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PROFITABILITY OF SOIL EROSION CONTROL TECHNOLOGIES IN EASTERN UGANDA HIGHLANDS

M. BARUNGI[1,2], D.H. NG'ONG'OLA[1], A. EDRISS[1] and J. MUGISHA[3]
[1]Department of Agricultural and Applied Economics, Faculty of Development Studies,
Bunda College of Agriculture, University of Malawi
[2]Economic Policy Research Centre, Plot 51, Makerere University, Kampala, Uganda
[3]Department of Agribusiness and Natural Resource Economics, College of Agricultural and Environmental
Sciences, School of Agricultural Sciences, Makerere University, P. O. Box 7062, Kampala, Uganda
Corresponding author: mbarungi@eprc.or.ug

ABSTRACT

The lack of farmer awareness of costs and benefits associated with the use of sustainable land management (SLM) technologies is one of the major constraints to technology adoption in sub-Saharan Africa. The objective of this study was to estimate the profitability of application of SLM in the form of soil erosion control technologies by communities in the highlands of eastern Uganda; a hot spot for this land degradation agent. A survey was conducted using 240 farmers in the highlands of eastern Uganda. The findings from Partial Budget Analysis indicate that the net returns associated with the use of soil erosion control technologies, are sufficiently high to offset the costs involved. For example, for every US$ invested per hectare in terracing and tree planting, there is a return of over US$ 15. However, these returns are likely to be much less if inflation is not regulated. For example, the profits expected from the use of terraces and trees would reduce by about 3 percent if inflation rose to 30 percent. Thus, for the benefits to be sustainable, farmers have to regularly maintain the structures (terraces, contours, and trenches) and the vegetation (trees and grasses). Also, use of soil erosion control technologies would remain profitable only if the Central Bank fulfils its mandate of keeping inflation low and stable.

Key Words: Partial Budget Analysis, sustainable land management

RÉSUMÉ

Le manque de connaissance sur les coûts et les bénéfices liés à l'utilisation des technologies de la gestion durable de terres (SLM) est l'une des contraintes majeurs à l'adoption des technologies en Afrique Sub-Saharienne. L'objectif de cette étude était d'estimer la profitabilité de l'application les technologies SLM de lutte contre l'érosion par les communautés des hautes terres de l'Est de l'Uganda, un lieu de prédilection de cet agent de dégradation de sol. Une enquête était conduite utilisant 240 fermiers dans les terre de l'Est de l'Uganda. Les résultats de l'analyse du budget partiel indiquent que les bénéfices provenant de l'utilisation des technologies anti-érosives sont suffisamment élevés pour compenser les coûts impliqués. Par exemple, pour chaque US$ investi par hectare dans les travux de terracement et plantation d'arbre, il ya un bénéfice de plus de US$ 15. Par ailleurs, ces bénéfices sont vraissemblablement réduits si l'inflation n'est pas régulée. Par exemple, les profits attendus de l'utilisation des terraces et arbres plantés se trouveraient réduits de trois pourcent si l'inflation augmente de trente pourcent. Ainsi, pour que les bénéfices soient durables, les fermiers doivent régulièrement maintenir les structures (terraces, contours et trenchées) et la vegetation (arbres et herbes). Aussi, l'utilisation des technologies de contrôle de l'érosion du sol pourraient demeurer bénéfiques seulement si la Banque Centrale remplit correctement son mandat de garder l'inflation basse et stable.

Mots Clés: Analyse du budget partiel, gestion durable de terres

INTRODUCTION

Land degradation is the major challenge to improving agricultural production and productivity. Uganda's highlands, especially in the eastern part have been recognised as one of the key hotspots where land degradation, due to soil erosion, is rampant (NEMA, 2010). In these highlands, 60 to 90 percent of the land is affected by soil erosion (NEMA, 2010); yet effective technologies for erosion control are available. Such technologies include contours, terraces, trenches, agroforestry, and planting of grasses along contours and terraces. Although, many farmers (over 90 percent) in eastern Uganda's highlands use at least one of these technologies, the intensity of use (about 69 percent of cultivated land) is not sufficiently high for effective control of soil erosion (Barungi *et al.*, 2012).

Inadequate adoption of Sustainable Land Management (SLM) technologies is largely blamed for the uninterrupted rate of soil loss in the highlands. Moreover, adoption of soil and water management practices at the farm level is strongly influenced by profitability of the practices being considered. For example, Doss *et al.* (2003) noted that lack of farmers' awareness of the costs and benefits associated with utilisation of a new technology is as one of the major obstacles to farmers adopting improved technologies. Similarly, Tukahirwa (2002) reported that unless farmers can expect an economic return to their level of investment, there will be little incentive for them to adopt sustainable land management practices. Furthermore, Tukahirwa (2002) argues that it is wrong to assume that conservation technologies will be attractive to farmers simply because they protect the resource base.

In Uganda, according to the National Agriculture Research Policy that was enacted in 2005, every agricultural technology should be evaluated in terms of its costs and benefits, including the opportunity cost of the required inputs and the market prospects for increased output (MAAIF, 2004). However, limited research has been done in the area of measuring the costs and benefits of investing in soil conservation practices. For example, Ellis-Jones and Tenberg (2000) used the Net Present Value technique to evaluate the impact of trash lines and mulching on soil productivity in Kabale district, in southwest Uganda. The authors found that both technologies resulted into increased crop yields.These study results, besides being relatively old, it was limited in scope; it involved one district (Kabale) in one part of the country's highlands. Equally so, the study focused on barely two technologies (trash lines and mulching), out of the variety available in the country.The objective of this study was to estimate the profitability of application of sustainable land management in the form of soil erosion control technologies by communities in the highlands of eastern Uganda.

METHODOLOGY

Data and sources. A survey of 240 randomly selected farmers was carried out in Bukwo and Kween districts on the slopes of Mountain Elgon in eastern Uganda. Simple random sampling was done using a table of random numbers. The selected farmers were interviewed face-to-face using a semi-structured questionnaire, which had been pre-tested for effectiveness in the neighbouring village.The interviews were conducted during the months of March and April in 2011. The semi-structured questionnaire was used to leverage from the flexibility it offers to the interviewer to prompt and probe deeper into a given situation, and to explain or rephrase the questions if the respondent was unclear about the questions. The survey data were largely based on farmers' memory because, in Uganda, record keeping is not a regular practice among smallholder farmers.

Data were collected per estimated size of farmland to which a given soil erosion control technology was applied. Following the recommendation by Ellis-Jones and Tenberg (2000), the data collected to assess the profitability of soil erosion control technologies included: technologies adopted by farmers to control soil erosion, size (hectares) of cultivated land under soil erosion control technologies, cost of labour and non-labour inputs, and the monetary value of crop output.

The cost of hired labour hectare^{-1} was recorded for each farm operations for application of a given soil erosion control technology, e.g. establishing and maintaining contours and terraces, planting Napier grass cuttings and tree seedlings. Household labour was valued at its opportunity cost as estimated by hired labour prices in the study area. The cost of inputs such as Napier grass cuttings and tree seedlings were measured by the price paid by the farmer to obtain them. Additionally, the value of crop output was computed to represent income accrued hectare^{-1} following the use of soil erosion control technologies. Income was computed as the product of physical output of each crop grown using a given soil erosion control technology and the actual price at which the farmer sold the crop(s). For purely subsistence farmers, the average market price in the study area was used

Partial budget analysis. The profitability of soil erosion control technologies was measured by drawing partial budgets. Partial budgeting analysis is concerned with evaluating the consequences of the changes in farm practices that affect only part rather than the whole farm (Dillon and Hardaker, 1993). It is a way of analysing differences in costs and benefits of two or more competing enterprises or technologies (Norman *et al.*, 1995). Partial budgeting examines alternative plans for farms and estimates profitability (Castle *et al.*, 1987; CIMMYT, 1988). Upton (1987) defined a partial budget as a technique for assessing the benefits and costs of using a technology relative to not using the technology. It thus takes into account only those changes in costs and returns that result directly from using a new technology. The advantage of partial budget analysis is that it is less demanding of data compared to whole farm budgeting. It is not necessary to have information on parts of the farm not affected by the change under review since performance of these sectors remains constant. Also, partial budget analysis is typically applicable to a wider range of farm circumstances than is the case of whole farm budgets (Upton, 1987).

Using the Castle *et al.*'s (1987) approach, the partial budget was calculated as the change in net farm income as a result of use of a given soil erosion control technology (Equation 1).

$$GM_i = TC_i - TD_i \quad \text{.......................................} (1)$$

Where:

GM_i = Gross margin (US\$ ha^{-1}); TC_i = Total credits (US\$ ha^{-1}); TD_i = Total debits (US\$ ha^{-1}); and $\mathbf{i}$ = Soil erosion control technology.

Total credits were computed by summing up the added revenue and reduced expenses associated with a given soil erosion control technology (Equation 2).

$$TC_i = AR_i + RE_i \quad \text{.......................................} (2)$$

Where:

AR_i = added revenue, that is, the monetary value of the output (a product of yield and sellingprice) for all crops grown using a given soil erosion control technology; and

RE_i= Reduced expenses, that is, expenses eliminated or decreased for a given soil erosion control technology.

Total debits were calculated by summing up reduced revenue and added expenses associated with a given soil erosion control technology (Equation 3).

$$TD_i = RR_i + AE_i \quad \text{.......................................} (3)$$

Where:

AE_i = added expenses, which are the estimated expenses directly associated with a given soil erosion control technology used by farmers; and

RR_i = reduced revenue, which is the estimated value of revenue that is no longer received as a result of using a given soil erosion control technology.

Hence, from Equations 1 to 3, net cash benefits or net income was calculated as:

$$GM_i = (AR_i + RE_i) - (RR_i + AE_i) \quad \text{.......... (4)}$$

Dominance analysis. The accruing net benefits and costs that variedwere then compared across the soil erosion control technologies in dominance analysis, based on the criterion that any technology that had net benefit equal to or lower than that of another technology with lower cost, was dominated and, as such, was not considered profitable for adoption by farmers (CIMMYT, 1988). Following Mubanderi *et al.* (1999), dominance analysis was done by listing technologies used in order of their increasing added variable costs and matching them with their respective net benefits. Technologies with net benefits less than the net benefits of technologies with lower added variable costs were dropped as dominated. The remaining technologies that were not dominated were used to determine the levels of input costs that is incurred to gain net benefits as the farmer shifts between financially profitable technologies.

Marginal analysis. Marginal analysis was carried out on the un-dominated technologies in a stepwise manner, starting from one with the lowest costs that vary to the next. Based on the net benefits and total added expenses from the partial budgets, marginal rates of return (MRRs) gained by shifting from one technology to another were computed following Mubanderi *et al.* (1999) as indicated in Equation 5.

$$MRR = \frac{MB}{MC} \times 100 \quad \text{.......... (5)}$$

Where:

MB = marginal benefits or change in net benefits;

MC= Marginal costs or change in added expenses;

$MB = GM_a - GM_b$; and $MC = TVC_a - TVC_b$

Where GM is net benefit, a is the next soil erosion control technology with higher TVC (costs) and b was the previous technology with lower TVC (costs) being abandoned.

The MRR analysis was done to show how net income from an investment in a given soil erosion control technology increases as the amount invested (costs) increases. Bereket and Asafu-Adjaye (1999) defined marginal rates of return as the rates at which net benefits change as investment changes. Marginal rate of return, therefore, indicates what a farmer gains, on average, in return for the investment when she/he decides to change from one technology (or a set of technologies) to another (or others). The MRR of 100% means a return of one unit resulting from a unit change in expenditure on a given variable input used under a particular production technology (CIMMYT, 1988).

Usually, a minimum rate of return is fixed as the baseline for acceptance of a technology (or combination of technologies) in order to account for the cost of capital, inflation and risk. In this regard, several authors have established that for the majority of situations, the minimum rate of return acceptable to farmers is between 40 and 100% (CIMMYT 1988; Dillon and Hardaker, 1993; Asumadu *et al.*, 2004). A minimum acceptable rate of return of 50% was set by CIMMYT (1988) with the assumption that a shift from one technology to another does not require the farmer to learn new skills or acquire new equipment. Accordingly, any technology that returns MRR above 50% is considered worthy of investment by farmers.

Sensitivity analysis. Sensitivity analysis was done to identify soil erosion control technologies that were likely to sustain acceptable returns to farmers despite inflation (increase in the general price level). Besides, according to Swinton and King (1994), farmers are not only concerned with whether or not the farm production practice is profitable, but also with the level at which it will not be profitable to continue its use. According to Horwitz (2003), inflation causes uncertainty about future prices, which in turn distorts resource allocation. In the same vain, inflations may make farmers less willing to invest in soil erosion control technologies simply because they are not sure about the prices they will receive for their crop output.The focus on sensitivity of net returns to inflation was motivated by the fact that in Uganda, inflation is highly volatile and in the past decade it has ranged from 5% to 30%. During the financial year 2003/04, inflation (annual percentage change) was estimated at 5% and by June 2011, inflation had shoot up to 30.5%. (UBoS, 2012).

RESULTS AND DISCUSSION

The main soil erosion control technologies available among farmers in the study area included terraces, contours, trenches, and planting of trees and Napier grass. Farmers used the technologies either singly or in combinations with other technologies. In the study districts, technologies were used in 27 different ways but only those ways adopted by at least 10 farmers were considered in the partial budget analysis (Fig. 1). This implied that they incur variable additional costs and get dissimilar returns.

Table 1 presents the general estimates of the added expenses that were incurred for use of particular technologies. Generally, two types of costs were incurred namely; wages for labour, and prices paid for other inputs (tree seedlings

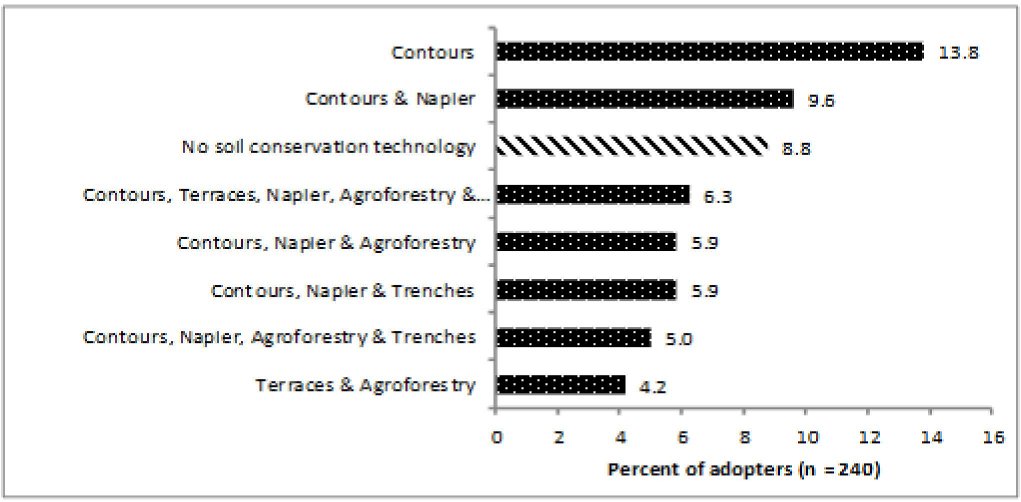

Figure 1. The commonest ways in which farmers use soil erosion control technologies in the highlands of eastern Uganda.

TABLE 1. Estimated added costs that varied among different activities related to application of soil erosion control measures in the highlands of eastern Uganda

Added costs that vary	Average cost per hectare (US\$)	Minimum cost $(\mathrm{US\$ha}^{-1})$	Maximum cost $(\mathrm{US\$\ ha}^{-1})$
Labour costs for:			
Citing contours	44	41	103
Constructing terraces	21	20	26
Digging trenches	33	23	37
Planting tree seedlings	5	6	9
Planting Napier grass cuttings	11	9	12
Input costs			
Tree seedlings	18	1	71
Napier grass cuttings	11	22	61

and Napier grass cuttings). Labour costs varied greatly depending on the type of technology, the number of structures - contours/terraces or trenches, the size (dimensions) of the structures; and the spacing used. Generally, siting contours and digging trenches were the most labour intensive technologies (Table 1). Other costs that varied were prices paid for tree seedlings and Napier grass cuttings, which were planted along contours and terraces to stabilise these structures. Examples of trees planted by farmers to stabilise contours/terraces included: Eucalyptus, Gravellia, Sesbania, Cyprus, Ovacado, Macademia, Jacaranda and Calliandra. The cost of tree seedlings was higher than that of Napier grass cuttings because the latter were raised in nursery beds, and there were costs involved in nursery bed management.Thus, farmers who planted trees to stabilise terraces and contours incured higher costs than those who plant Napier grass. However, the cost of tree seedlings and Napier grass cuttings varied greatly depending on the spacing used and the number of contours/terraces hectare^{-1} on which the vegetation was planted.

It was noted that the use of soil erosion control technologies did not result into reduced expenses, but rather farmers benefited from crops grown using the technologies. The direct benefits of using soil erosion control technologies were measured by the monetary value of the crop output. Farmers in the study area grew a variety of crops such as maize, common beans, bananas, coffee, cabbages, onions, potato, sweet potatoes, wheat, barley, peas, cassava, sorghum and finger millet.

Partial budgets for the most commonly used technological combinations are presented in Table 2. Compared to farmers who did not use soil erosion control technologies, those who used the technologies incurred varying extra costs. The additional costs were generally moderate but were highest for farmers using all the soil erosion control technologies considered in the study (contours, terraces, Napier grass, agroforestry and trenches). With regard to benefits, even farmers who did not use any soil erosion control technologies got positive net benefits. This meant that despite the challenge of soil erosion in Mt. Elgon highlands, the soils are still

TABLE 2. Partial budgets and dominance of soil erosion control technologies in the highlands of eastern Uganda

Soil erosion control technologies	Added expenses (US\$ ha^{-1})	Added revenue (US\$ ha^{-1})	Net benefits (US\$ ha^{-1})	Dominance
Contours + Terraces + Napier grass + Agroforestry + Trenches	96	1,010	914	U
Contours + Napier grass + Trenches	40	878	838	U
Terraces + Agroforestry	19	841	822	U
Contours + Napier grass + Agroforestry	39	808	768	D
Contours + Napier grass + Agroforestry + Trenches	72	642	570	D
No soil and water conservation technology	0	533	533	U
Contours + Napier grass	55	560	504	D
Contours	44	541	497	D

Under the column of Dominance, U = Un-dominated and D stands for dominated productive but perhaps producing below their potential. However, except in a few cases, farmers who used soil erosion control technologies got relatively higher net benefits than those who did not use them. Like in the case of costs, net benefits were highest for farmers using all the different soil erosion control technologies (Table 2). This could imply that using one technology is necessary but not sufficient to effectively control soil erosion. Therefore, even though it was earlier noted that most farmers had adopted at least one soil erosion control technology, there is need for them to combine a number of technologies to leverage from their synergistic benefits.

The results presented in Table 3 indicate that all the un-dominated technologies were profitable options for farmers because the lowest MRR recorded was 77. Terraces used in combination with agroforestry yielded the highest MRR of about 1,513, meaning that for every unit of US\$ ha^{-1} change in variable costs, there was a return of over 15 US\$ ha^{-1}. According to several authors (CIMMYT, 1988; Dillon and Hardaker, 1993; Asumadu *et al.*, 2004), the minimum rate of return acceptable to farmers lies between 40 and 100%. Therefore, in this case, Contours + Terraces + Napier grass + Agroforestry + Trenches; Contours + Napier grass + Trenches; and Terraces + Agroforestry, were the combinations of technologies with acceptable returns to farmers' investment.

The results of sensitivity analysis showed that the three technological combinations that passed the dominance test were likely to sustain acceptable financial returns despite increases in added variable costs and decreases in the value of crop output (benefits). Generally, the profits of using soil erosion control technologies were highly sensitive to decreases in the value of crop output due to inflation.

It was noted, in the One-way sensitivity analysis, that inflation reduced the net benefits of farmers using terraces and agroforestry to control soil erosion by about 31%. In the Two-way sensitivity analysis, inflation affected mostly farmers who were combining the five technologies – contours, terraces, trenches, agroforestry and Napier grass strips. Specifically, their net benefits reduced from 914 US\$ ha^{-1} to 582 US\$ ha^{-1} - a 36% reduction. Despite the

TABLE 3. Marginal Rates of Return of un-dominated technologies in the highlands of eastern Uganda

Soil erosion control technologies	Added expenses (US\$ ha^{-1})	Net benefits (US\$ ha^{-1})	Marginal cost (US\$ ha^{-1})	Marginal benefit (US\$ ha^{-1})	Marginal rate of return (%)
No soil and water conservation technology	0	533			
Terraces + Agroforestry	19	822	19	289	1,513
Contours + Napier grass + Trenches	40	838	21	16	77
Contours + Terraces + Napier grass + Agroforestry + Trenches	96	914	57	76	135

TABLE 4. Sensitivity of net benefits of soil erosion control technologies to inflation in the highlands of eastern Uganda

Soil erosion control technology	One-way sensitivity analysis - worst case scenario			
	Base case (US$ ha^{-1})	30% decreasein benefits (US$ ha^{-1})	Absolute reduction in net benefits (US$ ha^{-1})	Percentage reduction in net benefits (US$ ha^{-1})
Terraces + Agroforestry	822.0	569.7	252.3	30.7%
Contours + Terraces + Napier grass + Agroforestry + Trenches	914.0	688.0	226.0	24.7%
Contours + Napier grass + Trenches	838.0	595.6	242.4	28.9%
Technological combination	**Two-way sensitivity analysis - worst case scenario**			
	Base case (US$ ha^{-1})	30% decreasein benefits (US$ ha^{-1})	Absolute reduction in net benefits (US$ ha^{-1})	Percentage reduction in net benefits (US$ ha^{-1})
Terraces + Agroforestry	822.0	564.0	258.0	31.4%
Contours + Terraces + Napier grass + Agroforestry + Trenches	914.0	582.2	331.8	36.3%
Contours + Napier grass + Trenches	838.0	562.6	275.4	32.9%

huge reductions in net benefits that accrued to the use of soil erosion control technologies, it still remained financially rational for farmers to continue using these technologies.

CONCLUSION

All the different ways in which soil erosion control technologies were used by farmers yielded positive net benefits. Nonetheless, three technological combinations namely: Terraces + Agroforestry; Contours + Napier grass + Trenches; and Contours + Terraces + Napier grass + Agroforestry + Trenches dominated the rest. Results of the Marginal Rate of Return indicated that all the dominant technological combinations yielded net returns that were acceptable by farmers. Moreover, sensitivity analysis revealed that even in the face of inflation, it would remain profitable for farmers to continue using the three technological combinations alluded to herein.

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