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Evaluation of Existing Soil Conservation Measures in Central Highlands of Sri Lanka Through Participatory Approach

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Abstract:** The central highland of Sri Lanka is highly vulnerable to soil erosion. A number of programmes supported by donor funded projects have been implemented within the last three decades with the aim of sustainable management of land resources. However, farmers are reluctant to adopt measures to reduce the soil erosion and even when soil conservation structures are adopted, farmers fail to manage them. Hence, this study was conducted to assess the adoptability of different soil conservation options in central highlands of the country. Multi Criteria Analysis was applied with the participation of farmers and field officers to assess existing soil conservation options. The assessment was based on physical effectiveness, economic viability and the social acceptability of soil conservation measures. According to the evaluation of farmers and field officers, forward-slope terraces, reversed- slope terraces, bench terraces, grass strips and mulching are the best five conservation measures among evaluated options and bench terraces has been ranked to be the most effective soil conservation technology. Selection of soil conservation measures is highly dependent on the assumed benefits, input cost and personal attitudes of the individual farmer. Hence, an effective mechanism to change farmers' attitudes may significant to mobilize them towards modified conservation techniques.
***Keywords:** Farmers' attitudes, Multi criteria analysis, Participatory approach, Soil conservation, Soil erosion*

Introduction

Soil conservation (SC) has a long history in central highlands of Sri Lanka and various biological, cultural and physical soil conservation technologies are already exist. However, most of the land users have short term profit maximizing objectives while neglecting the need to protect soils for sustainable agriculture. Thus, soil conservation activities have become essential and included into every watershed management project launched in the country. Researchers have developed technologies and farming practices to reduce the impacts of soil erosion both on and off farm. There are several approaches implemented in many countries with the task of putting soil conservation into practice. The most common concept is to convince farmers of adverse impacts of soil erosion and makes them aware of the importance of soil conservation (Swanson *et al*., 1986; Nowak, 1987). Another approach is to use financial incentives to motivate the adoption of conservation measures. Common example is paying subsidies for the construction of approved works. The problem associated with this approach is farmers often neglect the maintenance of conservation structures when the subsidy program is over. Enforcing adoption of conservation measures through legislation is commonly practiced in many countries including Sri Lanka. These legislations come into practice in the form of withholding benefits until certain conservation practices are adopted. A penalty for violating legislations is another approach. In general, to be effective any strategy for soil conservation must have social acceptance. Hence, it must be a bottom-up movement, but not top-down instructions.

A number of programmes supported by donor funded projects have been implemented within the last three decades with the aim of sustainable management of land resources. There have been approximately 18 foreign funded projects pertaining to the protect natural resources since 1975 (Jayakody *et al*., 2005). All these projects have contributed in different ways by implementing variety of programs to conserve natural resources including soil and water. Generally, farmers are reluctant to adopt measures to reduce the soil erosion and even when soil conservation structures are adopted, farmers fail to manage them. According to Kerr and Sanghi (1992) adoption of recommended conservation measures was not much popular among farmers as they fail to produce perceptible economic gains. The low rate of acceptance of recommended practices can be attributed to the low tangible benefits from soil conservation measures (Pagiola 1999). On the other hand, water-harvesting structures are well maintained by the farmers due to higher economic benefits because of irrigation. Therefore, without any appreciable increase in internal economic incentives from soil conservation, farmers will not prefer such practices.

Multi Criteria Analysis (MCA) facilitates to integrate farmers preference and technical effectiveness of soil conservation measures to come up with best suited option and possible modifications. Thus, this paper discusses the possibilities of applying Multi Criteria Analysis in a participatory way to assess the adoptability of different soil conservation options in central highlands of Sri Lanka.

Methodology

Sampling for data collection

Data collection of this study involved questionnaire based household survey and group discussions. The sample size was 156 for household survey and a random sample of 50 farmers was selected for the farmers' group discussions. Thirty five field level agricultural officers were participated for officers' discussions as well. All the ranking exercises were conducted during discussions in order to get the equal participation of each and every participant.

Through household survey, farmers' objectives regarding land management were identified. The identified objectives were then confirmed by farmers during stakeholder meetings. These objectives were basically based on physical effectiveness, financial efficiency and the social acceptability. Soil, water and nutrient conservation were mainly considered under physical effectiveness. Financial efficiency covered increase crop yield and the cost incurred on labour, material and maintenance of conservation measures. Social acceptance included convenience for irrigation and other cultural practices and the simplicity (skill requirement).

The farmers and field officers were asked to list out the objectives of soil conservation. Similarly selection criteria were formed based on farmers' experiences and field officers' knowledge (Table 01). All the available soil conservation options (methods) were also identified by household survey and stakeholder meetings.

Evaluation of available soil conservation options

In the second step, all available soil conservation options were evaluated separately by farmers and field officers based on selected objectives. Soil conservation options were compared by giving scores to each criterion on the scale of 1 for not good and 4 for very good. The options with the highest total scores were then short listed for further analysis. Then the relative importance of each criterion was determined separately by farmers and field officers through pair-wise ranking method. The results of ranking exercise were expressed as weights (w_j), which is the ratio of the total scores for individual criterion to the overall score for all criteria (Defoer and Hilhorst, 1995).

Then the actual effects of alternative options were evaluated. The quantitative effects were determined by reviewing relevant literature findings. The qualitative effects were determined using appropriate PRA tools. Since the effects

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were measured in different units, standardization of the effects is a key factor in order to eliminate the influence of different units. Basically two standard methods were used for standardization in MCA. Method 1 (eq.1) is recommended if the effects are measured in ratio scale. The second method (eq.2) is more appropriate if the effects are expressed in interval scale (De Graff, 1996; Tenge *et al*., 2004).

$$Kji = {}^{Sji}/_{\max Sj} \quad \text{- eq (1)}$$

$$Kji = {}^{Sji - min\ Sj}/_{max\ Sj - minSj} \quad \text{- eq (2)}$$

Where,

k = standardized criterion

i = alternative i

j = criterion j

s = un standardized score

min s_j= lowest score of criterion j

max s_j= highest score of criterion j

If a criterion has a negative effect the standardized score is calculated as (1- k_{ji})

Last step involved aggregating the weighted scores for each alternative. The most common method of combining weights is the additive weighing method (eq. 3). The total weighted scores were then arranged in descending order. The alternative with the highest value of total scores (Ti) was selected as the best alternative.

$$Ti = \sum_{j=1}^{j} \mathbf{Wj} * \mathbf{Kji} \text{ ----------- (eq 3)}$$

Where,

T_i = score of alternative i

w_j = weight to criterion j

k_{ji}= standardized score of criterion j for alternative i

Results and Discussion

Soil conservation alternatives

Alternatives for achieving objectives include physical, cultural and biological soil conservation measures. Ten different conservation measures namely Forward-Slope Terraces (FT), Reversed- Slope Terraces (RT), Bench Terraces (BT), Stone Wall (SW), Lock and Spill drain (LS), Hedgerows (HW), Sloping Agricultural Land Technology (SL), Earth Bunds (EB), Grass Strips (GS) and Mulching (MC) were identified by farmers and field officers. Without Soil Conservation (WC) also included as an option to compare the results. According to matrix ranking by farmers, the five most important are Reversed- Slope Terraces (RT), Bench Terraces (BT), Forward-Slope Terraces (FT) Grass Strips (GS) and Mulching (MC) (Table 02). Field officers also ranked same conservation measures as first five options (Table 03).

Pair-wise ranking to determine weights of evaluation criteria

The relative importance of evaluation criteria and weights (w_j) given by farmers and field officers are indicated in Tables 02 and 03. The results reveal that farmers have given relatively high importance to effectiveness in soil conservation, soil fertility development and soil moisture retention. This reflects farmers' willingness on physical effectiveness of soil conservation measures than other selection criteria. Giving more weightage to physical effectiveness is an interesting factor because it indicates that farming community can be mobilized to a certain extent to adopt modern technology. They also have considered crop yield, labour cost and the simplicity as important criteria to evaluate soil conservation options. Other criteria are less important according to farmers' assessment and the lowest weight of zero was given to the irrigation possibility. The field officers have same criteria as farmers but they slightly differ in the weights attached to each (Table 03). According to the field officers point of view important criteria are soil loss, improvement of soil fertility and water conservation. This indicates that there is no much difference between farmers and field officers regarding selection criteria of conservation measures. The results further shows that field officers give relatively low importance to simplicity and relatively higher importance to irrigation possibility compared to farmers assessment. Since field officers have better awareness on soil conservation structures they are not much bother about the simplicity. However, farmers have to face many difficulties in constructing structures according to standard measurements. The importance of irrigation is realized by field officers and gave more weightage compared to farmers' assessment. Field officers also have not attached much importance to the maintenance cost because they believe that family labour is sufficient enough to maintain conservation structures.

Physical effectiveness

Physical effectiveness of selected conservation options were derived from a review of relevant literature about respective SC measures. Results revealed that, reversed slope terraces are very much effective in arresting soil erosion followed by bench terraces and mulching. But forward slope terraces and grass strips are not that effective with respect to soil conservation. When consider average nutrient loss, reversed slope terraces are better than all other options. However, nutrient loss from bench terraces and mulched plots are also comparable to reversed slope terraces. Highest moisture retention was recorded from mulched plots but moisture levels of reversed slope and bench terraces were also not much deviated from the highest level. Forward slope terraces and grass strips are not physically effective as soil conservation measures compared to other three options. Without conservation situation is not good in all aspects of physical effectiveness. These results are slightly different from farmers' ranking. For instance, they ranked FT as better than MC in soil loss and nutrient loss (Table 02). However, field officers' ranking is comparable to actual results obtain from literature survey. This observation implies that there is a knowledge gap or difference in farmers' perception on the effects of the SC options. There is a common argument that extension service of Sri Lanka is not appropriate and hence knowledge transferring is one of the lacking part in agriculture. However, Bandara and Thiruchelvam (2008) emphasized that, even though, the extension services are satisfactorily available, farmers are not following the advice given by the extension officers, because they believe that they are more experienced and knowledgeable than the extension officers. Different farmers may have different attitudes towards selection of soil conservation techniques. Sometimes farmers who have positive attitudes also may not practice appropriate soil conservation options due to the socio-economic constraints.

Economic viability

The effects of SC options on economic viability were also derived from household survey, expert judgments and the review of relevant literature. The results in Table 06 show that, highest crop yield recorded from BT followed by RT. However, labour and maintenance cost of these two is comparatively higher than other evaluated options. Though, GS and MC show higher material cost, labour and maintenance costs are much lower. These results indicate that RT and BT are good in increasing crop yield but average in other criteria used to evaluate economic efficiency. The without conservation option is not good with regard to crop yield but it has zero labour, material and maintenance cost. This confirms farmers' perception, as shown in Table 02, that the BT, RT and FT are not good in terms of labour cost but FT is much better in terms of maintenance cost.

Social acceptability

Since social acceptability can only be expressed in qualitative terms, ranking was applied to measure irrigation possibility, convenient for land preparation and skills required to construct SC options. Ranking was done based on available literature. Bench terraces were ranked better for irrigation potential and convenient for agronomic practices, but these are not effective in terms of simplicity because construction of BT need some skills and technical knowledge. Other types of terraces are also convenient for farm operations but average to not good with regards to irrigation potential and simplicity. These results are not much different from farmers' and field officers' ranking in the evaluation of SC options (Tables 02 & 03).

Final ranking of the soil conservation options

The results of the final evaluation were obtained using Equation 3. Results show that farmers and field officers have ranked six options in more or less similar order (Table 07). According to farmers' evaluation, BT is the best option followed by FT, RT, MC, WO and GS. All types of terraces have come very close and RT and FT have become second best option. The ranking results of field officers also indicate that BT is the best option followed by RT and FT. However, the difference between RT and FT is much higher compared to the farmers' evaluation. This difference is mainly due to the weightage given to the evaluation criteria by two actor groups (Tables 04 & 05). In the preliminary evaluation, farmers have selected FT as the best soil conservation option (Table 02). However, final evaluation reveled that BT is the best option among tested soil conservation measures. This indicates that, though farmers have some kind of sense on soil conservation they are not fully aware on the effectiveness on soil conservation options. On the other hand, field officers have selected BT as the best option in both preliminary and the final evaluation (Table 03). From the field officers point of view, important objective is reduction of soil loss and improvement of soil fertility. However, farmers give relatively high importance to reduced material and labour cost. Field officers do not attach high importance to social aspects possibly due to lack of social coherence. Today cultivation of any crop is a costly activity. Cost components are planting materials, fertilizer and other chemicals, irrigation, machinery, labour and soil conservation. They can be categorized as input cost, labour cost, cost for power and soil conservation cost. When farmers want to cut down production cost they simply reduce soil conservation cost because it does not show any short term effect. Whatever the farmers' knowledge on soil erosion they have neutral perception towards the soil conservation. Therefore, a government intervention is needed to treat the farmers' weaknesses on soil conservation practices. An appropriate subsidy system is urgently needed to improve farmers' adoption of soil conservation. Introducing low cost modifications to improve existing soil conservation measures is an essential issue.

Conclusions

When evaluating soil conservation options, both farmers and field officers have attached a relatively high importance to physical effectiveness mainly for soil conservation, soil fertility development and moisture retention in the soil. According to the evaluation of farmers and field officers, FST, RT, BT, GS and MC are the best five conservation measures among evaluated options and BT has been ranked to be the most effective soil conservation technology. Forward sloping terraces is the widely adopted soil conservation measure in the catchment and the main problem encountered in this technique is instability due to unprotected riser slope and the edge of the terrace. Planting hedgerows for soil conservation is not socially acceptable technique. Hence, it is rarely popular among farming community. This may be a possible reason for the failures of some donor funded soil conservation projects which highly promoted SALT system in selected sub catchments of the central highlands of the country. Selection of SC measures is highly dependent on the assumed benefits, input cost and personal attitudes of the individual farmer. Hence, an effective mechanism to change farmers' attitudes may significant to mobilize them towards modified conservation techniques.

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Table 01: Objectives and criteria in selection of soil conservation options

Objectives	Criteria	Unit of measurements
Physical effectiveness		
Soil conservation	Minimize soil loss	t ha^{-1} per year
Increase soil fertility	Minimize nutrient loss	kg ha^{-1}
Water conservation	Maximize moisture retention	Soil moisture content (%)
Economic viability		
Increase crop yield	Maximize crop yield	kg ha^{-1}
Labour requirement	Minimize labour cost	LD* ha^{-1}
Material requirement	Minimize material cost	Rs ha^{-1}
Maintenance cost	Minimize maintenance cost	Rs ha^{-1}
Social acceptability		
Possibility of irrigation	Maximize irrigation possibility	Rank
Convenience for other agronomic practices	maximize tillage convenience	Rank
Simplicity	Minimize skill requirements	Rank

LD* - Labour Days

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Table 02: Farmers' evaluation of soil conservation options

Physical effectiveness	FT	RT	BT	SW	LS	HR	SL	EB	GS	WC	MC
Soil loss	3	4	3	3	2	3	4	2	2	1	2
Nutrient loss	3	3	3	2	2	3	2	2	2	1	2
Moisture retention	2	4	3	2	3	3	3	2	2	1	4
Economic viability											
Crop yield	1	3	3	2	2	3	3	2	3	1	3
Labour cost	3	2	2	1	1	2	1	1	3	4	2
Material cost	3	3	3	1	3	2	2	3	2	4	2
Maintenance cost	4	2	2	2	1	2	1	2	3	4	2
Social acceptability											
Irrigation possibility	2	2	3	3	2	1	1	2	2	1	2
Convenient for cultural practices	3	3	3	3	2	2	1	3	2	2	2
Simplicity	4	1	2	2	2	1	1	3	3	4	3
Total	28	27	27	21	20	22	19	22	24	23	24
Rank	1	2	2	9	10	7	11	7	4	6	4

Scores: 4 = Very good, 3= Good, 2= Average, 1= Not good

Forward-Slope Terraces (FT), Reversed- Slope Terraces (RT), Bench Terraces (BT), Stone Wall (SW), Lock and Spill drain (LS), Hedgerows (HW), Sloping Agricultural Land Technology (SL), Earth Bunds (EB), Grass Strips (GS) Mulching (MC), Without Soil Conservation (WC)

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Table 03: Field officers' evaluation of soil conservation options

Physical effectiveness	FT	RT	BT	SW	LS	HR	SL	EB	GS	WC	MC
Soil loss	2	4	3	3	2	3	4	2	2	1	3
Nutrient loss	2	3	3	2	2	3	2	2	2	1	3
Moisture retention	1	4	3	2	3	3	3	2	2	1	4
Economic viability											
Crop yield	2	3	3	2	2	3	3	2	3	1	3
Labour cost	3	2	2	1	1	2	1	1	3	4	2
Material cost	4	4	4	1	3	2	3	3	3	4	3
Maintenance cost	3	2	2	2	1		1	2	2	4	2
Others											
Irrigation possibility	2	2	3	3	2	1	1	2	2	1	2
Convenient for cultural practices	2	3	3	3	2	2	1	3	2	2	2
Simplicity	3	1	2	2	2	1	1	3	3	4	4
Total	24	28	28	21	20	20	20	22	24	23	28
Rank	4	1	1	8	9	9	9	7	4	6	1

Scores: 4 = Very good, 3= Good, 2= Average, 1= Not good

Forward-Slope Terraces (FT), Reversed- Slope Terraces (RT), Bench Terraces (BT), Stone Wall (SW), Lock and Spill drain (LS), Hedgerows (HW), Sloping Agricultural Land Technology (SL), Earth Bunds (EB), Grass Strips (GS) and Mulching (MC), Without Soil Conservation (WC)

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Table 04 Farmers' pair-wise ranking of evaluation criteria

Criteria	SL	N	W	C	L	M	MT	I	CP	S	Score	Weight (w_j)
Soil loss (SL)	x	SL	SL	SL	SL	SL	SL	SL	SL	SL	9	0.2
Nutrient loss (N)		x	N	N	N	N	N	N	N	N	8	0.17
Moisture retention (W)			x	C	W	W	MT	W	W	S	4	0.09
Crop yield (C)				x	C	C	C	C	C	S	6	0.13
Labour cost (L)					x	L	L	L	L	S	4	0.09
Material cost (M)						x	MT	M	M	S	2	0.04
Maintenance cost (MT)							x	MT	MT	S	4	0.09
Irrigation possibility (I)								x	CP	S	0	0
Convenient for cultural practices (CP)									x	S	1	0.02
Simplicity (S)										x	7	0.16
Total											45	

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Table 05: Field officers' pair-wise ranking of evaluation criteria

Criteria	SL	N	W	C	L	M	MT	I	CP	S	Score	Weight (w_j)
Soil loss (SL)	x	SL	SL	SL	SL	SL	SL	SL	SL	SL	9	0.2
Nutrient loss (N)		x	N	N	N	N	N	N	N	N	8	0.17
Moisture retention (W)			x	W	W	W	W	W	W	W	7	0.16
Crop yield (C)				x	C	C	C	C	C	C	6	0.13
Labour cost (L)					x	L	L	L	L	S	4	0.09
Material cost (M)						x	M	M	M	S	3	0.06
Maintenance cost (MT)							x	I	MT	S	1	0.02
Irrigation possibility (I)								x	CP	I	2	0.04
Convenient for cultural practices (CP)									x	S	1	0.02
Simplicity (S)										x	4	0.09
Total											45	

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Table 06: Effectiveness of selected soil conservation options

Objective	Criteria and units	RT		BT		FT		GS		MC		WC	
Physical effectiveness		Actual	Standardized (K_{ij})	Actual	standardized (K_{ji})	Actual	Standardized (K_{ij})	Actual	Standardized (K_{ji})	Actual	Standardized (K_{ji})	Actual	Standardized (K_{ji})
Soil conservation	Average soil loss (t ha^{-1}) 30% slope	5	0.9	8	0.8	25	0.5	30	0.4	18	0.6	45	0
Increase soil fertility	Average nutrient (N, P, K) loss (kg ha^{-1})	3	0.9	4	0.8	10	0.6	14	0.4	10	0.6	25	0
Water conservation	Moisture retention (%)	28	0.9	26	0.8	21	0.7	18	0.6	31	1	19	0.6
Economic viability													
Increase crop yield	Crop yield (tomato)(t ha^{-1})	16.5	0.9	17.5	1	12.0	0.7	10.0	0.6	12.0	0.7	7.8	0.4
Labour requirement	Labour cost (LD ha^{-1})	320	0	275	0.1	225	0.3	25	0.9	10	0.97	0	1
Material requirement	Material cost (Rs ha^{-1})	2500	0.8	3000	0.8	2000	0.9	10000	0.3	15000	0	0	1
Maintenance cost	Maintenance cost (Rs ha^{-1})	12000	0	9000	0,3	5000	0.6	5000	0.6	3000	0.8	0	1
Social acceptability													
Irrigation	Irrigation possibility (Rank*)	2	0.3	4	1	2	0.3	1	0	1	0	1	0
Other agronomic practices	Convenience for land preparation (Rank**)	3	0.6	4	1	3	0.6	2	.3	1	0	2	.3
Simplicity	Skill requirement (Rank***)	1	0	1	0	3	.6	2	.3	2	.3	4	1

*Rank: (1- 4) 1= low, 4 = High **Rank: (1- 4) = 1= less convenience, 4 = more convenience ***Rank: (1- 4) = 1= high, 4 = low Forward-Slope Terraces (FT), Reversed- Slope Terraces (RT), Bench Terraces (BT), Grass Strips (GS), Mulching (MC), Without Soil Conservation (WC) **Sources**: Department of Agriculture, Sri Lanka (unpublished), Nayakekorala, (1997), Anonymous, (2000).

Table 07: MCA ranking of the SC measures for KurunduOya catchment by farmers and field officers

Criteria	Weighted scores												
	Farmers							Field officers					
Physical effectiveness	RT	BT	FT	GS	MC	WC		RT	BT	FT	GS	MC	WC
Soil loss	.18	.16	.09	.07	.08	0		.18	.16	.09	.07	.08	0
Nutrient loss	.15	.14	.10	.07	.06	0		.15	.14	.10	.07	.06	0
Moisture conservation	.08	.07	.06	.05	.09	.05		.14	.13	.11	.09	.16	.09
Economic viability													
Crop yield	.12	.13	.09	.07	.08	.06		.12	.13	.09	.07	.08	.06
Labour cost	0	.01	.03	.08	.08	.09		0	.01	.03	.06	.07	.07
Material cost	.03	.03	.03	.01	0	.04		.05	.05	.05	.02	0	.06
Maintenance cost	0	.02	.05	.05	.06	.09		0	0	.01	.01	.01	.02
Social acceptability													
Irrigation	0	0	0	0	0	0		.01	.04	.01	0	0	0
Convenience for operations	.01	.02	.01	0	0	0		.01	.02	.01	0	0	0
Simplicity	0	0	.11	.04	.04	.13		0	0	.05	.03	.03	.08
Total	.57	.58	.57	.43	.49	.46		.65	.68	.55	.42	.49	.38
Rank	2	1	2	6	4	5		2	1	3	5	4	6

Forward-Slope Terraces (FT), Reversed- Slope Terraces (RT), Bench Terraces (BT), Grass Strips (GS), Mulching (MC), Without Soil Conservation (WC)

