*Agricultural Economics Research Review*
Vol. 26(No.1) January-June 2013 pp 63-71

# Economic Assessment of Soil Erosion Damage on Smallholder Farms in Marginal Lands of Mahi Ravines in Gujarat

**V.C. Pande[a*], R.S. Kurothe[a], H.B. Singh[a], S.P. Tiwari[b], Gopal Kumar[a], B.K. Rao[a], A.K. Vishwakarma[a] and G.L. Bagdi[a]**

[a]Central Soil & Water Conservation Research & Training Institute, Research Centre, Vasad-388 306 (Anand), Gujarat
[b]Central Soil & Water Conservation Research & Training Institute, Research Centre, Datia-475 661, Madhya Pradesh

**Abstract**

Economic damage due to soil erosion has been assessed for a scenario representing the agricultural practice followed on a typical smallholder farm adjacent to ravines. Using on-farm trial data from a research farm in the Mahi ravines, yield-erosion relationship has been estimated and erosion damage function has been developed with local output and input prices realized by smallholder farmers. Pearl millet + pigeon pea being the most prominent cropping systems on smallholder farms in the Mahi ravines, has been taken for study. Farmers' existing erosive practice has been compared with a conservation practice, viz. ridge and furrow technique (RFT). According to the study, a decline in yield to the extent of 50 per cent and 75 per cent will take much longer period in the case of conservative practice than in erosive practice. The paper has also studied farmer's decision on switching over to conservation practice from the existing erosive practice. The analysis has revealed the switching over decision year to be insensitive to discount rate, and little sensitive to output price, suggesting thereby that these policy variables would have little effect. The paper has suggested that favourable input-output price scenario and initial support of the state would help in incentivizing the farmers to switching over to conservative practice.

**Key words:** Economic assessment, soil erosion damage, smallholders, marginal lands, Mahi ravines

**JEL Classification:** D04, D13, D79, Q12, Q24

## Introduction

Soil erosion, world over, is becoming a serious problem because of considerable economic damage it causes to the society at large. In India, the annual average loss of nutrients from land due to soil erosion has been estimated as 5.4-8.4 million tonnes (Mt) and the loss of production due to non-development of ravines has been estimated to be 3 Mt/ annum (Fertiliser Statistics, 2007-08). It has intrigued the conservationists due to the difficulties in estimating the economic damages of soil erosion (Herath, 2001). Formulation of erosion control policies and prioritization of resource allocation to address the problem warrants assessment of bio-physical causes and economic effects. While scholars have drawn attention to the soil erosion magnitude (Kurothe *et al*., 1997), attempts to assess the economic damage have been only a few (Ananda *et al*., 2001; Herath, 2001). Complexities between soil erosion, crop yield and economic loss have also been highlighted by many scholars (Thampapillai and Anderson, 1994). While efforts have been made to examine the impact of soil erosion on crop yields using data from field plot trials

* Author for correspondence
Email: vcpande_2000@yahoo.com

(Van Kooten *et al*, 1989), scholars have also used subjective elicitation procedure to examine soil erosion damage (Ananda *et al*, 2001; Herath, 2001). However, little empirical work has been carried out on the economics of soil conservation on smallholder farms in developing countries (Eaton, 1996).

## Materials and Methodology

The study has used a hybrid approach incorporating two methods. Using the on-farm trial data from research farm in the Mahi ravines, yield-erosion relationship has been developed. It was used to develop erosion scenario for the smallholder farms in the Mahi ravines, and then erosion damage function was developed. The study, then, tried to incorporate on-site data of the existing production system into farmers' decision-making by employing erosion damage function so developed. It was contended that such a hybrid approach, where applicable, can provide appropriate relationships between soil erosion, crop yield and economic loss for assessment of economic damage. The application of this approach in assessing erosion damage for large degraded lands can help the policymakers in designing suitable policies. The relationship of adoption of conservation measures and policy variables such as land tenure and output price has been observed to be weak and uncertain in marginal lands of ravines (Pande *et al*., 2011). In view of this, this study has tested the hypothesis that policy variables such as output price, discount rate and farmers' planning horizon play a significant role in the adoption of soil conservation measures and hence, farmers' decision on switching over to conservation practice from erosive practice. This has been achieved through developing the erosion damage function from yield-erosion function and then performing sensitivity analysis with respect to these policy variables.

Economic damage due to soil erosion has been assessed for a scenario representing the agricultural practice followed on a typical smallholder farm adjacent to a ravine. The study has used both primary and secondary data. The primary data pertained to socio-economic and input-output details of cropping system practised on the smallholders' farms in the Mahi ravines of Gujarat. The secondary data on soil erosion and crop yields were collected from the Research Project Records of the Central Soil & Water Conservation Research & Training Institute, Research Centre, Vasad. The research farm of the Centre, located in the vicinity of Mahi ravines, represents the marginal lands. It, therefore, justifies the development of soil erosion and crop yield relationship and projecting it for the soil erosion scenario being examined for the Mahi ravines.

## Study Area, Sample Size and Data Collection

Of the total ravine-affected land in Gujarat, the largest gullied area of 61,888 ha is along the river Mahisagar (Sharma *et al.*, 1981) and, therefore, these ravines were selected for the study. Two districts — Vadodara and Anand — were selected along the left and right banks of the river, where most of the ravine lands are spread. Five villages, two in the Anand district and three in the Vadodara district, were selected based on the ravine area in these districts. A list of farmers, comprising marginal, small and medium farm-categories, with their lands adjacent to ravines was finalized and data on land-use and crops were collected. However, the farms, for which complete and consistent information was not available, were dropped from the sample. Thus, a sample of 100 farms was retained for the analysis. A well-structured questionnaire was used to collect information from the fields during 2003-04 through 2004-05. Surveys were conducted to elicit primary information on soil conservation problem, crop and cropping system, perception of farmers about erosion and soil losses from their fields, its intensity and measures of soil and water conservation. The secondary data on area, production and farm harvest price were also collected for the district.

The soil in the region belongs to the alluvial group. Soils are sandy loam to loamy sand in texture and very deep having admixture of kankar, i.e. lime nodules ($CaCO_3$), ranging from 7 to 9 per cent at varying depths. The bulk density ranges between 1.42 and 1.59 g/cc and infiltration rate is very high (2.5 - 5.0 cm/hour). The fertility status of these soils is poor due to erosion hazards. The soils are, in general, low in organic carbon, low to medium in phosphorus and medium to high in potassium contents.

## Methodology

The data collected on different economic variables were analyzed by computing statistical averages and economics was worked out following the standard discount cash flow technique, viz. present value of net benefit. Using secondary data from the Research Farm located in the Mahi ravines, relationship between erosion and yield was examined. The erosion – yield relationship was then used to estimate the erosion damage function following Walker (1982) for the representative smallholder farm using the crop input-output data collected from farmers and local prices of input and output.

### Yield Erosion Relationship

This model captures the relationship between crop yield and loss of top soil providing insights to the magnitude of the loss of physical output due to soil erosion. Soil erosion alters the physical, chemical and biological characteristics of soil which determine crop productivity. This function considers yield of crop as the dependent variable and land degradation measure as the independent variable. The degradation measure, in literature, has been taken either topsoil depth or cumulative soil loss. Interactions among factors such as soil properties, climate and input levels also affect crop productivity (Pierce and Lal, 1994). The region under study has witnessed the effect of soil erosion in terms of loss of productivity and loss of inputs from fields adjacent to ravines. As there are no historic records of change in depth of soil, hence soil loss resulting from erosion was considered proxy for degradation in the region. Field observations have indicated that input management on small and marginal farms does not vary drastically over a given span of time. It is particularly true in view of the financial and infrastructural constraints like market, extension services delivery, etc. with which such smallholder farms operate in the rural areas. This fact was drawn from field observations in the study region. The remote villages adjacent to ravines along the Mahi river lacked these services.

Taking climate, crop management and ravine land management as given, the yield damage function gives the relationship between crop yield and soil loss. Various functional forms including linear, curvilinear and exponential, have been used to express the relationship between soil loss and crop yield (Smith and Shaykewich, 1990). Following Lal (1987), data on crop yields and soil loss have been used to develop relationship between crop yield and cumulative soil loss in the absence of data on soil depth.

### Damage Function Analysis on Marginal Farms

The yield erosion relationships developed from research farm data were used for damage function analysis along with field data from smallholder farms in the Mahi ravines. The yield erosion relationships for conventional (erosive) practice and conservation practice were projected for the erosion and non-erosion scenarios on marginal farms. These relationships were used to compute the rate of yield decline on smallholder farms under the two scenarios of soil loss. The average yield levels of crops for erosion and non-erosion farms were taken as those realized on marginal farms in the Mahi ravines. Using the average yield levels and rate of yield declines, the average yield levels to be realized in time frame were projected under the two scenarios. This information along with information on conservation measures taken by the farmers in the study area was used to compute erosion damage function.

### Erosion Damage Function

This refers to the private economic benefits forgone when an erosive practice is adopted instead of a conservation practice (Walker, 1982). An erosion damage function thus represents the monetary losses associated with soil erosion. This is vital to internalize the on-site effects of soil erosion to the farm economy. Various approaches have been used to estimate erosion damage function using yield erosion relationship (Walker, 1982; Pagiola, 1995; Taylor and Young, 1985; Smith and Shaykewich, 1990; Gunathilaka and Abeygunawardena, 1993). While most of these studies have used yield as the dependent variable and top soil depth as the independent variable, the present study has used cumulative soil loss as explanatory variable. Walker (1982) has defined the damage function as the difference between the present value of net revenue streams of erosive farming practice and a conservation practice, i. e.

$$DFV_t = PNB_e - PNB_c \qquad \ldots(1)$$

where, $DFV_t$ is the value of the damage function in the year t; $PNB_c$ is the private profitability of choosing the conservation practice in the current year, and $PNB_e$ is the private profitability of choosing the erosive (conventional) practice currently and postponing the conservation decision to another year.

$$PNB_e = P.Y_e(t, D_{t-1}) - C_e(t, D_{t-1}) + \sum_{i=1}^{T-1} \frac{P.Y_c(t+i, D_t) - C_c(t+i, D_t)}{(1+r)^i} \quad \ldots(2)$$

$$PNB_c = P.Y_c(t, D_{t-1}) - C_c(t, D_{t-1}) + \sum_{i=1}^{T-1} \frac{P.Y_c(t+i, D_{t-1}) - C_c(t+i, D_{t-1})}{(1+r)^i} \quad \ldots(3)$$

where,

P = Price of crop (₹/q),

$Y_e$ = Crop yield with erosive practice as function of cumulative soil loss with time (q/ha),

$Y_c$ = Crop yield with conservation practice (q/ha),

$D_t$ = Cumulative soil loss (t/ha/annum),

$C_c$ = Variable cost of production with conservation practice (₹/ha),

$C_e$ = Variable cost of production with erosive practice (₹/ha),

T = Number of years in time horizon, and

r = Real private rate of discount (%)

The yield erosion equations were used to estimate the value of damage function by incorporating local prices and costs. This was justified in view of the localized nature of yield-erosion equation developed for the area. This relationship is highly site-specific and would depend, among other things, on initial soil depth. The reason for estimating the value of damage function was to determine the optimal year for a farmer to switch over from an erosive practice to a less-erosive practice. The damage function was assessed in respect of ridge and furrow system of conservation practice as this was found to be quite effective on research farm at Vasad.

## Results and Discussion

### Profile of Farms, Land-use and Cropping System

Among sample farms, the land belonged mostly to marginal, small and medium farm- categories, with average holding size of 1.6 ha. About 22.4 per cent landholdings were being cultivated by tenants and they belonged to small farm-category. The farm holdings studied were adjacent to ravines. As the holding-size increased, the proportion of ravine land also increased in different classes of holdings (Table 1). The land-use pattern of farms revealed that the distribution of arable and non-arable land was not markedly different within different landholding classes. The farm holdings lied adjacent to ravine with varying slopes. Among the farms studied, the marginal farmers owned an average landholding size of 0.5 ha, small and medium farms had the average holding size of 1.4 ha and 2.9 ha, respectively (Table 1). Across different landholding classes, the share of ravine land in farm holding increased from 14 per cent in marginal holdings to 51 per cent in medium holdings.

**Table 1. Profile of farmers in the Mahi ravines of Gujarat**

| Farm-category | No. | Land-holding size (ha) | Arable land (ha) | Non-arable (Ravine) land (ha) |
|---|---|---|---|---|
| Marginal | 70 | 0.52 | 0.45 | 0.07 |
| Small | 16 | 1.41 | 1.15 | 0.27 |
| Medium | 14 | 2.87 | 1.39 | 1.48 |

*Source:* Primary Survey

Bajra (Pearl millet) and bajra-based cropping system was most prevalent across all the categories of farms (Table 2). Farms with irrigation facility also cultivated irrigated crops like wheat, tobacco and *summer* bajra. *Kharif*-bajra and *kharif*-bajra followed by *summer*-bajra were the two prominent cropping systems. Some farms also practised paddy, followed by wheat and paddy followed by jowar. It was observed that farms, particularly in the medium size-category, that had leased-in some better parcels of levelled land, took cash crops like tobacco and wheat.

**Table 2. Share of different cropping systems practised in Mahi ravines**

| Cropping system | Percent of the gross cropped area |
|---|---|
| *Kharif* bajra | 39.9 |
| *Kharif* bajra-*summer* bajra | 35.5 |
| *Kharif* bajra-fodder-*summer* bajra | 13.1 |
| *Kharif* bajra-wheat | 3.2 |
| *Kharif* bajra-jowar | 1.9 |
| Paddy-wheat | 6.4 |

**Table 3. Perception of farmers about incidence of run-off and soil loss**

| Farm category | Per cent of respondent-farmers | | | |
|---|---|---|---|---|
| | Farms with conservation history | | Farms without conservation history | |
| | Soil loss | Run-off | Soil loss | Run-off |
| Marginal | 87 | 87 | 93 | 56 |
| Small | 63 | 88 | 88 | 94 |
| Medium | 75 | 83 | 67 | 67 |

## Problem of Soil/Water Loss

Most of the farmers reported the incidence of run-off and the consequent soil loss during rains (Table 3). The farmers without conservation history reported a higher incidence of runoff than those with conservation history; though the difference was non-significant. The farmers in the former group reported a higher effect of run-off on loss of top soil (Table 4) and yield loss, though effect on loss of fertilizer and seed from fields was similar in both the groups. It was inferred that the loss of top soil on farms with no conservation measures was of relatively high magnitude having effect on yield loss.

## Estimation of Yield-Erosion Relationship

For developing this function in respect of farms in the Mahi ravines, experimental plot data at Vasad research farm was used for farmer's practice as well as improved conservation practice (Ridge & Furrow Technique) for pearl millet + pigeon pea cropping system taken in the experiment conducted during 1990-91 through 1993-94. It is a dominant cropping system of the smallholders in the Mahi ravines.

In the absence of data on loss of top soil depth and other parameters, crop yield was fitted to the cumulative soil loss data following Lal (1987). It has, however, been contested that the relationship is site-specific (Eaton, 1996). Transferring this relationship to other sites could be fraught with problems if not accounted for soil type and profile of erosion. In the present study, several forms in addition to the exponential function were tried. This is so because several scholars, including Lal (1987), have developed relationships for Alfisols, while the soils in the Mahi region are Entisol associated with Inceptisol. The following quadratic form was finally used for further analysis to develop two scenarios, viz. erosive practice and conservation practice:

(I) Farmers' practice (Conventional tillage)

$$Y = 34.9-0.74X-0.10X^2, \quad R^2=0.90, \text{ S. E.} = 4.59$$

This explains an erosive production system.

(II) Conservation practice: Ridge and furrow tillage practice was considered to develop the scenario of conservation practice. An exponential function of the following form was used:

$$Y= 19.4+0.93X-0.06X^2, \quad R^2=0.91, \text{ S. E.} = 2.45$$

where, Y is the yield (q/ha) and X is the cumulative soil loss (t/ha/annum).

## Temporal Impact of Soil Erosion on Yield

The data used for yield-damage function were collected from the secondary records of an experiment, conducted at a research farm adjacent to the ravines during 1990-91 through 1993-94. The average yield of crops in the region is given in Table 5. The yield-damage functions developed above were used to explore the effects of soil erosion on yield over time (Figure 1). The yield loss depended on the initial soil depth and the rate of soil erosion over time. Data on soil loss and yield, available from the experimental

**Table 4. Farmers' perception about effect of run-off and soil loss**

| Farm-category | Per cent of respondent-farmers | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Top soil getting washed | | Fertilizers getting washed | | Seeds getting washed | | Yield loss | |
| | WC | WOC | WC | WOC | WC | WOC | WC | WOC |
| Marginal | 70 | 91 | 17 | 27 | 23 | 33 | 33 | 47 |
| Small | 63 | 94 | 13 | 13 | 13 | - | 25 | 29 |
| Medium | 75 | 44 | 42 | 22 | 33 | 32 | 25 | 33 |

WC – With conservation measures, WOC – Without conservation measures

**Table 5. Average yield of crops**

| Crop | Average yield (kg/ha) |
|---|---|
| Kharif bajra | 1925 |
| Summer bajra | 2110 |
| Wheat | 2962 |
| Paddy | 5000 |
| Jowar | 500 |
| Fodder | 2187 |

*Source:* Primary survey

farm, were used to simulate yield loss from the cumulative soil loss over time. This information was used to know the time period when 50 per cent and 75 per cent reduction in crop yield would occur with non-conservation or conservation practices on farm (Table 6). These scenarios were examined for an average soil loss of 30 t/ha/annum[1] (Shekinah and Saraswathy, 2005).

Under the conventional (erosive) practice, it would take 59 years and 87 years to realize a reduction in yield to the tune of 50 per cent and 75 per cent, respectively (Table 6). But if a conservation practice is adopted, this period is extended to 150 years and more than 200 years, respectively. In other words, the conservation production practice defers yield reduction in time scale substantially.

## Estimation of Erosion Damage

The value of damage function was estimated for a decision period of 20 years considering a 10 per cent discount rate with output price of pearl millet as Rs 5/kg (Table 7).

At 30 t/ha/year soil loss, a farmer switches over to the conservative practice in the 54th year, the decision year reducing to 34 years at soil loss of 50 t/ha/year and to 18 years at soil losses of 100 t/ha/year. A change in discount rate lower than 10 per cent was also used to examine the effect of varying discount rates on decision to switch over.

The study has revealed insensitivity of switching over decision to discount rate. Depending upon the discount rate considered by smallholder, at 30 t/ha/year soil loss the period of switching over to conservation practice was found 54 years at both 7 per cent and 5 per cent discount rates (Table 8). The optimal time frame though changed with different soil loss scenarios, the decision year did not change.

Against pearl millet output price of ₹ 5/kg, an increase of ₹ 1/kg enhanced the decision year only marginally. At 5 per cent discount rate, the decision year switched to 63rd, 40th and 21st years at 30, 50 and 100 t/ha/annum soil loss. Beyond that loss, the decision year to switch over to conservative practice would change only slightly (Table 9).

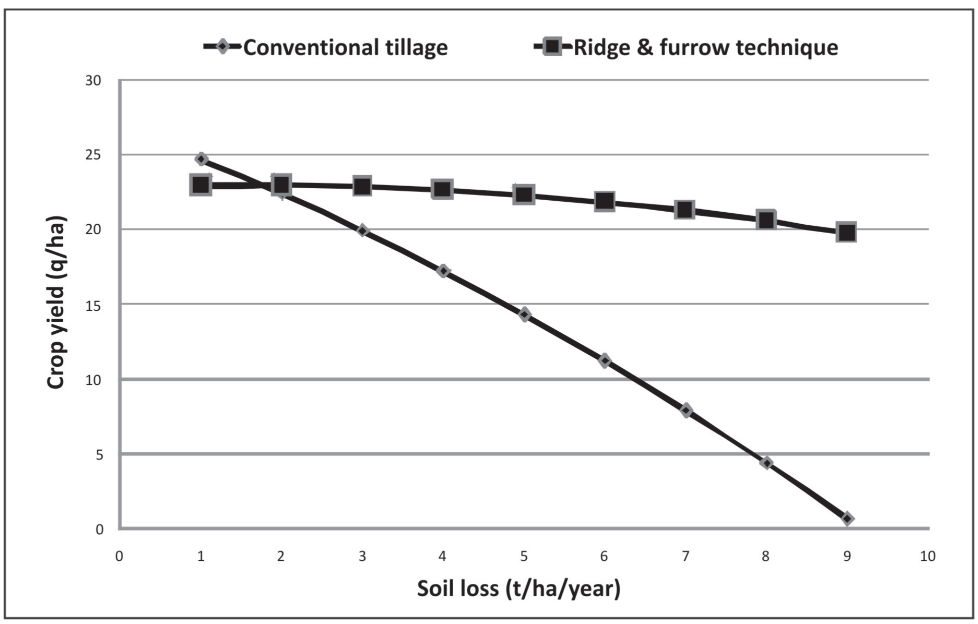


**Figure 1. Relationship between yield and soil loss, Mahi ravines**

**Table 6. The long-term productivity effects of soil erosion, 30 t/ha/annum**

| Time for yield reduction | Production practice | | Years deferred on adoption of conservation practice (to realize adverse effect on yield) |
|---|---|---|---|
| | Erosive practice | Conservation practice (RFT) | |
| 50 per cent (years) | 59 | 150 | 91 |
| 75 per cent (years) | 87 | > 200 | > 113 |

RFT = Ridge & Furrow Technique

**Table 7. Present value of damage function on smallholder farms, Mahi ravines**

| Soil loss (t/ha/year) | Damage function value (₹/ha) | Decision year for switching over to conservative practice (years) |
|---|---|---|
| 30 | -33 | 54 |
| 50 | -23 | 34 |
| 100 | -21 | 18 |

## Discussions

The assessment of the productivity effects of soil erosion is a challenging task because crop yield is the integrative effect of numerous variables. Further, the effect of erosion on crop yield is a function of soil depth and other parameters specific to the region under study. The soil depth in the region under study does not put severe limitation on the yield loss due to erosion. Further, farmers tend to offset yield reduction with application of higher doses of fertilizers which further shifts the decision year of switching over to conservation practice. The assessment of economic damage of soil loss on smallholder farms in ravine region with the given hybrid approach brought to light some facts. It revealed insensitivity of switching decision to the discount rate and planning horizon, though an increase of 1 ₹/ha enhanced the decision year by 6-9 years. This is supported by works from other scholars like Collins and Headley (1983) and Eaton (1996). It, therefore, puts a limitation on such policy interventions in the region. Farmers' planning horizon is a function of land ownership vis-à-vis land tilling decisions. A weak relation with planning horizon and land tenure relationship with adoption of conservation practice (Pande *et al.*, 2011) in ravines

**Table 8. Sensitivity of discount rate to decision year for switching over to conservative practice**

| Soil loss (t/ha/year) | Discount rate - 7% | | Discount rate - 5% | |
|---|---|---|---|---|
| | Damage value function (₹/ha) | Decision year | Damage value function (₹/ha) | Decision year |
| 30 | -35 | 54 | -39 | 54 |
| 50 | -17 | 34 | -14 | 34 |
| 100 | -65 | 19 | -41 | 19 |

**Table 9. Crop price sensitivity analysis, Pearl millet price: ₹ 6/kg**

| Discount rate (%) | Decision year (years) | |
|---|---|---|
| | Soil loss (t/ha/annum) | Decision year |
| 5 | 30 | 63 |
| | 50 | 40 |
| | 100 | 21 |
| 7 | 30 | 64 |
| | 50 | 41 |
| | 100 | 21 |
| 10 | 30 | 64 |
| | 50 | 41 |
| | 100 | 21 |

turns it a poor policy variable. This, though, did not support the findings of scholars about planning horizon in particular and property rights in general elsewhere (Bishop, 1992). This could be explained by the topography of marginal lands of ravines which puts constraint on land consolidation.

A favourable input-output price policy, however, would largely alter farmers' decision-making approach incentivizing them to invest on conservation (Pande *et al*., 2011) in general and switching over to conservation practice in particular. Further, the local farmers could be incentivized for adoption of conservation measures through initial support from the state. The damage function approach used in this study was specific to a crop or cropping system, viz. pearl millet + pigeon pea. A different cropping system in other part of the region would yield a different scenario.

## Conclusions

The economic damage due to soil erosion has been assessed for a scenario representing the agricultural practice followed on a typical smallholder farm adjacent to the ravine. Using the on-farm trial data from a research farm in the Mahi ravines, yield-erosion relationship has been developed. It has been used to develop erosion scenario for the smallholder farms in the Mahi ravines and erosion damage function with local output prices and cost of production realized by them. Scenarios have been developed regarding farmer's decision on switching over to conservation practice from the existing erosive practice at 10 per cent discount rate considering 20 years of production horizon for different soil losses.

Sensitivity analysis has been performed for different discount rates, viz. 7 per cent and 5 per cent and planning horizon of 30 years. The pearl millet + pigeon pea cropping system, being the most prominent cropping system on smallholder farms in the Mahi ravines, has been taken for study. Farmers' existing erosive practice has been compared with a conservation practice, viz. ridge & furrow technique (RFT). It has revealed that decline in yield to the extent of 50 per cent and 75 per cent would take a longer time in the case of conservative practice than the time span realized in the case of erosive practice. The decision year to switching over to conservative practice would reduce from 54 year to 34 years if soil loss gets increased from 30 t/ha/year to 50 t/ha/year.

Sensitivity analysis performed for different discount rates and output prices has found the switching over decision year to be insensitive to the discount rate though the decision year would slightly change with change in price, suggesting thereby, that policy prescriptions might not play a role in the decision-making process of these farming groups. Favourable input-output price scenario could help in internalization of the user cost of erosion by incentivizing farmers to switch over to conservative practice early in time-frame.

## Acknowledgements

The data used for this study were collected in a research project approved by the Institute Research Council. Financial help and encouragement provided by the Director of the institute are acknowledged. The support provided by the head of the centre in conducting field surveys and technical support in data collection are duly acknowledged. The authors thank the anonymous referee for suggesting important changes in the presentation of the facts in the manuscript.

## End-Note

1 Scholars have computed the rate of soil erosion from gullies as 33 t/ha/annum in ravine regions. The computations done under this study revealed the time frame for decision to switching over to conservative practice to be longer if erosion rate is considered less than 30 t/ha/annum.

## References

Ananda, J., Herath, G. and Chisholm, A. (2001) Determination of yield and erosion damage functions using subjectively elicited data: Application to smallholder tea in Sri Lanka. *The Australian Journal of Agricultural and Resource Economics*, **45**(2): 275-289.

Bishop J. (1992) *Economic Analysis of Soil Degradation*. Gatekeeper Series No. LEEC 92-01. IIED/UCL London Environmental Economics Centre, London.

Collins, R. A. and Headley, J. C. (1983) Optimal investment to reduce the decay rate of an income stream: The case of soil conservation. *Journal of Environmental Economics and Management*, **10**: 60-71.

Eaton, E. (1996) *The Economics of Soil Erosion: A Model of Farm Decision-making*. Discussion paper, DP 96-01, International Institute for Environment and Development, London.

*Fertiliser Statistics* (2007-08) The Fertilizer Association of India, New Delhi.

Gunathilaka, H. M. and Abeygunawardena, P. (1993) An economic analysis of soil conservation in tobacco lands in the Hanguranketha area of Sri Lanka. *Indian Journal of Agricultural Economics*, **48** (1): 106-112.

Herath, Gamini (2001) Estimating the user cost of erosion in tea smallholdings in Sri Lanka. *Australasian Journal of Regional Studies*, **7**( 1): 97-111.

Kurothe, R. S., Butta, R. K. and Sharma, J. P. (1997) Soil erosion map of Gujarat. *Indian Journal of Soil Conservation*, **25**(1): 9-13.

Lal, R. (1987) Effects of erosion on crop productivity. *Critical Reviews in Plant Sciences*, **5**(4): 303-67.

Pagiola, S. (1995) *Price Policy and Returns to Soil Conservation in Kitui and Machakos, Kenya*. Environment Department, The World Bank, Washington DC.

Pande, V. C., Kurothe, R. S., Singh, H. B. and Tiwari, S. P. (2011) Incentives for soil and water conservation on farm in ravines of Gujarat: Policy implications for future adoption. *Agricultural Economics Research Review*, **24**(1): 109-118.

Pierce, F. J. and Lal, R. (1994) Monitoring the impact of soil erosion on crop productivity. In: *Soil Erosion: Research Methods*, Ed: R. Lal. Soil and Water Conservation Society.

Sharma, A. K., Pradhan, I. P., Nema, J. P. and Tejwani, K. G. (1981) *25 Years of Research on Soil & Water Conservation in Ravine Lands of Gujarat*. Monograph No. 2. Central Soil & Water Conservation Research & Training Institute, Research Centre, Vasad, Gujarat.

Shekinah, D. Esther and Saraswathy, R. (2005) Impacts of soil erosion by water – A review. *Agriculture Review*, **26**(3): 195-202.

Smith, E. G. and Shaykewich, C. F. (1990) The economics of soil erosion and conservation on six soil groupings in Manitoba. *Canadian Journal of Agricultural Economics*, **38**: 215-231.

Taylor, D. B. and Young, D. L. (1985) The influence of technological progress on the long-run farm level economics of soil conservation. *Western Journal of Agricultural Economics*, **1**(1): 63-76.

Thampapillai, D. J. and Anderson, J. R. (1994) A review of the socio-economic analysis of soil degradation problems for developed countries. *Review of Marketing and Agricultural Economics*, **62**: 291-315.

Walker, David J. (1982) A damage function to evaluate erosion control economics. *American Journal of Agricultural Economics*, **64** (4): 690-698.

Received: June, 2012; Accepted: December, 2012