Farmers' Adoption of Soil and Water Conservation Technology: A Case Study of The Bokole and Toni Sub-Watersheds, Southern Ethiopia

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Abstract

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In order to investigate the rate of adoption, and factors affecting dissemination of soil and water conservation (SWC) technologies, a formal survey was conducted with 201 households in two sub-watersheds of Bokole and Toni in southern Ethiopia. Key-informant interviews and an archival search were also conducted. The majority of farmers perceived that SWC structures reduce surface run-off and erosion. Among ten variables, the binary logit test showed that farmland size (P<0.1) and workability of structures (P<0.05) were significantly correlated with adoption in Bokole sub-watershed. In Toni sub-watershed, the distance from the nearest local market showed significantly negative (P<0.05) correlation with adoption. Other variables such as number of cattle, family size, frequency of contact with development agent, age, educational level, responsibility in the kebele and perception of the seriousness of erosion, showed various effects. The study revealed that socioeconomic factors influenced the adoption of SWC technologies, and should therefore be considered in planning such interventions.

***Keywords*:** adoption, Dawuro, socioeconomic factors, sub-watersheds, workability

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INTRODUCTION

Soil erosion is accelerated by exposure of the soil surface; hence land use frequently governs erosion to a greater extent than climate (Morgan, 1986). The greatest risk of land degradation arises when land is used merely for sustenance and income (FAO, 1983). Thus, man is acting both as the beneficiary and the destroyer of his environment and its production capacity (FAO, 1985). Soil nutrient loss due to erosion reduces land productivity; hence it hampers attempts to attain food security in developing countries such as Ethiopia.

The problem of land degradation due to soil erosion received great attention in Ethiopia following the 1973/74 famine (Lundgren, 1993). The rate of soil loss from Ethiopia is estimated to be about 2 billion Mg $year^{-1}$ (Woldeamlak & Sterk, 2003). Erratic and erosive rainfall, steep terrain, deforestation, inappropriate land use, land fragmentation, overgrazing and farmers' management practices are among the factors that cause land degradation in the country (Osman & Sauerborn, 2001). Intense and continuous cultivation on sloping land, without supplementary use of soil amendments and conservation technologies, poses a serious threat to sustainable land use (Bekele & Holden, 1999). Traditional soil conservation practices and agronomic measures have been historically practiced in various parts of the country (Lundgren, 1993; Osman & Sauerborn, 2001). However, the importance of soil and water conservation technology for sustainable development and continuous production in agriculture has been recognized in recent decades.

A massive soil and water conservation (SWC) program was started during the 1970s and 1980s (Woldeamlak, 2007). A total of 1,252,000 km of terraces and bunds was constructed and 472 million trees were planted (Osman & Sauerborn, 2001).

A variety of conservation structures**,** applicable to different soil types, rainfall conditions and topography such as soil bunds, stone bunds, *Fanya juu* (to throw up') were developed (Hurni, 1986).

Hillside terraces were implemented extensively at the two study sites from 2000 onwards by the World Food Program (WFP) and Action-Aid Ethiopia. The WFP applied a 'Local Level Participatory Planning Approach' (LLPPA). It also supported a food self-sufficiency programme in localities with minimal rainfall, mainly in Bokole sub-watershed. In the Toni sub-watershed, an irrigation project was initiated to improve the farming practices of the *Mana* ethnic group (engaged in pottery). However, siltation became a problem in the constructed irrigation scheme in the downstream part of the sub-watershed. To alleviate this problem, physical and biological SWC measures were implemented.

In different parts of Ethiopia, factors influencing adoption and management of SWC have been investigated (Graaff et al 2008; Kassie et al 2008; Kato 2011; Teshome 2012). Although many resources (money, labour, grain) have been invested in the construction of SWC structures in sub-watersheds, but their socioeconomic impact and sustainability is not well studied. Furthermore, there is inadequate information on people's adoption for these SWC structures. Thus, this study is aimed to investigate farmers' adoption of SWC technology, and the community's efforts to sustain and maintain SWC structures.

MATERIALS AND METHODS

Study Sites

The survey was conducted on two selected sub-watersheds: Bokole and Toni, Dawuro zone, Southern Ethiopia. These sites are located between 6º56'N–7º36'N latitude and 36º34'E–37º64'E longitude, 500 km south of Addis Ababa, the capital of Ethiopia (Figure 1) with an altitude between 1200-2400 m. Mean annual rainfall is 1400–1800 mm and the mean temperature is 18–27.5 ºC. The soils are grouped under Dystric Nitosols and Orthic Acrisols (SNNPRS-BoFED, 2004).

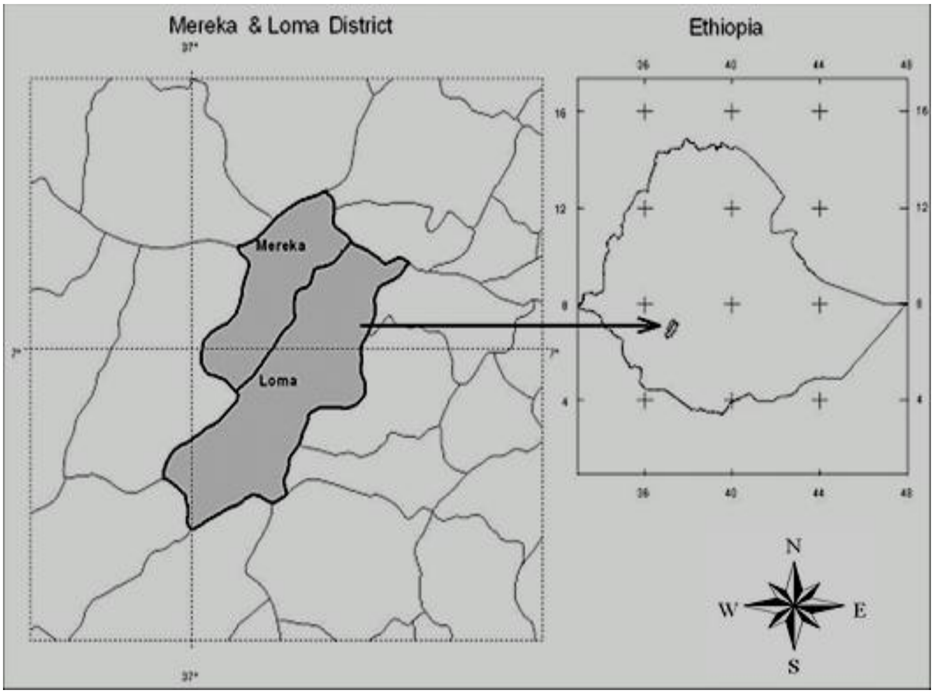

Figure 1. Location of the study sites.

The predominant economic activity and land use is mixed agriculture; having land use systems of agricultural land (mainly rainfed), grazing land, and forest/bush. The population of the study districts is *ca.* 235,800 (FDRE-PCC, 2008).

Methods of Data Collection

Two sub-watersheds, namely, Toni and Bokole were selected for the study where intensive SWC interventions were carried out for about seven years by the two NGOs of 'WFP' and 'Action-Aid

Ethiopia'. Multistage stratified random sampling methods were employed for selecting sample households. Each sub-watershed was stratified into upper, middle and lower sections; and based on SWC practices, farmers were grouped into 'adopters' (have already adopted SWC structures on at least one of their holdings) and 'non-adopters' (have not adopted on any of their holdings). Then, 10% of the households were randomly selected from each category for interview. A total of 201 households (125 adopters and 76 non-adopters) from both sub-watersheds were interviewed using a structured questionnaire.

In addition, a total of 60 key informants were selected, thus representing 30 from each sub-watershed and 10 to represent each from upper, middle and lower catchments. Discussions were held about the past and present SWC activities and adoption situation in the study areas. Those interviewed had lived in the area since birth and knew it well. Furthermore, discussions were held with three district agricultural office experts, six development workers and the area representative of the WFP in the southern region. Available secondary data, especially reports and records, were also reviewed to triangulate and complement the discussions.

Method of Data Analysis

Both descriptive statistics and the binary logistic regression model were employed using SPSS version 12 (2003). Rate of adoption, constraints and farmers' perception of SWC technologies were analyzed using descriptive statistics. The binary logistic model was used to analyze the effect of selected variables (Table 1) on the farmers' adoption of SWC. Moreover, the same model was used to compute the relationship between maintenance of structures and selected variables, by following the analytical approach of Mendenhall & Beaver (1994):

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_6 x_6 + \beta_7 x_7 + \beta_8 x_8 + \beta_9 x_9 + \beta_{10} x_{10} + \epsilon ,$$

Where y = response variable (adoption);

β_0= unknown constant;

$\beta_1, \dots B_{10}$ = unknown coefficients later computed using the SPSS program;

$X_1 \dots X_{10}$ = family size, age of household head, responsibility in the *kebele*, number of cattle, educational level, farmland area, distance from nearest market, frequency of contact with development agent, perceptions concerning the seriousness of the soil erosion problem, and perceptions about the workability of SWC structures by farmers, respectively;

ϵ = error term.

Table 1. Variables of adoption and maintenance of SWC structures

Variables	Definition	Values
Adoption	Adopted soil and water conservation	0=not adopted (no structures on his/her farmland; 1=adopted at least one of the structures
Family size	Number of people in the family	Continuous
Age	Age of family head	Continuous
Responsibility	Responsibility in kebele	0=not responsible in kebele in any position; 1=responsible
Cattle	Number of cattle owned	Continuous
Education	Education level of the family head	0=illiterate; grade1, 2,..... (continous)
Land area	Landholding of the family	Landholding, hectares (continuous)
Distance from market	Distance from nearest local market	Hours, continuous
DA contact	Frequency of contact of the household head with development agent	1=every week; 2=every two weeks; 3=every three weeks; 4=every four weeks
Erosion Seriousness	soil erosion is serious problem	1=strongly agree; 2=agree; 3=agree to some extent; 4=disagree
Workability	Perception of workability of structures by farmers	1=easy to work; 2= moderate; 3= difficult
Maintain	Maintenance of structures when broken	0=not maintained; 1= maintained

RESULTS AND DISCUSSION

Household Characteristics and Income Sources:

Household (HH) characteristics and sources of income for the two sub-watersheds are given in Table 2. The average family size in both the sub-watersheds was approximately the same (8 persons/HH) for both adopters (7.79–8.15) and non-adopters (7.63-7.86), indicating the availability of family labour to construct and maintain SWC structures. The average age of the head of the family ranged between *ca.* 36–44 years, also showing the availability of a workforce for the same purpose. Farm size per HH averaged 2.13 and 1.7 ha in Bokole and 1.65 ha and 1.97 ha in Toni for adopters and non-adopters, respectively.

Table 2. Household characters and income sources in Bokole and Toni sub-watersheds

		Adopters		Non-adopter	
		Bokole (n=73)	Toni (n=52)	Bokole (n=39)	Toni (n=37)
House hold characteristics (mean)	Family size	7.79	8.15	7.63	7.86
	Household head's age	42.92	43.88	36.05	43.65
	Cattle (number)	5.74	5.21	6.21	4.11
	Farm size (ha)	2.13	1.65	1.7	1.97
Source of income (% of respondents)	Cash-crop	45.2	11.5	51.3	0.0
	Food crop	87.7	88.5	87.2	89.2
	Livestock	83.6	80.8	71.8	73.0
	Fruit	12.3	5.8	5.1	0.0
	Tree product	24.7	28.8	28.2	21.6
	Weaving	2.7	0.0	2.6	0.0
	Off-farm	31.5	13.5	12.8	8.1
	Remittance	2.7	1.9	2.6	0.0
	Honey production	1.4	1.9	0.0	13.5

The major source of income for both sub-watersheds was food crops (88% Bokole and 89% Toni), followed by livestock and its products for adopters (Table 2). The same pattern was noted for non-adopters. This implies the importance of environmental management for improving productivity and ensuring sustainable production.

Adoption and Perception of SWC

The relationship of variables about the adoption and perception of SWC is presented in Table 3. The age of the household head was negatively and insignificantly related to the adoption of SWC in both sub-watersheds. This may be explained by the fact that older farmers resisted the adoption of new technology.

The educational level of the household head was also negatively and insignificantly associated with adoption in both sub-watersheds. It is explained by the fact that, as the educational level increases, the tendency to seek off-farm employment increases, while attention to the rural lifestyle decreases. Moreover, educated young farmers are more interested in jobs and business, rather than in taking up cultivation as an occupation (Bagdi, 2005).

Responsibility in the *kebele*, family size, and farmers' perception of erosion, were all found to influence the adoption of SWC technology positively in both sub-watersheds. Responsibility in the *kebele* provides an opportunity to participate in various meetings, and opportunities of obtaining information about newly introduced SWC technology corroborating the findings in Burkina Faso (Sidibe, 2004). An increase in family size increases the workforce at household level. The present study indicated that farmers in both sub-watersheds perceived erosion as a problem, and that the tendency to adopt the technology was correspondingly high. However, this result contradicts findings by Awdenegest & Holden (2007) in Southern Ethiopia, where farmers' own initiatives were minimal, even under serious, advanced erosion.

Table 3. Relationship for adoption and maintenance/repair of SWC structures

Variables	Adoption of structure				Maintenance of structure			
	Bokole		Toni		Bokole		Toni	
	Coeff.	P	Coeff.	P	Coeff.	P	Coeff.	P
Family size	0.098	0.460	0.051	0.615	–0.161	0.344	0.050	0.721
Age of household head	–0.043	0.178	–0.007	0.738	0.036	0.244	–0.026	0.399
Responsibility in kebele	0.732	0.273	0.384	0.771	0.893	0.379	–0.895	0.547
Number of cattle owned	0.055	0.309	–0.135	0.244	–0.041	0.765	–0.111	0.280
Educational level	–0.440	0.171	–0.244	0.409	0.825	0.070[a]	0.299	0.489
Farmland area	–0.415	0.082[a]	0.160	0.288	0.099	0.805	–0.219	0.517
Distance from nearest market	–0.074	0.426	–0.303	0.020[b]	–0.154	0.397	–0.317	0.078[a]
Frequency of DA contact	–0.016	0.950	0.106	0.688	0.310	0.404	–0.193	0.683
Perception of soil erosion seriousness	0.125	0.659	0.471	0.335	0.022	0.956	–0.267	0.794
Workability of SWC structures	1.391	0.005[b]	–0.863	0.386	–1.132	0.083[a]	0.686	0.636
Constant	–2.568	0.265	3.462	0.313	–0.527	0.868	2.374	0.648

[a] = significance at $P < 0.1$; [b] = significance at $P < 0.05$
Note: DA= development agent; S.E. standard error

The number of cattle, an indication of economic security, had a positive influence in the Bokole sub-watershed and a negative influence in the Toni sub-watershed. The discrepancy is attributed to the circumstance that the wealthier farmers in Bokole take risks by investing and adopting SWC technology; whereas in Toni such wealthy farmers have other resource options besides farmland and less concerned about adopting SWC technologies for improving productivity.

In both sub-watersheds, the distance to local markets was also negatively related to adoption. The shorter the distance to the market, the less time and money is spent on transportation. This would motivate farmers to produce more products, thus gaining a higher income. In turn, proper management of their land would allow them to improve their production.

The influence of development agents (DAs), however, showed inconsistent trends. In Bokole, DAs negatively influenced the adoption of SWC technologies by farmers due to their involvement in activities such as rural land-tax estimation. Farmers hesitate to contact the DAs, and thus are less likely to accept the technology. However, in Toni it was positive because of more frequent visits by DAs helped to convince farmers to adopt the technology.

Farm size had different results for the two communities. In Bokole, tendency to adopt SWC structures decreased as farmland area increased. However, in Toni adoption improved because farmers in this sub-watershed have smaller landholdings (Herwerge & Ludi, 1999).

Workability of SWC structures also showed different influences in Bokole and Toni sub-watersheds. Farmers in Bokole perceived the technology as being difficult to build and maintain, but they adopted the structures because of the seriousness of erosion. Farmers evaluated the workability of the structure in terms of the material resources, affordability, simplicity of application, cost-effectiveness and technical skills required. This finding agreed with findings of Woldeamlak Bewket (2007) in the northeastern highlands of Ethiopia. Bagdi (2005) also showed that the adoption of SWC can be influenced by the high cost, feasibility in field situations and the availability of resources to farmers.

Maintenance of the Structures

The binary logistic model test showed that, in Bokole sub-watershed, the age of the household head, responsibility in the *kebele*, education level, farm size, frequency of DA contact and perception of soil erosion seriousness, had positively but insignificantly affected maintenance of SWC structures. In Toni sub-watershed, family size, educational level and workability of structures showed a positive effect (Table 3). Both educational level and farmers' perception of the workability of the structures were significantly correlated with maintenance of the structures. In Toni sub-watershed, the distance from the nearest market was negatively and significantly correlated.

The positive effect of age shows that with increasing age, farmers accumulate experience about the importance of land management. Thus, the tendency to maintain the structures increases. From the standpoint of awareness point of view, responsibility in the *kebele* positively influenced maintenance of the adopted structures, as in the case of Bokole sub-watershed. However, those farmers who have responsibilities in *kebeles* have less time to work on farmland, and if they can obtain an alternative income, the tendency to maintain the structures may decline, as happened in Toni.

Contact with DAs showed a positive impact on the maintenance of SWC structures in Bokole. This confirms the thinking that rural farmers who maintain contact with officials of rural village institutions and extension agencies, are likely to contribute more effectively to the maintenance of structures (Bagdi, 2005). However, contact with DAs had a negative coefficient in Toni. This is probably due to the fact that development agents are not solely involved in agriculture and natural resource management activities, but also in other off-farm and extra-curricular affairs. For instance, involvement of development agents in issues related to rural land-tax collection may disrupt their acceptance in the community as extension agents. Daniel (2006) also indicated a less interest on the part of farmers to seek technical support of DAs, due to their involvement in 'unfavorable decisions' such as resettlement, tax assessment and collection.

An increase in landholding size in Bokole sub-watershed encouraged management of the land resource. This result agreed with findings in Baressa sub-watershed, central highlands of Ethiopia (Aklilu & de Graaff, 2006). Contrary results were obtained from Toni sub-watershed, indicating that farmers with large farms have alternative land to plough, and can allow for a fallow period; hence, they may neglect the maintenance of SWC structures. .

In addition, farmers who have large numbers of cattle may ignore structure maintenance, expecting frequent damage by cattle. Dung from a relatively large number of cattle can, to some extent; substitute for nutrients lost by erosion, if properly managed and distributed, and thus can reduce attention to the maintenance of structures. In fact, the social significance of cattle in large numbers but of poor quality causes ecological stress (Hudson, 1981).

Family size was positively correlated with the maintenance of SWC structures in Toni showing that large families can provide more help in maintaining and repairing damaged SWC structures (Bagdi, 2005). However, a contradictory result was obtained in Bokole. This may be due to some family members attending school; consequently, have little time for and interest in participating in the maintenance of SWC structures. On top of this, an increase in family size demands more food. Thus, family members may become involved in off-farm work to generate income for securing a consistent food supply, confirming to the findings of Aklilu & de Graaff (2006) in the central highlands of Ethiopia.

Rate of Adoption of SWC

In Bokole sub-watershed, the percentage of farmers who adopted SWC was highest (44%) in 2005, and declined thereafter, whereas the number of adopters reached a peak in Toni sub-watershed in 2004 (Figure 2). These periods directly corresponded to the intensive implementation of SWC structures by the NGOs. It is attributed to the availability of financial incentives to farmers**.** After this, the rate of adoption declined abruptly, due to the phasing-out of project aid supporting the SWC interventions implying that farmers were heavily dependent on project interventions and resource support, rather than creating their own capacity. This is partly attributed to the weak extension approach, in that the intervention focused on establishing the structures on the ground, rather than changing people's attitudes. A similar experience was also reported in northern Ethiopia (Woldeamlak Bewket, 2007).

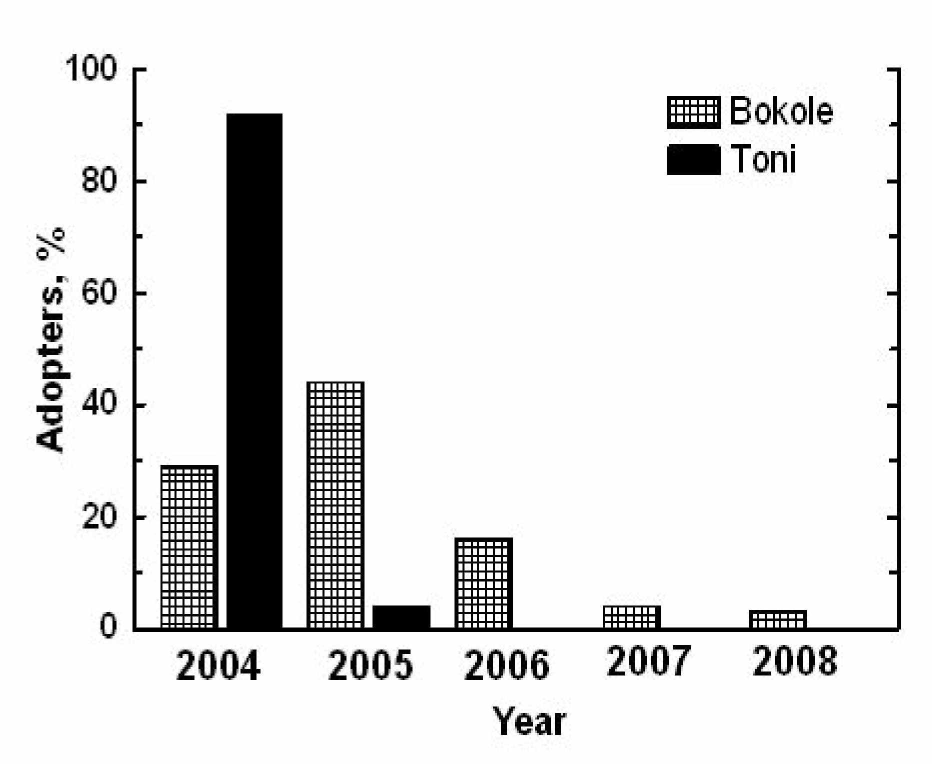

Figure 2 . Farmers (%) year wise to adopted SWCs, in Bokole and Toni sub-watershed.

Farmers' Attitude and Major Constraints on Adoption to SWC

Farmers' responses concerning perceptions and constraints for adopting SWC are presented in Table 4. The perceptions of farmers contribute substantially to the acceptance and dissemination of SWC technology. Bagdi (2005) asserted that farmers having a favorable attitude to SWC readily adopt the new technologies. Correspondingly, both adopters and non-adopters perceived positive roles of SWC for improving crop productivity, reducing soil loss and run-off in the two sub-watersheds. However, a substantial proportion of Bokole adopter farmers (39.7%) indicated that the introduced SWC technology was incompatible with their farming. This was due to the narrow space between terraces, which caused difficulty for their ox-plough. In comparison, the majority of the Toni respondents (63.5%) positively perceived the existence of the structure on the farms. They explained that the removal of stones for the construction of stone bunds, especially in the lower and middle part of the sub-watershed, made the plot better for farming.

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Table 4 . Farmers responses on perception and constraints for adoption of SWC

Attitudes on effect of SWC/ constraints		Adopters		Non-adopters	
		Bokole (n = 73)	Toni (n = 52)	Bokole (n = 39)	Toni (n = 37)
		%	%	%	%
Attitudes on effects of SWC	Improve crop production	78.1	94.2	69.2	100
	Reduce soil loss	87.7	100	84.6	97.3
	Reduce surface run-off	86.3	98.1	84.6	97.3
	Improve soil fertility	80.8	98.1	74.4	97.3
	Create better farming plot	39.7	63.5	41.0	73.0
Constraints	Labour	57.5	44.2	87.2	62.2
	Technical advice	13.7	25.0	17.9	5.4
	Government support	23.3	30.8	35.9	51.4
	Skills	15.1	32.7	41	54.1
	Awareness	12.3	46.2	33.3	54.1
	Material shortage	5.5	15.4	12.8	8.1

The three major challenges cited by adopters for adopting SWC were labour shortage, lack of awareness and lack of skills (Table 4). Labour constraints were also reported as the dominant challenge among non-adopters in both sub-watersheds. The SWC interventions are labour-intensive and this often challenges households. Desta et al. (2005) also showed that soil bunds, *fanya juu* and stone bunds respectively demand a construction labour force of 150, 200 and 250 persons day^{-1} km^{-1}. In both sub-watersheds, shortage of construction materials was mentioned to be the least important problem. This is because SWC technology uses local materials.

The majority of respondents mentioned that government support for constructing SWC technologies was adequate, revealing that an incentive under some conditions can help in sustaining and promoting the introduced SWC technology. A study conducted in Australia on a land-care programme confirmed that well-thought-out and applied government incentives could be very effective in motivating land-users to continue and to utilize new and better conservation practices (Sanders and Dannis, 1999). However, the same report also pointed out that government support has a negative effect as land-users may ignore their conservations efforts once incentives are phased out.

Most of the survey responders stated that the technologies were difficult for the farmers to apply on their own. This will hamper the expansion of the technology, and together with other factors, will affect its adoption at the local level. Farmers' dependency on external assistance has remained unchanged from previously introduced SWC structures that were constructed by NGOs and government. Thus, the participatory approach that encourages self-help did not replace external support-seeking. This will be a challenge to the expansion of the technology in areas where the government or an NGO fails to provide sufficient support.

CONCLUSIONS

Farmers in the two study areas clearly understand that soil erosion is a serious problem affecting agricultural production. However, the introduced SWC program is technically, as well as economically difficult for farmers to construct and maintain. Thus, they should coordinate in a team approach. They also need on-going support by government or NGOs for the construction and maintenance of SWC structures. In addition, the feeling of dependence on the government and non-governmental aid has influenced the adoption and sustainability of the technology.

Responsibility in local-level administration units gives farmers better access to new technology. Distance to markets also influenced to improve land productivity through better conservation and management practice. However, the role of development agents in influencing farmers depends on the trust they build and on the extension inputs delivered and on the frequency of extension contacts. The perceptions of farmers concerning the seriousness of soil erosion and the workability of SWC structures are matters to be considered.

Further, implementation of sub-watershed management, including SWC, should be undertaken only after thorough discussion and agreement on the fate of the structures. The community should be committed to the continued maintenance of current structures and the construction of new erosion control devices. Finally, it is fair to conclude that every SWC intervention should critically consider the community's socioeconomic factors as well as the complexity of the technology, for effective implementation and sustainment of conservation structures.

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