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Authors: Mishra, Prabuddh Kumar, and Rai, Suresh Chand

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A Cost–Benefit Analysis of Indigenous Soil and Water Conservation Measures in Sikkim Himalaya, India

Prabuddh Kumar Mishra and Suresh Chand Rai*
** Corresponding author: raisc1958@rediffmail.com*
Department of Geography, Delhi School of Economics, University of Delhi, Delhi-110007, India

Soil and water conservation (SWC) measures are needed to control erosion and sustain agricultural production in mountain regions. This study assessed the costs and benefits of indigenous SWC measures in a predominantly rural watershed in Sikkim Himalaya, India, from 2009 to 2010. Physical data were obtained through field measurements of soil erosion and runoff in plots with and without SWC measures; further information was collected through a structured questionnaire survey of 150 farm households. Major costs and benefits of various measures implemented in the study area were quantified using net present value, internal rate of return, time horizon, discount rate, payback period, and sensitivity analysis. For a 10-year period and with a 6% discount rate, all the practices were found to have a positive net present value and to help ensure economic and environmental sustainability. The sensitivity analysis showed that the most widespread SWC practices are worth implementing. Some practices not only prevented nutrient loss and retained soil moisture but also provided additional income and increased crop yield. Our findings suggest that agroforestry and vegetative barriers are the most favorable practices.

Keywords: *Cost–benefit analysis; soil erosion; agroforestry; watershed; net present value; India.*

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Introduction

By the 1990s, about 20% of agricultural land in Asia had been degraded (WRI 1993). In most parts of Asia, forest area is still shrinking, agriculture is gradually expanding to marginal and sloping lands, and land degradation is accelerating through nutrient leaching and soil erosion (Napier 1991; Rambo 1997; Scherr and Yadav 2001). The pace of degradation is much higher in environmentally fragile areas such as mountains (Jodha 2005). It has been estimated that over 300 million hectares of land in the Hindu Kush–Himalayan region has been degraded (Pratap 2003). The main effects of soil erosion on soil properties are reduction in rooting depth, loss of nutrient-rich topsoil, loss of soil water storage capacity, crusting, and soil compaction (Becher et al 1985; Biot 1988; Andraski and Lowery 1992). These can result in a serious decrease in yield, depending on the resilience of the soil (Frye et al 1982; Stocking and Peake 1986).

Land degradation caused by unsustainable agricultural intensification raises concerns about the long-term sustainability of agricultural systems (WRI 2000). Some agricultural practices provide economic benefits while conserving natural resources and ecosystem services—such as modulating water quality and quantity, organic waste disposal, soil formation, biological nitrogen fixation, maintenance of biological diversity, biotic regulation, and contribution to global climatic regulation (Paoletti et al 1992; Pimentel et al 1997; Bjoerklund et al 1999). But other agricultural practices degrade natural capital and ecosystem services. A particular type of agricultural practice may be highly beneficial to an individual but may degrade the environment through soil erosion, carbon emission, biodiversity loss, and other negative externalities (Balana et al 2012).

Failure to recognize the economic value of environmental services of different land use systems often leads to policies that provide disincentives to environment-friendly agricultural practices. It is therefore imperative to value both economic and environmental benefits of agricultural practices in order to show the real costs and benefits of soil and water conservation (SWC) practices (Bjoerklund et al 1999; Ninan 2007). However, unlike the results of other investments, the benefits of SWC are not directly observable, may differ among different groups of farmers, and may take a long time to be realized (Posthumus and De Graaff 2005; Tenge et al 2005). This requires a complex approach to the issue. In the past 10 years, cost–benefit analysis (CBA) has been used to evaluate SWC practices in a number of countries (Renaud 1997; Uri 2000; Tenge et al 2005; Posthumus and De Graaff 2005;

Balana et al 2012; Bizoza and De Graaff 2012), but not in the Sikkim Himalaya, India, where 80% of the population depends on agriculture.

Livelihoods in the rural areas of the Himalayan region primarily depend on subsistence farming. Such farming systems are location specific, have developed over centuries as a comparative advantage to other livelihood options, and are highly dependent on the surrounding natural resource base. Indigenous practices such as contour bunding, minimum tillage, use of vegetative barriers, terracing, and agroforestry are widely implemented in the Sikkim Himalaya, and protection is regulated by local bylaws. Besides protecting ecological services, these practices are also expected to boost production of biomass—mainly fuel and fodder—to satisfy the growing demand for these products. Hill farmers in the study area use different structural and biological measures to control erosion and landslides and apply different types of fertilizers (Mishra and Rai 2013). Increased production of biomass within the watershed is one of the important economic benefits of SWC measures dealt with in this article. The indigenous SWC measures in the study area—which are often integrated within agricultural production systems— were analyzed to assess their longer-term sustainability, with a particular focus on their financial efficiency in different elevational (ie ecological) zones.

Study area

This research was conducted in Papung-Ben Khola watershed, located in the southern part of Sikkim state (27°16′12″ to 27°13′34″N and 88°22′18″ to 88°27′15″E) (Figure 1). It has an elevational range of 326–2600 masl and covers approximately 27.77 km^2. It had a population of 10,841 in 2001 (Census of India 2001). The terrain is hilly with very steep slopes, the average angle being 30–40°. Agriculture is the main source of livelihood. The area supports 3 basic farming systems—livestock farming, agroforestry, and mixed crop–livestock farming—all of which are livestock based and responsive to climate, topography, and resource availability (Rai 1995). The climate of the watershed is monsoonal; the average annual rainfall is 3204 mm, most of which occurs from July to September; and rainfall varies in the 3 ecological zones that constitute the study area (Temi Tea Garden 2010). The watershed represents most of the human habitation zones that exist in the Sikkim Himalaya.

Methodology

CBA of SWC measures requires an in-depth understanding of the effects of soil erosion and the effectiveness of SWC to reduce soil erosion and increase crop yields and other benefits. The following quantitative and qualitative methods were used in the study area.

Data collection

Data on the effectiveness of SWC measures were obtained from field experiments comparing soil erosion and runoff in plots with SWC measures and 1 plot without SWC measures used as control plot (Rai and Sharma 1998). Additional information on indigenous conservation measures was collected from a 2009–2010 survey of 150 randomly selected households. The validity of information provided by individual farmers was verified through interviews with key informants, agricultural extension staff, and forest officials as well as focus group discussions. The unit used in the CBA was 1 hectare of land. The survey identified 16 SWC and integrated SWC measures commonly practiced by farmers in the watershed (Table 1); among these, the most widespread or financially significant were selected to determine the efficiency of SWC measures, using CBA and sensitivity analysis.

Quantification and valuation of costs and benefits

Data from the field experiments and the formal and informal surveys were itemized into costs and benefits. Costs are incurred during establishment and maintenance of each conservation measure, and in boosting production of a crop that functions as an integrated conservation measure or a cash crop. Production costs include labor, equipment, and material required during land preparation, planting, manuring, weeding, and harvesting (Table 2). Other related costs for different SWC practices, and the economic return from the crop yields, were estimated based on information on local yields and grain prices collected during the survey in 2010 (Table 3). These estimates did not take into account fixed costs, such as value of land, interest on capital, and depreciation.

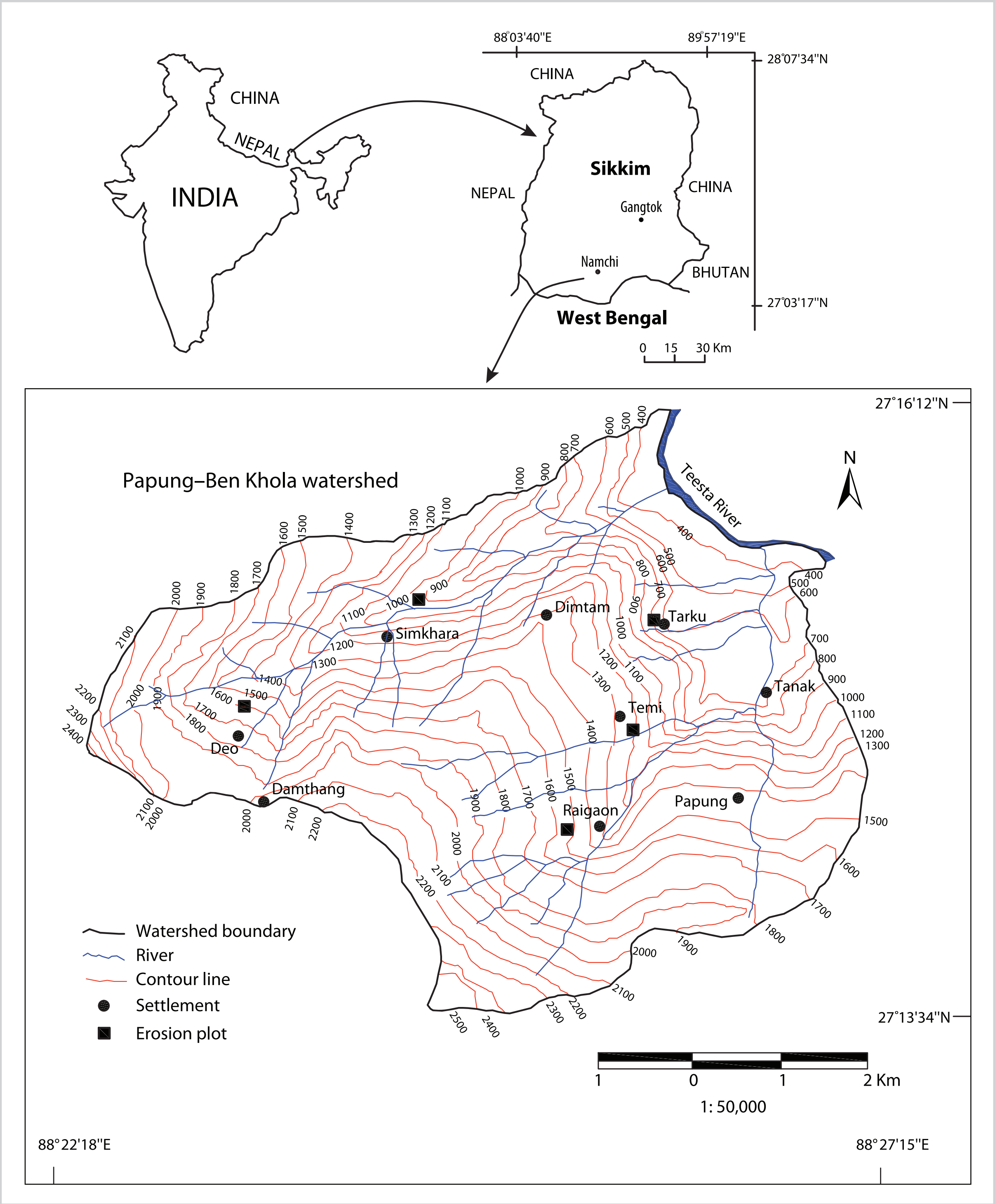
Benefits included all gains in current and future production caused by implementing SWC measures. The major benefit considered in the analysis—based on the information provided by the farmers—was increased yield due to reduced soil erosion. Benefits were converted into monetary values by multiplying them by their market prices (Table 3) and then added to obtain the total benefit.

Net present value and internal rate of return: We used 2 criteria to compare the economic profitability of land uses treated with SWC measures: net present value (NPV) and internal rate of return (IRR). These values were calculated using discount rates that take into account future costs and benefits induced by a management system (Gittinger 1982; Bojo 1992). NPV shows the present value of an income stream generated by an investment and is calculated as follows:

$$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+r)^t}$$

where B_t = benefits at time t, C_t = investment and recurrent cost at time t, t = time horizon, and r = discount rate.

FIGURE 1 Location map of Papung-Ben Khola watershed showing drainage pattern, settlements, contour lines, and erosion plots. (Map by Prabuddh Kumar Mishra)



IRR equates the present value of benefits and costs due to investments. From the perspective of the household making the investments, it is the maximum interest that an investment could pay for the resources used if the investment is to recover its initial and operating costs and break even. The rate of discount that equates the NPV of each SWC practice to zero corresponds to the IRR. An SWC practice with an IRR exceeding the prescribed rate

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TABLE 1 Indigenous SWC practices implemented in Papung-Ben Khola watershed of Sikkim Himalaya: percentage of times the practices were mentioned as being implemented in the different ecological zones.

SWC measures	% Responses per ecological zone			
	Low (<900 m)	Middle (900–1800 m)	High (>1800 m)	Mean
Mechanical measures				
Terracing	100	100	100	100
Contour bunds	90	96	50	79
Construction and maintenance of waterways	85	88	75	83
Gully control	65	69	55	63
Diversion channels	50	41	20	37
Stone barriers	91	89	90	90
Biological measures				
Alley cropping	27	30	33	30
Mulching	91	90	88	90
Minimum tillage	80	75	70	75
Crop rotation	100	100	100	100
Mixed cropping	41	49	45	45
Vegetative barriers	100	100	100	100
Agroforestry	65	70	75	70
Soil fertility measures				
Farmyard manure	87	78	55	73
Green manure	32	29	23	28
Crop residue and weed burning	100	100	100	100

of discount would be profitable. The IRR is determined as follows:

$$\sum_{t=1}^{n}\frac{B_t - C_t}{(1+r)^t} = 0 \text{ when IRR} > r: \text{ NPV} > 0$$

where B_t = benefits at time t, C_t = investment and recurrent cost at time t, t = time horizon, and r = IRR.

The NPV and IRR were determined for each SWC practice. Each practice has its own production and conservation functions and therefore generates a different stream of costs and benefits.

Discount rate and time horizon: The effects of discounting are important for projects that require immediate expenditures but do not accrue benefits until later, as is the case for the SWC practices analyzed in this study. The CBA was carried out from the farmers' perspective—based on the survey results—and used a discount rate based on the interest rate payable by the farmers on bank loans. Farmers in the study area receive credits from the bank and from cooperative groups (such as milk and vegetable cooperatives and self-help groups) at the rate of 6% on a group accountability basis. Thus, the interest rate used for discounting was 6%.

Specification of the discount rate and time horizon for CBA should be carried out simultaneously, as the two interact in their effects on the results. Therefore, in order to see the impact of SWC practices on farmers' economic returns in the long term, the time horizon was set at 10 years. This period of analysis was chosen because several SWC practices require about 5 to 6 years to reach a break-even point.

Sensitivity analysis

Any CBA is based on less than perfect information regarding past and current costs and benefits, and this is

TABLE 2 Parameters used for the cost-benefit analysis.

Production costs (US$)	
Bullock (rental per pair per day)	6.770
Labor (per worker per day)	3.380
Manure (per kg)	0.017
Crop price (per kg, in US$)	
Maize	0.680
Paddy rice	0.500
Large cardamom	4.510
Ginger	0.450
Potato	0.270

Note: Amounts are given in 2010 market prices, reported by participants in the survey.

even more true regarding the future (Bojo 1992). Sensitivity analysis is used to test the assumptions and to specify the uncertainty of the CBA outcome. It is a technique for calculating the quantitative effect of a unit change on a cost or benefit item in an NPV or IRR, and it improves understanding of the critical elements on which the outcome of an intervention depends. It may focus attention on the variables for which a further effort should be made to firm up the estimates and narrow the range of uncertainty (Squire and van der Tak 1975).

The ability of each SWC measure to withstand changes in both physical and socioeconomic conditions was analyzed based on the CBA results with different combinations of overall cash flows and discount factors. These variables were subjected to sensitivity analysis because they had the greatest impact on the costs and benefits. We selected only 8 SWC measures in the sensitivity analysis because these measures were the most widely practiced in the watershed.

Results

Effectiveness of SWC measures in preventing soil erosion

Four dominant crop and vegetation covers with SWC and 1 without SWC were assessed to determine the SWC values in the watershed. The highest runoff was recorded on barren land, followed by cultivated areas (Table 4).

Overland flow (percentage of rainfall during the rainy season) was recorded to be highest in the control plot (barren land) where there was no vegetation and where the soil is prone to erosion in the rainy season. Among the land uses with integrated SWC, the next highest rate of overland flow was recorded for mixed cropping, followed by mandarin-based agroforestry, terrace cultivation, and large-cardamom–based agroforestry (Table 4).

Estimated soil loss was highest for large-cardamom–based agroforestry (210 kg ha^{-1} y^{-1}), because of the steepness of the slope of the land where cultivation of large cardamom had begun 2 years earlier only, as an integrated SWC conservation method known by the farmers to be efficient and proven to be so by earlier studies as well (Sharma et al 2001). The next highest soil loss was found on barren land, followed by mixed cropping, mandarin-based agroforestry, and terrace cultivation (Table 4).

TABLE 3 Costs and benefits per hectare of crops under selected SWC practices.

SWC practices	Input cost per ha (US$)	Price obtained for crop (US$ per ha)	Benefit per ha (US$)
Terracing			
Construction for initial 2 y	2635	1580	−1055
Maintenance cost after 2 y	1010	1580	570
Contour bunds	812	1174	362
Vegetative barriers	208	835	627
Large cardamom	1036	3408	2372
Mandarin[a]	794	2370	1576
Mulching	934	3047	2113
Farmyard manure[b]	53	212	159
Crop rotation	1978	4434	2456

[a]Productivity is attained only 5 years after planting the trees.

[b]Cost-benefit analysis of farm yard manure applied to 1 ha from a pit size of 6 × 10 m.

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TABLE 4 Overland flow and soil loss during the rainy season (2009–2010) on land cover with different SWC practices.

Practice	Overland flow (% of rainfall)	Annual soil loss (kg/ha)
Control plot (barren land)	1.34	71.972
Mixed cropping	1.21	67.665
Terrace cultivation	1.10	39.447
Large-cardamom–based agroforestry	1.08	210.449
Mandarin-based agroforestry	1.11	56.775

Cost–benefit analysis

The CBA carried out for selected SWC measures in the watershed for a 10-year period yielded a wide range of values for profitability, cost–benefit ratio (CBR), NPV, IRR, and payback period (Table 5). A 6% discount rate was used to calculate the NPV. The payback period (time until a profit can be earned) for some SWC practices can be almost 6 years. However, eventually even these practices turn out to be profitable and are worth implementing on financial as well as environmental grounds.

Terrace construction had negative returns in the initial 2 years because of high initial costs. However, in the third year after construction, the CBR was 1:1.56, which implies higher revenue than the costs incurred for establishment and construction. For a 10-year period, the estimated NPV for 1 hectare of terraced land with paddy cultivation and a discount rate of 6% was US$ 8530, and the estimated IRR was 58.09%. Terrace cultivation has a 5-year payback period. The payback period for contour bunds is also long, but not as long as that for terraces. In both cases, the profit increases in the second year by comparison with the first year. This is mainly due to the construction costs of these practices. The CBR of the contour bunds for the second year was 1:1.73, compared to 1:1.24 for the first year. The estimated NPV was US$ 3718, and the IRR was 123.77%. Contour bunds require little economic input and thus are an option even for farmers without much money.

Of the practices analyzed for this study, mulching combined with ginger cultivation had the highest estimated NPV per hectare (US$ 20,818). CBR for this practice was 1:3.26. The high NPV and CBR are due to the fact that ginger is a cash crop with a high profit margin. The investment rate, though substantial in terms of fertilizer, is much less than the revenue generated. The estimated IRR is 326.09%.

The practice of crop rotation has a CBR of 1:2.24, NPV of US$ 15,592 per hectare, and IRR of 124.10%. Thus, this practice is also worth implementing on financial grounds. Vegetative (broom grass, *Thysolaena maxima*) barriers can earn high profits within a year of their harvesting. The CBR is 1:3.02 in the first year and 1:13.80 in the second year, with the highest IRR (402.17%) of all the practices considered in this study. Broom grass barriers not only provide income without requiring much initial investment but also prevent soil and water loss and conserve land. The payback period is 1 year.

Large-cardamom– and mandarin-based agroforestry systems are suitable to the ecological conditions of the region and are cash crops that can provide high income. Large-cardamom–based agroforestry gives a CBR of 1:1.99, NPV of US$ 1968 per hectare, and IRR of 228.98%; the payback period is 1 year. Mandarin-based agroforestry gives a CBR of 1:1.99, NPV of US$ 875 per hectare, and IRR of 51.72%, with a payback period of 6 years, much longer than for large cardamom. The use of farmyard manure is also worth implementing in the area, with a CBR of 1:3.98, NPV of US$ 1444 per hectare, IRR of 398.94%, and payback period of 1 year.

Sensitivity analysis

For the selected SWC practices, 3 NPVs—pessimistic, expected (the actual NPV calculated from the present cash flow), and optimistic—were calculated (Table 6). The table clearly illustrates that even in a pessimistic projection, the practices would be worth implementing on financial grounds.

Discussion

Indigenous SWC measures and integrated SWC measures are widely practiced in the Sikkim Himalaya. The qualitative study revealed that all of them are technically effective and easy for farmers to implement. Overland flow varies with different types of SWC measures depending on their capacity to protect against the erosive power of rainfall. Soil loss was substantially higher in large-cardamom–based agroforestry because of the steepness of the slopes on which this SWC was introduced very recently, as a means to reduce soil loss. The use of vegetative barriers was also beneficial. High

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TABLE 5 CBA of selected SWC practices.

Practice	CBR[a]		NPV per ha (US$)	IRR per ha (%)	Payback period (y)
Terracing	First 2 years	1:0.60	8802	58.09	5
	After 2 years	1:1.56			
Contour bunds	First year	1:1.24	3837	123.77	2
	After first year	1:1.73			
Vegetative barrier	First year	1:3.02	5935	402.17	1
	After first year	1:13.80			
Large-cardamom agroforestry	1:1.99		2031	228.98	1
Mandarin agroforestry	1:2.29		903	51.72	6
Mulching (ginger)	1:3.26		21,485	326.09	1
Farmyard manure	1:3.98		1489	398.94	1
Crop rotation	1:2.24		16,091	124.10	1

Note: All practices were found to be financially attractive.
[a]If the CBR is >1, the benefit is higher than the cost; if it is 1, the benefit and cost balance; if it is <1, the cost is higher than the benefit.

water and soil conservation values suggest that SWC measures are of value in both economic and environmental terms, confirming findings by Sharma et al (2001).

Comprehensive data on economic and environmental effects are difficult to compute. SWC measures differ in the time needed before they are of direct benefit to the farmer; it is therefore important that farmers are aware of the time after which a measure will produce benefits. Study participants indicated that terraces initially incur high costs and take at least 2 to 3 years to yield a profit. This is due not only to the high investment costs but also to the initial decline in yield caused by soil disturbances during construction (Tenge et al 2005). Considering that the majority of the households in the study area have limited cash resources, this can be a major hindrance to establishing terraces. Labor-sharing groups, financial incentives, and increased access to credit are possible solutions (Tenge et al 2005).

Vegetative measures provide numerous ecosystem functions, such as biodiversity enhancement, microclimate regulation, reduction of soil erosion, carbon

TABLE 6 Sensitivity analysis of selected SWC practices.

Practice	NPV per ha (US$)		
	Pessimistic	Base scenario	Optimistic
Terracing	7131	8802	10,449
Contour bunds	3160	3837	4333
Vegetative barrier	4762	5935	7267
Large-cardamom agroforestry	22,365	24,035	25,118
Mandarin agroforestry	7538	8418	9298
Mulching (ginger)	19,815	21,485	23,132
Farmyard manure	993	1489	1760
Crop rotation	1442	16,091	17,738

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sequestration, and provision of habitat for wildlife (Sharma and Rai 2007). Even after overcoming the initial investment costs, the return on investment from vegetative barriers is lower than that for the other SWC measures. As underlined by Paudel and Thapa (2004), crop rotation not only balances input and outflow of soil nutrients but increases overall productivity; this was confirmed by the present study. The results of CBA for large-cardamom–based agroforestry show that in the long term it is financially attractive to farmers and has low input costs; in the present study large cardamom cultivation had started only very recently on the watershed's steepest slopes, and its conservation functions remain to be assessed.

All the SWC practices showed profits in both optimistic and pessimistic scenarios, implying that they are beneficial. However, the CBA cannot be the only indicator used by decision-makers when selecting SWC practices. For example, when using high discount rates, NPVs can remain positive if the initial investment has a short payback period.

Conclusions

The CBA carried out for several indigenous SWC practices showed that for a 10-year period and with a 6% discount rate all the practices had a positive NPV and were environmentally and economically sustainable. Their widespread adoption also shows that they are socioculturally sustainable.

Terraces were found to be more costly to establish than other measures but to have higher long-term financial returns than the other SWC measures. We also observed that various practices not only conserved soil and water but also acted as a subsidiary source of income and increased crop yields. According to our preliminary findings and the literature, agroforestry and vegetative barriers are the most economical practices for checking soil erosion and increasing income. This entails a reorientation of the entire agricultural extension policy. Consistent with such a policy, there is a need for providing training of extension agents at all levels to improve their knowledge of land management in the region.

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