southern and Central Malawi who observed contour ridges and terraces being the most and least adopted soil conservation technologies respectively. Such differences in technology use justify that the application of the type of soil conservation technology is a site specific and therefore technology use should not be generalized among different regions.

The Composite Index of Adoption (CIA) which is the average of the Index of Adoptions (IAs) of farming households was used by the study to identify variations of adoption of soil conservation technologies among farming households. According to Paudel and Thapa (2004) cited in Barungi and Maonga (2011), the calculation of this index helps to understand the variation in technology adoption and thus contributing to the formulation of policies for effective implementation of land management programmes.

On the other hand, another key informant, the Chairperson of Tema-Nkelenge Farmers' Irrigation Association added that following the prolonged drought periods which contributed to the drying of irrigation infrastructures, particularly dams, and the plots on hillside with irrigation infrastructures were no longer prioritized by farmers since they became less profitable and therefore less effort was directed towards conservation. Farmers are now concentrated in the valley bottoms where moisture lasts for some months after the end of the rain season. In view of this, farming activities were now exceeding the carrying capacity of the available agricultural land.

Similar observations to the above have been reported by Napier and Camboni (1988), Nowak (1983) and Barrows and Gardner (1987) who found that attitudes toward a proposed soil conservation program were significantly influenced by a number of factors related to the perception of soil erosion problems including believing that soil erosion problems had high priority and no internalized costs of soil conservation programs were incurred since an individual farmer usually avoided risky activity.

The study assessed information pertaining to household farm plot size on the hillside which is currently under soil conservation intervention and revealed that the majority of households in all surveyed villages operated at most half an acre (Table 2). The overall 11.3% of the surveyed households were found to be operating farm plot size of more than an acre which is under sustainable land management while not exceeding 2 acres. The overall minimum and maximum farm plot sizes under soil conservation intervention were 0.06 acres and 2 acres respectively, while 0.54±0.45 acre was the overall average farm plot size under conservation management in the study site.

Table 2: Distribution of respondents based on household hillside farm plot sizes which are under conservation intervention

Village	Acres under soil conservation						
	0.01 -0.5	0.51-1.0	1.01 -1.5	1.51-2.0	Min	Max	Mean
Mambo(n=25)	64	4	28	4	0.13	2.00	0.78±0.56
Tema(n=25)	76	16	4	4	0.17	1.75	0.57±0.42
Nkelei(n=25)	84	16	0	0	0.06	1.00	0.38±0.29
Emao(n=23)	82.6	13	0	4.4	0.10	2.00	0.42±0.41
Overall(n=98)	76.5	12.2	8.2	3.1	0.06	2.00	0.54±0.45

The highest household average land size in the hillsides which is under soil conservation intervention was observed in Mambo village (0.78±0.56 acre) followed by Tema village (0.57±0.42 acre). However, each surveyed household in Nkelei village found to possess not more than one acre (Table 2).

When interviewed, most farmers admitted to have fragmented plots which are mostly scattered and located very distant from home. They further explained that they devoted their conservation efforts on the hillside plots which were nearby their home surroundings and those in valley bottoms since other physical soil conservation technologies such as bench terraces and *fanya juu* were labour intensive. However, the farmers admitted that they had been farming even in other plots with no conservation measures. Bebbington(1999) noted that conditioning variables related to human asset such as availability of labour force are important since they give a farmer the capacity to act effectively by investing soil conservation technologies

The above findings concur with the reality that despite some efforts undertaken by farmers in the adoption of the disseminated soil conservation technologies in the study area, the coverage of agricultural land was still low as most of the hillside farm areas were left by farmers without any conservation initiatives and hence highly susceptible to soil erosion and experienced low crop productivity.

3.3 Contribution of Soil Conservation Technologies and Crop Production in Hillsides

Based on Irish potatoes (*Solanum tuberosum*), the study observed an increase in the average crop productivity from the same cultivated land in all four surveyed villages following the application of SCTs (Table 3). Each village was observed to have a significant ($p<0.001$) increase in Irish potato productivity at 5% level of significance since farmers decided to invest on soil conservation technologies in their farm plots (Table 3). High standard deviation of the average crop productivity indicates that despite the significance in improvement of crop productivity, there was high variation in yields per acre between the surveyed households.

Moreover, according to Irish potatoes farm plot productivity distributions of 1-1000 kg/acre, 1001-2000 kg/acre, 2001-3000 kg/acre, and above 3000 kg/acre, the Chi-square test revealed a significant association between the Irish potato productivity before and after the adoption of soil conservation technologies in three surveyed villages of Mambo ($\chi^2_{(3)}$ =10. 931; p=0. 012), Nkelei ($\chi^2_{(9)}$ = 19.767; p<0.019), Emao ($\chi^2_{(9)}$ = 20.969; p<0.013) and the overall study area ($\chi^2_{(9)}$ = 55.237; p<0.001) at 5% level. Therefore, there was a significant change in Irish potato productivity between these two periods. This shows that the adoption of SCTs improves crop productivity due to various factors such retaining soil moisture, fertility and reducing soil erosion.

Table 3: Contribution of SCTs to Irish potato productivity (kg/acre)

Village name	Average productivity before adoption	Average productivity after adoption	t-value	p-value
MAMBO (n=25)	874.98±389.81	1767.04±1085.74	5.345	<0.0001
TEMA (n=25)	1018.08±474.53	3384.89±1813.25	7.778	<0.0001
NKELEI (n=25)	1386.52±1267.95	2632.88±1874.66	6.504	<0.0001
EMAO (n=23)	1396.61±1117.47	2665.48±1820.10	6.136	<0.0001

Note: Figures added and subtracted (±) are the standard deviations

The patterns of averages of crop productivity observed in all villages depict the improvement of productivity since farmers decided to invest on soil conservation technologies in their farm plots. Hence, soil conservation technologies are effective in curbing soil erosion and contribute significantly to the improvement of soil fertility in hillside farm plots.

Significant crop performance observed in the study area following the application of recommended SCTs is similar to that reported by Shively (1999) on the hillside farms in the Philippines, Dutilly-Diane *et al.* (2003) in Burkina Faso and Niger, Dosteus (2011) cited in Branca *et al.* (2011) in the Uluguru mountains in Tanzania, Verchot (2007) in Malawi, and Posthumus (2005) in Peru based on specific crops and environmental conditions. This gives the impression that the adoption of soil conservation technologies has significant contribution to crop productivity on the hillside farm plots of the West Usambara highlands.

4.0 CONCLUSION AND RECOMMENDATIONS

In the study area, it was found that at least each of the farming household applied at least one type among the seven disseminated soil conservation technologies and the majority used more than four technologies. This shows that farmers were aware of the seriousness of the soil erosion problem. The integration of grass strips, trees and bench terraces were popular soil conservation technologies in the study area followed by mulching, cut-off drain, *fanya juu* and contour ridges. Generally, there was a medium level of adoption of conservation technologies. Moreover, soil conservation technologies demonstrated significant contribution to crop productivity on the hillside farm plots. However, the coverage area under land management intervention was still small. There were variations in the capacity of farmers to adopt the number of soil conservation technologies.

To ensure effective control of soil erosion and improved agricultural productivity in the West Usambara highlands, this study recommends various measures to be undertaken such as the following:

- The government of Tanzania and other natural resources conservation partners should enable the extension agents to reach the majority of farmers; and

- Men and women who depend on hillside agricultural plots as well as having more programs on technical training which are relevant in land management for the effective adoption of soil conservation technologies should be the main target for the training.

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