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FARMERS' PREFERENCE FOR SOIL AND WATER CONSERVATION PRACTICES IN CENTRAL HIGHLANDS OF ETHIOPIA

ZENEBE ADIMASSU, BEZAYE GORFU, DEMEKE NIGUSSIE, J. MOWO[1]
and KIDIST HILEMICHAEL
Ethiopian Institute of Agricultural Research, P. O. Box 2003, Addis Ababa, Ethiopia
[1]World Agroforestry Centre, P. O. Box 30677 - 00100 Nairobi, Kenya
Corresponding author: zenebeteferi@yahoo.com

ABSTRACT

Land degradation is a major socio-economic and environmental concern in the Ethiopian highlands where the phenomenon has rendered vast areas of fertile land unproductive. To reverse this trend, the adoption of soil and water conservation (SWC) practices is crucial. However, failure by research and development organisations to take into consideration farmers preference for SWC practices have resulted into low adoption of these technologies. This paper presents the findings of a study that evaluated farmers' preferences of SWC practices, including the economic perspective; as a basis for enhancing adoption of the technologies in the central highlands of Ethiopia. Four soil and water conservation (SWC) practices; (i) soil bunds alone (SB), (ii) soil bunds with vetiver grass (SB+Vg), (iii) soil bunds with *Susbania susban* (SB+Ss) (iv) and soil bunds with elephant grass (SB+Eg), were evaluated in the Borodo Watershed in the central highlands of Ethiopia. These are the only SWC measures introduced and implemented in Borodo watershed. Data on these SWC practices were collected from farmers using focus group discussion. A multi-criteria analysis (MCA) approach was used to analyses the data. The criteria were weighted using pair-wise ranking and SWC practices were scored with a scale of 1(not good) to 5 (best) based on each criterion. The overall weighted scores were obtained using the Simple Additive Weighting Model. Farmers assigned highest relative weights to criteria related to economic criteria (0.58) than technical (0.29) and stability criteria (0.13). Based on the overall weighted scores obtained using MCA approach, farmers prefer different SWC practices in an order of SB+Eg> SB+Ss> SB+Vg> *SB.* In general, this paper argues that farmers' economic concerns should be accounted for or more seriously taken into account by research and development institutions. Therefore, there is a need to develop SWC practices which are technically effective and economically efficient.

Key Words: Elephant grass, *Susbania susban,* vetiver grass

RÉSUMÉ

La degradation des terres est un problème socio-économique et environnemental majeur dans les hautes terres de l'Ethiopie où le phenomena a rendu improductifs des vates étendues dorénavant fertiles. Pour inverser cette tendance, l'adoption des pratiques relatives à la conservation de sol et des eaux (SWC) est cruciale. Par ailleurs, l'échec des organisations de recherche et de développement dans la prise en compte des préférences des fermiers en cette matière ont résulté en une faible adoption de ces technologies. Cet article présente les résultats d'une étude qui a évalué les préférences des fermiers concernant les pratiques de conservation de sol et des eaux, incluant la perspective économique comme fondement d'une adoption réussie des technologies dans les hautes terres de l'Ethiopie centrale. Quatre pratiques de conservation de sol et des eaux; (i) sol cultivé en bandes seulement (SB), (ii) sol en bandes avec herbes en vetiver (SB+Vg), (iii) sol en bandes avec *Sesbania sesban* (SB+Ss) et sol en bandes avec *Penisetum purpureum* (SB+Eg) étaient évalués dans le basin versant de Borodo dans les hautes terres du Centre de l'Ethiopie.Celles-ci sont des pratiques de SWC introduites et exécutées dans le basin versant de Borodo. Les données sur les préférences de fermiers eu égard à ces pratiques de SWC étaient collectées chez les fermiers par l'approche du Groupe focal de discussion. Une analyse par approche multi-critères (MCA) était utilisée pour analyser les données. Les critères étaient pondérés utilisant le test de pair-wise et les pratiques de SWC étaient côtées avec une échelle de 1 (pas bon) à 5 (meilleur) sur base de chaque critère. Les totaux mesurés de toutes les côtes étaient obtenus utilisant le Modèle Simple de pondération additive. Les fermiers ont assigné les poids relatifs élevés aux critères en relation avec les critères économiques (0.58) que techniques (0.29) et les critères de stabilité (0.13). Basé sur les totaux des scores pondérés obtenus par l'approche MCA, les fermiers préfèrent les pratiques SWC dans l'ordre de SB+Eg> SB+Ss> SB+Vg> *SB.* En general, cet article montre que les problems économiques des fermiers devront être considérés par des institutions de recherche et de développement. Ainsi, le développement des pratiques de SWC qui sont techniquement efficaces et économiquement profitables.

Mots Clés: Penisetum purpureum, Susbania susban, herbes en vetiver

INTRODUCTION

Land degradation has been a major global agenda because of its adverse impact on environment and food security and the quality of life (Slegers, 2008). Productivity impacts of land degradation are largely due to decline in soil depth and soil fertility (Falkenmark *et al*., 2009; Stroosnijder, 2009) and off site where sediments are deposited (Pender and Gebremedhin, 2007).

The situation is severe in the Ethiopian highlands where land degradation has rendered vast areas of fertile lands unproductive (Gilligan and Hoddinott, 2007; Kassie *et al*., 2010). Soil erosion and nutrient depletion are the most important forms of land degradation in this country (Tekle, 1999). Although estimates of the extent and rate of soil erosion and associated nutrient losses lack consistency, several studies reveals the severity of the problems in the country. The highest rate of soil loss occurs from cultivated lands, ranging from 50 t ha^{-1} yr^{-1} (Adimassu *et al*., 2012a) to 179 t ha^{-1} yr^{-1} (Shiferaw and Holden, 1999).

Apart from these scientific evidences, the occurrence of soil erosion in most parts of the country is directly visible. Most cultivated lands in the hills and mountains of the country have suffered from loss of top soil, leaving bare stones. Gullies are observed everywhere in the deep soils of the country. The severity of soil erosion in Ethiopia is visible from the thick mass of soil taken away by major rivers, such as the Nile, Awash, Omo and Baro. These rivers are coloured dirty brown during the main rain season due to soil erosion from their catchments.

In terms of nutrient depletion, Haileslassie *et al*. (2005) estimated Ethiopia's nutrient rates of 122 kg N, 13 kg P and 82 kg K ha^{-1} yr^{-1}. Similarly, Adimassu *et al*. (2012) estimated 47.8 kg N, 0.60 kg P_20_5, and 0.40 K_2O ha^{-1} yr^{-1} through soil erosion alone in the central highlands of Ethiopia. As a consequence of both soil erosion and nutrient depletion, more than 30,000 ha of croplands are estimated to become out of production annually (Grepperud, 1996).

Efforts to regulate the impacts of land degradation on soil productivity have been undertaken in various parts of the country. These include scaling-out of soil and water conservation (SWC) practices in the central highlands of Ethiopia (Amsalu, 2006; Adimassu *et al.* 2012a). Generally, the adoption of SWC practices is very low (German *et al.* 2007; Adimassu *et al.* 2012a); but varies considerably within the country (Shiferaw and Holden, 1999; Bewket, 2007; Tefera and Sterk, 2010).

Profitability of the technologies appears to be one of the major economic factors which affect the adoption of SWC technologies (de Graaff *et al*., 2008; Kassie *et al*., 2010; Sattler and Nagel, 2010). The dominant profitability evaluation technique in SWC has been mostly cost-benefit analysis (Tenge *et al*., 2005; Bizoza and de Graaff, 2012). However, investments in land management must consider outcomes that cannot easily be quantified in monetary terms (Posthumus and de Graaff, 2005; Tenge *et al*., 2005; Bizoza and de Graaff, 2012). Multi-criteria analysis (MCA) technique has emerged as an alternative and relatively comprehensive evaluation tool for soil and water conservation practices that include non-economic criteria. So far, no studies have been conducted on the performance of SWC practices that explicitly integrates farmers' economic needs and environmental objectives at a local level in Ethiopia and eastern Africa in general. This paper evaluated farmers' preferences of SWC practices, including economic considerations; as a basis for enhancing adoption of the technologies in the central highlands of Ethiopia.

MATERIALS AND METHODS

The study area. The study was conducted in Borodo Watershed in the central highlands of Ethiopia, covering an area of 374 ha. The watershed is part of the Awash basin which is situated at an altitude of 2210 to 2720 m above sea level. It is located at 9^{o}01'54'' N to 9^{o}04'03'' N and 38^o 09' 10" E to 38^o 10' 40'' E.

The area is characterised by three soil types, namely, *Koticha (Vertisols)*, *Abolsi Nitisols)* and *Dimile (Cambisols)* based on colour, fertility level and workability. The watershed receives high annual rainfall (>1100 mm) mainly, concentrated in July and August. The farming system is a typical mixed crop-livestock system on a subsistence scale. The dominant crops grown in the watershed are wheat (*Triticum* sp.), Tef (*Eragrostis tef*) and chick pea (*Cicer arietinum*). Livestock including cattle, sheep and equines are also an important part of the farming system.

Data collection and analysis. Data were collected using two focus group discussions (n=8) on different SWC practices. The small numbers of FGDs (n=2) is due to limited numbers of farmers who had implemented the aforementioned SWC practices. As a result, almost all farmers participated in the FGDs.

Multi-Criteria Analysis (MCA) technique was employed to assess the preferences. Multi-Criteria Analysis is an evaluation framework that ranks the performances of decision options against multiple objectives/criteria (Hajkowicz and Collins, 2007; Hajkowicz, 2008). Typically, the criteria were weighted using pair-wise ranking by decision makers (farmers) to reflect their relative importance. Criteria are attributes or indicators used to measure performance against decision makers' objectives. MCA is a systematic way of making choices according to criteria and available options (Hajkowicz, 2008; Herva and Roca, 2013). It does not rely on monetary values and offers a great potential to address the short comings of other evaluation methods (e.g. cost benefit analysis). This method has been widely used by several authors to evaluate natural resource management technologies (Kajanus *et al*., 2004; Ananda and Herath, 2009). In this study, the following major MCA procedures were employed:

(i) Establishing the decision context/ determination of objectives. The first procedure in MCA is always to establish a shared understanding of the decision context (Garmendia et al. 2010; Garmendia and Gamboa, 2012). It is crucial to have a clear understanding of objectives. To establish objectives and criteria, we had to involve decision-makers who were affected by the decision. In this study, farmers were identified as decision makers in the implementation of SWC practices.

(ii) Identifying options/alternatives. Having established the decision context, the next step was to list the set of alternatives to be considered to meet objectives of SWC practices in the area. Four SWC practices (alternatives) related to soil bunds were introduced in Borodo Watershed for evaluation and further scaling-out. Due to lack of soil stones in the area, only soil bunds (graded) were implemented to control soil erosion in the watershed. These SWC practices include: soil bund alone (SB), soil bund with Vetiver grass (*Vetiveria Sp.) (SB+Vg),* soil bund with Elephant grass (*Pnnisetum purpureum*) *(SB+Eg),* and soil bund with *Susbania susban (SB+Ss).*

Soil bunds in the watershed were constructed based on the soil and water conservation guideline of the Ministry of Agriculture (MoARD, 2005). The horizontal distance between two successive soil bunds was determined based on the vertical interval (HI) between bunds (usually 1 m for Ethiopia) and the slope angle (Ludi, 2004). The dimensions of the bund were 1.2 m bottom width, 0.3 m top width, 0.5 m height and 1:2 side slope (MoARD, 2005). Grasses and shrubs were planted on the riser of the bund during the main rain season.

(iii) Identifying criteria. The criteria are the measures of performance by which the options/ alternatives are judged (Hajkowicz, 2008; Salgado *et al*. 2009). A large proportion of the 'value-added' by a MCA process derives from establishing a sound set of criteria against which, the alternatives is judged. These criteria serve as the performance measures for the MCA (Salgado *et al*., 2009; Merad *et al*., 2013). A measurement or judgment needs to specify how well each option meets the objectives expressed by the criteria.

Usually, farmers aim at multiple objectives with SWC practices, such as reduced soil loss, improved soil fertility, increased crop yield and increased income. Farmers were asked to list criteria they would like to consider in the preference of SWC practices. Eleven criteria were defined after focus group discussions. These criteria included reduced soil loss, reduced nutrient loss, improved soil fertility, retained soil moisture, increased crop yield, increased fodder, maximised cultivable land, low labour requirement, suitability for free grazing and easy for maintenance. These criteria reflected the advantages and disadvantages of the different SWC practices. These criteria can be categorised into technical, economical and stability (Table 1).

(iv Determining the effects of alternatives. Farmers prioritised different SWC practices by giving scores based on each criterion from the scale of 1 for not good to 5 for the best. The scores were averaged scores for the two focus groups.

(v) Standardising the effects of alternatives. This step aims at eliminating the effect of inconsistent scoring of alternatives. After farmers and experts had given scores to the alternatives based on the criteria, the scores were standardised using the following equation (Eq. 1) (Hajkowicz, 2008).

$$v'ji = (vji - Minvj)/(Maxvj - Minvj) \quad \text{(Eq. 1)}$$

Where v' = standardised score, i = alternative i, j = criterion j, v = unstandardised score, Maxvj = highest score of criterion j, Minvj = lowest score of criterion j

(vi) Ranking the criteria. Using FGDs, the list of criteria from the farmers' perspective was developed. A pair-wise ranking matrix approach was used for weighing these criteria. The list of criteria was written both on the top and on the left side of the matrix. The criteria were weighted in pairs each at a time and the dominant ones were written in the matrix. The FGDs were asked to make comparative judgments on the relative importance of each pair of criteria. In cases of lack of consensus, group members voted by raising hands. This was repeated for each pair until the entire matrix was completed. These judgments were used to assign relative weights to the criteria. The results of ranking were expressed as weight (Eq. 2), which is the ratio of the total scores for individual criteria to the overall scores for all criteria (Howard 1991; Zanakis *et al.*, 1998). Similar to scoring of alternatives, the relative importance of criteria for farmers was obtained by averaging the weights of both focus groups.

$$Wj = St/(\sum_{j-1}^{n} Sa) \quad \text{(Eq. 2)}$$

Where, *St* is total score for individual criteria, *Sa* is the overall scores for all criteria and *Wj* is the weight for criteria j

(vii) Aggregating results and ranking alternatives. The Simple Additive Weighting (SAW) model (Howard, 1991; Zanakis *et al.*, 1998; Ananda and Herath, 2009) was used to obtain the overall weighted scores for each alternative (SWC practices). This was done by multiplying

TABLE 1. Soil and water conservation evaluation criteria of farmers in the central highlands of Ethiopia

Technical criteria	Economic criteria	Stability criteria
Reduce soil loss (SL)	Increased crop yield (CY)	Easy stablised (ES)
Reduce nutrient loss (NL)	Increase fodder (IF)	Easy for maintenace (EM)
Improve soil fertility (SF)	Maximise cultivable area (CL)	Suitability for free grazing (FG)
Retain soil moisture (SM)	Low labour requirement (LR)	

the value of score on each criterion by the weight of that criterion, and then adding all those weighted scores together (Eq. 3). The alternative with the highest total weighted score was considered as the most preferred SWC practices.

$$P\,i = \sum_{j=1}^{j} wj * v'ji \qquad \text{(Eq. 3)}$$

Where, Pi is overall weighted score of alternative i, wj is weight to criterion j, v'ji is standardised score of criterion j for alternative i

RESULTS AND DISCUSSION

Soil and water conservation scores. Results for the farmers' scores of the SWC practices are presented in Table 2. The values reflected the perceived degree of importance of each SWC practices based on their criteria. Generally, farmers gave higher scores for criteria related to technical effectiveness for most SWC alternatives (SB+Vg, SB+EG and SB+Ss). This implies that these SWC practices are more technically effective than economically efficient. The overall average shows that farmers gave the highest total score for SB+Eg followed by SB+Ss and SB+Vg. In all criteria, farmers gave the lowest total score for soil bund alone (SB). This is because, in SB alone, there is no grass or shrub to improve its technical effectiveness and financial efficiency. A study in the central highlands of Ethiopia shows that SB alone reduced crop yield by about 7 percent, which is entirely explained by the reduction of the cultivable area by 8.6 per cent (Adimassu *et al*., 2012b). Similar results were reported in the highland areas in Ethiopia that soil and stone bunds decreased crop yield for

TABLE 2. Farmers' average scores[1] of different SWC practices[2] based on evaluation criteria

Criteria	Alternative			
	SB	SB+Vg	SB+Eg	SB+Ss
Technical criteria				
Reduce soil loss (SL)	3	4	5	4
Reduce nutrient loss (NL)	2.5	4	5	4.5
Improve soil fertility (SF)	2.5	4	3.5	4.5
Retain soil moisture (SM)	2.5	4.5	4.5	4.5
Average	2.63	4.13	4.50	4.38
Economic criteria				
Increased crop yield (CY)	2	3.5	4	4.5
Increase fodder (IF)	1	3	5	4
Maximise cultivable area (CL)	2	2.5	3	3
Low labour requirement (LR)	3	3	2.5	3
Average	2.00	3.00	3.63	3.63
Stability criteria				
Easly stablised (ES)	2.5	3.5	4	3.5
Easy for maintenace (EM)	3.5	3	4	3
Suitability for free grazing (FG)	3	3	1.5	1.5
Average	3.00	3.17	3.17	2.67
Over all average score	2.50	3.45	3.82	3.64

[1] Scores; 5 = Best, 4 = Very good, 3 = Good, 2 = Average, 1 = Not good

[2]SB = Soil bund alone, SB+Vg = Soil bund with Vetiver grass, SB+Eg = Soil bund with Elephant grass, SB+Ss = Soil bund with *Susbania susban*

the first 5 years (Shiferaw and Holden, 1999). This implies that suitable measures are needed to compensate the yield losses caused by the construction of soil bunds. So, it is crucial to plant grasses and shrubs on soil bunds to re-enforce the structures and increase the financial efficiency of the soil bunds.

Aggregating the results and ranking SWC practices. Table 5 presents the aggregated results of SWC practices on the evaluation criteria related to technical effectiveness, economic efficiency and stability. Both Table 2 (unstanderdised scores) and Table 4 (standardised scores) show that most SWC practices (except SB) are technically effective to reduce soil and nutrient and retain soil moisture as compared to their economic criteria. Nevertheless, Table 5 shows that the highest aggregate score values are given for economic criteria as opposed to results in Tables 2 and 4. This is due to the fact that farmers gave the highest relative importance for economic criteria (58%) as compared to technical criteria (29%) and stability criteria (13%) (Table 3).

Generally, the overall score of the MCA shows that *SB+Eg* is the first preferred SWC practices followed by *SB+Ss and SB+Vg* (Table 5, Table 6). Farmers prefer SB as the least alternative**.** The ranks of alternatives based on unstanderdised, standerdised and agregated scores related to technical, economic and stability criteria are presented in Table 6. The trend of ranks is similar in unstanderdised, standerdised and agregated scores. In terms of technical criteria, SB+Ss, SB+Eg, SB+Vg and SB are 1st, 2nd, 3rd, and 4th, respectively. In terms of economic criteria, SB+Eg, SB+Ss, SB+Vg and SB are 1st, 2nd, 3rd, and 4th, respectively. The result shows that soil bunds become technically effective and economically visible when they are integrated with grasses or shrubs. This implies that farmers want to maximise their economic benefit by utilising the soil bunds (risers) and reduce the maintainance cost. Research show that farmers are sensitive to economic returns and invest in technologies that offer highest net economic returns (Shiferaw *et al.*, 2009). Their decision to invest in SWC technologies is affected by the (perceived) profitability of the technology (Getinet, 2008).

TABLE 3. Farmers' pair-wise ranking and relative weights of SWC criteria

Criteria	Pairwise ranking										Score	Weight
	SL	NL	SF	SM	CY	IF	CL	LR	ES	EM	FG	
Reduce soil loss (SL)	NL	SF	SM	CY	IF	CL	SL	SL	SL	FG	3	0.055
Reduce nutrient loss (NL)		NL	NL	CY	IF	CL	NL	ES	EM	FG	4	0.073
Improve soil fertility (SF)			SF	CY	IF	CL	LR	SF	SF	SF	5	0.091
Retain soil moisture (SM)				CY	IF	CL	LR	SM	SM	SM	4	0.073
Increased crop yield (CY)					CY	CY	CY	CY	CY	CY	10	0.181
Increase fodder (IF)						CL	IF	IF	IF	IF	8	0.145
Maximise cultivable area (CL)							CL	CL	CL	CL	9	0.163
Low labour requirement (LR)								LR	LR	LR	5	0.091
Easily stablised (ES)									ES	ES	3	0.055
Easy for maintenace (EM)										EM	2	0.036
Suitability for free grazing (FG)											2	0.036

TABLE 4. Standardised scores of farmers for SWC practices

Criteria	Alternative			
	SB	SB+Vg	SB+Eg	SB+Ss
Technical criteria				
Reduce soil loss (SL)	0.000	0.500	1.000	0.500
Reduce nutrient loss (NL)	0.000	0.600	1.000	0.800
Improve soil fertility (SF)	0.000	0.750	0.500	1.000
Retain soil moisture (SM)	0.000	1.000	1.000	1.000
Average	0.000	0.713	0.875	0.825
Economic criteria				
Increased crop yield (CY)	0.000	0.750	1.000	1.250
Increase fodder (IF)	0.000	0.500	1.000	0.750
Maximise cultivable area (CL)	0.000	0.500	1.000	1.000
Low labour requirement (LR)	1.000	1.000	0.000	1.000
Average	0.250	0.688	0.750	1.000
Stability criteria				
Easly stablised (ES)	0.000	0.666	1.000	0.666
Easy for maintenace (EM)	0.500	0.000	1.000	0.000
Suitability for free grazing (FG)	1.000	1.000	0.000	0.000
Average	0.500	0.555	0.667	0.222
Overall average score	0.227	0.661	0.773	0.724

TABLE 5. MCA ranking (standerdised) of the different SWC practices by farmers in Borodo watershed

Criteria	Alternative			
	SB	SB+Vg	SB+Eg	SB+Ss
Technical effectiveness				
Reduce soil loss (SL)	0.000	0.028	0.055	0.028
Reduce nutrient loss (NL)	0.000	0.044	0.073	0.058
Improve soil fertility (SF)	0.000	0.068	0.046	0.091
Retain soil moisture (SM)	0.000	0.073	0.073	0.073
Sub-total score	0.000	0.213	0.247	0.250
Economic efficiency				
Increased crop yield (CY)	0.000	0.136	0.181	0.226
Increase fodder (IF)	0.000	0.073	0.145	0.109
Maximise cultivable area (CL)	0.000	0.082	0.163	0.163
Low labour requirement (LR)	0.091	0.091	0.091	0.091
Sub-total score	0.091	0.382	0.580	0.589
Stability criteria				
Easly stablised (ES)	0.000	0.037	0.055	0.037
Easy for maintenace (EM)	0.018	0.000	0.036	0.000
Suitability for free grazing (FG)	0.036	0.036	0.000	0.000
Sun-total score	0.054	0.073	0.091	0.037
Overall score (Pi)	0.145	0.666	0.918	0.876

Farmers' rank of SWC alternatives based on Pi: SB+Eg> SB+Ss> SB+Vg> SB

This affects the adoption of SWC technologies. Studies on the adoption and continuous use of stone terrace in Tanzania and Ethiopia revealed that farmers' investments are highly influenced by the (perceived) profitability of the SWC technologies (Tenge *et al.*, 2004; Amsalu and De Graaff, 2007).

This implies that improving the productivity of conservation structures using grasses and shrubs can provide opportunities for enhancing the adoption of the technologies. Nevertheless, the de facto free-grazing system (including open access during dry period) exercised in the study area poses serious limitations to grow these grasses and shrubs that (German *et al*., 2008). Therefore, a new land use policy that restricts free grazing and improves the productivity of SWC measures such as soil bunds is required at different administrative levels in the Ethiopian highlands.

CONCLUSION

Farmers have several criteria to select SWC practices. They also assign the highest score for criteria related to economic efficiency and prefer SWC practices that have the highest economic benefits. There is a need to strengthen participatory planning with farmers and develop best future alternatives; for example, by finding niches for improving the economic efficiency of SWC practices.

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