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Economic Analysis of Bamboo Plantation in Three Major Ravine Systems of India§

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Abstract

Deep and narrow gullies are recommended to be put under permanent vegetation of grasses and trees. The study has recommended bamboo plantation for productive and protective utilization of such degraded lands. Economic analysis has been carried out using data from three major ravine systems, viz. Mahi, Chambal and Yamuna to examine economic viability of plantation under different soil conditions. The analysis has suggested a cash outflow ranging from ₹ 30,550/ha to ₹ 48,000/ha from the 7th year onwards to individual stakeholders in the region, in addition to the benefits accrued to society in terms of value of nutrient (₹ 2125 – 5555/ha) saved through soil conservation and incremental soil carbon build-up (₹ 41,000/ha) with the recommended harvest practice of harvesting one-third old culms per clump over the life of plantation. The study has suggested that high cost of establishment may be met through financial incentives to the group/ village community on a collective basis and such policy instruments can be converged with land base schemes of central and state governments like MGNREGA or such similar schemes. The large-scale bamboo plantation could be undertaken with assistance from such schemes and the remaining cost of plantation could be met from the group/ village society towards environmental services provided by the locational bamboo ecosystems.

Key words: Bamboo plantation, ravines, social/economic analysis, financial analysis, degraded land

JEL Classification: Q23, Q34, Q51, Q57

Introduction

In India, ravines are spread over an area of 3.67 million hectares (Mha) to 4.0 Mha largely along the rivers and their tributaries. Serious ravine intrusions occur along the banks of Beas in Punjab; Chambal in Madhya Pradesh, Rajasthan and Uttar Pradesh; Kalisind, Banas, Morel and Gambhir in Rajasthan; Yamuna in Uttar Pradesh; and Mahi, Sabarmati, Narmada and Tapti in Gujarat. Ravines have been classified into small, medium and deep & narrow gullies, depending upon their depth, width and side slope in India. Accordingly, their reclamation measures also differ. Despite advances in ravine reclamation engineering, adoption and maintenance of such measures involve capital investment with sustained community involvement. Therefore, it has been suggested to necessarily retire ravine lands to

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permanent vegetation (Tejwani *et al.,* 1975). While small and medium gullies are reclaimed for cultivation safely, the deep and narrow gullies are recommended to be put under permanent vegetation of grasses and trees (Tejwani and Dhruva Narayana, 1960). Since the country can ill afford to retire much of these degraded lands from economic production, a productive utilization of such degraded lands is called for with conservation of natural resource as the major objective. Among the different tree species tried, bamboo appears to be highly promising in not only conserving the soil and but also for productive utilization of gullies.

With about 22 genera and 130 species, India is the second largest reservoir of bamboos, next only to China (Nath *et al.,* 2009). India's share in the global bamboo market is estimated to be of US $1 billion and is expected to increase to US $5.7 billion by 2015 (Omari, 2009). India today exploits only one-tenth of its bamboo-producing potential. Of nearly 130 species, only about 10 are being commercially exploited. These are: *Bambusa arundinacea, Bambusa affinis, Bambusa balcooa, Bambusa tulda, Dendrocalamus strictus, Dendrocalamus hamiltoni, Dendrocalamus asper, Oxytenanthera stocksii* and *O.travancorica*. Among these species, *Dendrocalamus strictus* has been found quite promising in the ravine lands. This has been tested for protecting severely eroded gullies of ravine class VI and VII lands[1] with promising production potential (Dhruva Narayana, 1993). Bamboo is well suited to polycyclic harvesting; it can be grown on steep hillsides and along the banks of rivers. Its interlocking root system and leaf deposit inhibit soil erosion. Production of bamboo is reported to improve with the age of plantation, though the percentage of new to old culms decline with age. Harvesting of bamboo is started after 7 years with 10 old and 3 new culms available per clump in the ravine land (Dhruva Narayana, 1993). Bamboo plantation is useful for enhancing natural resource conservation (Lawler, 1993; Yanhui *et al.,* 1995). In addition, benefits of living biomass and soil organic matter content in bamboo stands have been well reported (Lin *et al.,* 2004; Tong, 2007). A bamboo grove releases some 35 per cent more oxygen into the air than a similar-sized stand of trees, and it matures (and can be replanted) within seven years (compared to 30-50 years for a stand of trees), helping to improve soil health and prevent erosion along the way. Bamboo is so fast-growing that it can yield 20- times more timber than trees on the same area (http://life.gaiam.com/article/how-eco-friendly-bamboo, accessed 19 December, 2011).

Advances towards technological remedies for ravine reclamation through bamboo plantation notwithstanding, relatively little has been accomplished in the realm of social science (Haigh, 1984). Therefore, understanding the economics of bamboo plantation would not only help a large section of stakeholders at local, regional and national levels but also prove beneficial to policymakers, funding agencies and non-government organizations embarking upon the ravine reclamation programmes. The present study is one such attempt; it examines the economics of bamboo plantation for ravine reclamation with policy implications for conservation as well as large scale utilization of degraded ravines into productive lands in the country.

Materials and Methods

The data on bamboo plantation are being generated by Central Soil & Water Conservation Research & Training Institute at its three regional research centres at Vasad, Kota and Agra. The research centre at Vasad studied Mahi ravine, Kota centre studied Chambal ravine and Agra centre studied Yamuna ravine. The details of the three locations are given in Table 1. The data collected included conservation measures (trench) adopted prior to bamboo plantation and input and output details of bamboo plantation in these ravines. While data on production potential was available for all the three ravines, data on resource conservation potential was available only for Mahi ravines. However, this information has been projected for all the three ravines. The costs and benefits have been estimated at the 2010-11 local prices in the three regions. Although bamboo has a very long productive cycle in the ravine lands, the present analysis has been conducted for a period of 20 years. For financial

[1] These lands are classified based on land form, slope and distance from gully rim. Class VI ravine lands are gully rim and the table land with 0-15 per cent slope within 6 m of the gully rim. In addition, this also includes table land with 15-20 per cent slope, very small, small and medium gully sides and beds. Class VII ravine land is classified as table land with 25 per cent slope, deep and narrow gullies (Sharma *et al.,* 1980).

Table 1. Details of the study sites

Details	Mahi ravine	Chambal ravine	Yamuna ravine
Latitude, Longitude	22°16′ N 72°58′ E	22°27′ N to 26°29′ N 75°31′ E to 79°15′ E	25°30′ N to 31°01′ N 78°27′ E to 81°53′ E
Rainfall (mm)	850	787	755
Temperature range (°C)	10.7–39.0	7.5–38.2	8.6 –40.0
Vegetation	Tropical ravine thorn forest	Tropical ravine thorn forest	Tropical ravine thorn forest

Source: Wikipedia

analysis of plantation, a discount rate of 8 per cent was used, though its sensitivity has been analyzed using different discount rates. For social analysis, a social discount rate of 2 per cent has been suggested by Sharma *et al.* (2008). Atkinson *et al.* (2006) have used a discount rate of 5.9 per cent based on an estimate of a social discount rate for India. In the present study, this discount rate was used.

The three ravines are different in terms of climate and soil. The climate of Agra region is semi-arid with annual rainfall of 755 mm, 97 per cent of which is received during the months of July-September and 3 per cent is received during the winter. Kota region is characterized by dry sub-humid micro-thermal climate with an average rainfall of 787 mm, 91 per cent of which is received during July to October. The climate of Vasad region is semi-arid, with an average annual rainfall of 850 mm, 98 per cent of which is received during June to September. While the ravines of Yamuna and Mahi are broad-based U-shaped, the ravines in Chambal are narrow deep and V-shape (Dhruva Narayana, 1993). Further, the parent material at the bank of river Chambal is quite deep with clay to clay loam, light-textured and in the river Yamuna and Mahi, it is coarse sandy loam in texture.

Economic evaluation techniques have been used to estimate the value of land and other resources used in the development of economy, and the information generated has helped in understanding how funds, land, natural products and other resources are allocated and used in the society. Since, many of the economic, social and environmental benefits associated with environmental goods and services are omitted in the conventional economic analysis, discounted cash flow technique was used in analyzing the economics of bamboo plantation.

Economic Analysis

The economic analysis of bamboo plantation was carried out using benefit-cost ratio, net present worth and internal rate of return.

The formal mathematical equations used are given below:

$$\text{Benefit-cost ratio} = \frac{\sum_{t=1}^{n} B_t(1+r)^t}{\sum_{t=1}^{n} C_t(1+r)^t}$$

$$\text{Net present worth} = \sum_{t=1}^{n} \frac{(B_t - C_t)}{(1+r)^t}$$

Internal rate of return is that discount rate 'r' such that

$$\sum_{t=1}^{n} \frac{(B_t - C_t)}{(1+r)^t} = 0$$

where,

B_t = Benefits in each year, t = 1, 2, ..., n

C_t = Costs in each year, t = 1, 2, ..., n.

n = Number of years, and

r = Discount rate.

Intangible Benefits of Soil Conservation due to Plantation

Intangible benefits can be assessed from different points of view depending on the context. Soil erosion may affect downstream reservoir, commercial fish production pond, recreational lake down stream and the like. Erosion carries the topsoil off fields, which reduces the land's productivity. Some, but not all, yield losses can be offset by increasing the nutrient-use.

Since soil loss decreases output and increases costs, the damage function approach is used for modelling impact of erosion on soil productivity. The values of soil productivity were based on the assumption that the land is in production, because benefits will not accrue while the land is fallow. Similarly, replacement cost approach has been used to impute the resource value to soil erosion (Hufschmidt *et al.,* 1983; Dixon and Hufschmidt, 1986; Dixon *et al.,* 1994). The replacement cost approach has been deployed to impute the resource value of soil conserved with bamboo plantation. The soil loss from the degraded ravine lands moves to the adjacent river (Mahi river in Vasad, Chambal river in Kota and Yamuna river in Agra). Since there is no direct loss to production (agricultural production or electricity production of reservoir) and public property in the downstream, the choice of the technique is justified. It assumed that the productivity of soil could be maintained if the lost nutrients and organic matter were replaced artificially. This further justified the use of 'Replacement Cost Approach'. Moreover, this approach becomes still easier if data on nutrient loss and market price of nutrient are readily available (Drechsel *et al.,* 2004). Under this approach, the loss of the nutrient with soil erosion is valued in terms of the annual marginal cost of their replacement. The basic premise of the replacement cost method is that the cost incurred on replacing the productive assets damaged by an economic activity can be measured and interpreted as benefits if the damage were prevented. The resource value of soil erosion can be given by Equation (2) (Kumar, 2004):

$$B = \sum_{n=1}^{N} \frac{P_i D_i}{(1+r)^n} \qquad \ldots(2)$$

where,

P_i = Price of the i^th nutrient supplemented though a fertilizer,

D_i = Quantity of the i^th nutrient lost through soil erosion,

r = Discount rate, and

n = Number of years.

The carbon build-up in the soil under bamboo plantation has been estimated under a scenario that the degraded ravine land with no vegetation would have lost not only the soil nutrients but also the opportunity of building the soil carbon under the plantation. Therefore, the intangible benefit of carbon build-up is the additional benefit which if valued at the shadow price of carbon, would justify the utility of bamboo plantation in the degraded ravines to national and international stakeholders and the policymakers.

Shadow Price of Carbon

Soil carbon accumulation has been valued using an estimate of the shadow price of carbon drawn from the climate change damage literature. This price conveys information about the present value of (future) damages caused by a tonne of carbon (equivalent) emissions and is usually calculated using Integrated Assessment Models (Mendelsohn, 2003). A value of US $ 20/t C is used as the social cost of carbon (Atkinson *et al.,* 2006). This value is at the upper end of the range of meta-estimates done by Tol (2003) and in the middle of the range suggested by Pearce (2003). The sensitivity analysis was performed with estimates of US $5/t C and US $40/t C also following Atkinson *et al.,* (2006).

Results and Discussion

The basic data used for estimating cost of cultivation of bamboo in different ravines are presented in Table 2. The costs differed in terms of irrigation cost, viz. number of irrigations and price per irrigation and to some extent, in price of bamboo seedlings in the three ravines. The sale price of bamboo was also higher in case of Yamuna ravines (Table 2). Bamboo is planted at 5m×5m spacing in the ravines. This spacing provides sufficient space for bamboo clump to grow in subsequent years, though a closer spacing has been tried at Mahi ravines (Sharma *et al.,* 1980). The field study suggested a mortality replacement of 20 per cent at Mahi ravines and a higher at Yamuna ravines. Damage due to wild life accounted for the major part of crop destruction, the other causes being water stress and local management. The differential supportive irrigation in the three ravines has been explained in terms of rainfall and soil.

Economic Analysis

The total cost on bamboo plantation in ravines was accounted for by (i) land preparation, (ii) soil and moisture conservation measures (trench), (iii) plantation establishment, including planting material,

Table 2. Basic data for working out cost of cultivation of bamboo in selected ravine systems of India

Description	Mahi Ravine	Chambal Ravine	Yamuna Ravine
Spacing (m×m)	5 × 5	5 × 5	5 × 5
No. of plants / ha	400	400	400
Mortality replacement (%)	20	20	30
Manure required (kg/plant/year)	10	10	10
Fertilizer required (kg/plant/year)	0.02	0.02	0.02
Cost of fertilizer (₹/ kg)	9.5	9.5	9.5
Irrigation cost / No. (₹)	500	800	100
No. of irrigations / year	15	8	21
Seedling price (₹ / seedling)	5.0	5.0	6.5
Labour wages (₹ / manday)	120	120	150
No. of harvestable plants per ha (%).			
(i) Initial four years	30	30	30
(ii) Fifth year onwards	40	40	40
Sale price per bamboo pole (₹)	35	35	40

and (iv) protection and maintenance, which included irrigation, cleaning of bamboo clump, etc. The analysis revealed that 35-46 per cent of the total cost was incurred during the first year, the major expenditures being on trench making, irrigation and plantation establishment (site preparation and planting). The remaining 54-65 per cent expenditure was spread over the next six years, primarily for irrigation, cleaning of clump and mortality replacement during the second year and plantation maintenance and protection from years 2 to 7. The break-even is expected in the eleventh year, when maintenance and protection cost would be offset by bamboo sales.

Land preparation before bamboo plantation in ravines was required to remove obnoxious weeds. Competition for moisture otherwise would raise the expenditure on irrigation. The expenditure on establishment items was spread over a period of seven years. Only protection and harvest costs would occur beyond that period. The major expenditures are occurred during the initial four years, while only the minor costs are spread over the subsequent years. The expenditure on cleaning of bamboo clump is done at an interval of two years. The total cost over a period of seven years worked out to be ₹ 106,142/ ha in Mahi ravines, out of which ₹ 44,422/ ha was spent in the first year (Table 3). Bamboo plantation in Chambal ravines exhibited a similar pattern. The cost items, however, differed in terms of irrigation and soil working/ clump cleaning operations. The total cost over a period of seven years worked out to be ₹ 108,548/ ha, out of which ₹ 40,480/ ha were spent in the first year (Table 4). In Chambal ravines, the cost items differed in terms of soil and moisture conservation, irrigation, planting and soil working/ clump cleaning. While irrigation cost in Chambal ravines was less, the planting cost was more due to higher labour wages. The total cost, in Yamuna ravines, worked out to be ₹ 117,248/ ha, out of which ₹ 42,768/ ha were spent during the first year (Table 5).

Harvesting commences from the 7th year onwards. The minimum sale price per piece of green bamboo was ₹ 35/- . On an average 3 to 4 good culms per clump of bamboo can be harvested from the 7th year (Table 6). A harvest of 3 mature culms per clump during the first four harvest-years and 4 mature culms per clump was considered for the production systems studied in the three ravines. A net income of ₹ 30,550/ ha could be realized during 7th year and ₹ 31,000/ha from 8th to 10th years. This increased to ₹ 43,000/ ha from the 11th year onwards. At Chambal ravines, a net income of ₹ 28,950/ ha could be realized during 7th year and ₹ 29,400/ha during 8th to 10th year (Table 6). This increased to ₹ 41,400/ ha from 11th year onwards. The sale price per piece of green bamboo was ₹ 40/- at Agra. A net income of ₹ 39,550/ ha could be realized during 7th year and ₹ 34,000/ha during 8th to 10th year and ₹ 48,000/ ha from the 11th year onwards.

Table 3. Unit cost for raising 1 ha bamboo plantation in ravine land (2010-11 prices), Mahi Ravines

Items	1 year	II year	III year	IV year	V year	VI year	VII year	Total
			Material					
Planting material including 20 per cent mortality replacement in second and third year	800	80	80					960
Manure and fertilizers (DAP) (50 g/plant)	190							190
Plant protection (LS)	600							600
Irrigation, 15 No (₹ 500 per irrigation)	7500	7500	7500	7500				30000
Sub-total	**9090**	**7580**	**7580**	**7500**				**31750**
			Labour (mandays)					
Land preparation (LS)	6650							6650
Digging of trench, refilling @ ₹ 45 per trench (400 No.)	18000							18000
Planting and staking (400 No.)	6000	600	600					7200
Soil working and others		2000	2000	2000	2000	2000	2000	12000
Watch & ward (LS)	3000	3000	3000	3000	3000	3000	3000	21000
Harvesting - 7th year onwards							6000	6000
Sub-total	**33650**	**5600**	**5600**	**5000**	**5000**	**3000**	**9000**	**70850**
Contingency (5%)	1682	280	280	250	250	150	450	3542
Grand total	44422	13460	13460	12750	5250	3150	9450	106142

LS - Lump sum

Table 4. Unit cost for raising 1 ha bamboo plantation in ravine land (2010-11 prices), Chambal Ravines

Items	1 year	II year	III year	IV year	V year	VI year	VII year	Total
			Material					
Planting material including 20 per cent mortality replacement in second and third year	2000	200	200					2400
Manure and fertilizers (DAP) (50 g/plant)	190							190
Plant protection (LS)	600							600
Irrigation, 8 No (₹ 800 per irrigation)	6400	6400	6400	6400				25600
Sub-total	**9190**	**6600**	**6600**	**6400**				**28790**
			Labour (mandays)					
Land preparation (LS)	6000							6000
Digging of trench, refilling @ ₹ 45 per trench (400 No.)	18000							18000
Planting and staking (400 No.)	2800	280	280					3360
Soil working and others (2)		3600	3600	3600	3600	3600	3600	21600
Watch & ward (LS)	3000	3000	3000	3000	3000	3000	3000	21000
Harvesting - 7th year onwards							6000	6000
Sub-total	**29800**	**6880**	**6880**	**6600**	**3600**	**3000**	**9000**	**75960**
Contingency (5%)	1490	344	344	330	180	150	450	3798
Grand total	40480	13824	13824	13330	3780	3150	9450	108548

LS - Lump sum

Table 5. Unit cost for raising 1 ha bamboo plantation in ravine land (2010-11 prices), Yamuna Ravines

Items	1 year	II year	III year	IV year	V year	VI year	VII year	Total
Material								
Planting material including 30 per cent mortality replacement in second and third year	2600	780	780					4160
Manure and fertilizers (DAP) (50 g/plant)	190							190
Plant protection (LS)	2228							2228
Irrigation, 21 No. (₹ 100 per irrigation)	2100	2100	2100	2100				8400
Sub-total	**6018**	**2880**	**2880**	**2100**				**14978**
Labour (mandays)								
Land preparation (LS)	6000							6000
Digging of trench, refilling @ ₹ 30 per trench (400 No.)	12000							12000
Planting and staking (400 No.)	14000	4200	4200					22400
Soil working and others (2)		5000	5000	5000	5000	5000	5000	30000
Watch & ward (LS)	3000	3000	3000	3000	3000	3000	3000	21000
Harvesting - 7th year onwards (LS)							6000	6000
Sub-total	**35000**	**12200**	**12200**	**8000**	**8000**	**3000**	**9000**	**97400**
Contingency (5%)	1750	610	610	400	400	150	450	4870
Grand total	**42768**	**15690**	**15690**	**10500**	**8400**	**3150**	**9450**	**117248**

LS - Lump sum

Table 6. Yield and Income of bamboo plantations in different ravine systems

Year	Yield (Poles No./ ha)			Net income (₹/ha)		
	Mahi	Chambal	Yamuna	Mahi	Chambal	Yamuna
VII	1200	1200	1200	30550	28950	39550
VIII to X	1200	1200	1200	31000	29400	34000
XI year onwards	1600	1600	1600	43000	41400	48000

The financial indicators for bamboo plantation in ravines are given in Table 7. The net present worth varied from ₹ 5636/ha/year in Chambal ravines to ₹ 7031/ha/year in Yamuna ravines. Similarly, the benefit cost ratio has been found to be sound (1.76 - 1.89) in all the three ravines. The internal rate of return revealed that bamboo in Yamuna ravines gave the best rate of return (19.3%), followed by Mahi ravines (18.4%) and Chambal ravines (18.1%). The economic analysis of bamboo propagation carried out by Uriarte and Pinol (1994) in Philippines had shown that a one-hectare bamboo farm has a benefit-cost ratio of 1.82 and internal rate of return of 31per cent.

Indirect Benefits

The bamboo plantation in ravines provides some indirect benefits also. These include prevention of soil erosion. Carbon stock build-up under bamboo plantation comprises living biomass and soil organic matter. While the former is depleted with the harvest of bamboo, the latter is retained in the soil till the bamboo plantation lasts. It has been extensively quantified by several authors (Isagi *et al.,* 1997; Lin *et al.,* 1998; Morisada, *et al.,* 2004; Zhou and Jiang, 2004; Li *et al.,* 2006, Chen *et al*, 2009). Soil conservation benefits of bamboo are a bonus in ravines, which are

Table 7. Economic analysis of bamboo cultivation in selected ravines of India

S. No.	Parameters	Mahi ravines	Chambal ravines	Yamuna ravines
1	NPV (₹/ha/year)	6010	5636	7031
2	Benefit- cost ratio	1.85	1.76	1.89
3	Internal rate of return (%)	18.4	18.1	19.3
4	Pay back period (years)	10	10	9

Table 8. Organic carbon profile in top layer under different vegetative covers

S. No.	Conservation land use	Organic carbon at different depths of soil profile (kg/m^2)							
		0-15 cm	15-30 cm	30-45 cm	45-60 cm	60-75 cm	75-90 cm	90-105 cm	Total
1	Ravine land under *Dendrocalamus strictus* plantation*	1.32	0.71	1.17	0.91	0.94	0.77	0.64	6.47
2	Fallow ravine land	0.45	0.59	0.42	0.32	0.33	0.14	0.12	2.37

*Soil samples taken after 20 years of plantation

prone to soil loss but have not been much studied. Research studies in ravines have proved that bamboo is quite effective in conserving soil erosion in ravines (Kurothe *et al.,* 1997). The present study has evaluated these benefits under bamboo plantation based on the field data collected from the research farm.

(a) Soil Organic Carbon Enhancement

For this study, soil samples were taken from bamboo plantation sites after 20 years of plantation. Similar samples were taken from the fallow ravine lands. The soil samples were collected from different depths and averaged for a comparison (Table 8). The soil carbon decreased with soil depth. The unusual trend observed at 15-30 cm depth could be attributed to soil erosion at that depth at some point of time. Nevertheless, the cumulative soil carbon build-up was higher under bamboo plantation than in the fallow ravine lands. The analysis revealed a soil carbon build-up of 41 t/ha over a fallow ravine lands. This carbon build-up sustains in the soil if plantation is maintained for a longer period, following the recommended harvest cycle of harvesting 30 per cent mature culms per clump. Imputing a value to this at a shadow carbon price of US $20/t C (Atkinson *et al.,* 2006) (₹ 50=US $1), worked out to be ₹ 41,000/ha, ranging between ₹ 10,250/ha and ₹ 82,000/ha at carbon price range of US $5/t C and US $40/t C, respectively.

(b) Soil Conservation

The soil conservation effects of bamboo studied at the research farm, Vasad, have shown that the bamboo plantation retains 80-100 per cent of rainwater. This water is either used by the vegetation or recharges the groundwater. The sediment yield is reduced to 1.4 t/ha in a high rainfall year, which is 10-20 times less than an untreated watershed (Kurothe *et al.,* 2002-03). Further, the studies conducted at the farm also showed the conservation effect of bamboo plantation on improved soil health over a period of time (Tiwari *et al.,* 1998). Various approaches have been used to evaluate the soil loss conserved. The nitrogen, phosphorus and potash content of soil in a degraded ravine lands of this region ranges between 101-470 kg/ha, 24-95 kg/ha and 216-470 kg/ha, respectively. This works as a lower and upper bound for the nutrients in the soil conserved as a result of bamboo plantation. Local/ organic fertilizers have not been considered in literature (Drechsel *et al.,* 2004). In ravine lands also, farm yard manure is applied by the farmers in small quantity prior to plantation, but the quantity is too small to replace the nutrients lost through soil erosion. Hence, only chemical fertilizers are used for replacement of nutrients lost. Further, nitrogen is closely related with carbon in the soil under plantation. Since evaluation of carbon is done separately, the benefit of this nutrient was not summed up in the nutrient saved. The border price of nutrients was considered for economic benefit-

Table 9. Cash inflow and outflow in bamboo plantation in Mahi ravines

(₹/ha, Discount rate 0.059, 2010-11 prices)

	1	2	3	4	5	6	7 to 10	11-19	20	Total
a) Tangible benefit										
Timber poles - Bamboo	0	0	0	0	0	0	42000	56000	56000	
b) Intangible benefit										
i) Soil Organic Carbon									41000	
ii) Soil conservation									3840	
Total (₹)	0	0	0	0	0	0	168000	504000	100840	772840
Present value	0	0	0	0	0	0	103415	215644	32041	351100
Input										
Labour										
Site preparation/ land clearing	6650	0	0	0	0	0	0	0	0	
Staggered contour Trench	18000	0	0	0	0	0	0	0	0	
Plantation	6000	600	600	0	0	0	0	0	0	
Irrigation	7500	7500	7500	7500	0	0	0	0	0	
Harvest	0	0	0	0	0	0	24000	72000	8000	
Weeding/ interculture	0	2000	2000	2000	2000	2000	8000	18000	2000	
Protection	3000	3000	3000	3000	3000	3000	12000	27000	3000	
Miscellaneous										
Plants	800	80	80	0	0					
Fertilizer	190	0	0	0	0					
Chemical	600	0								
Contingency	1532	130	130	100	100	150	450			
Total (₹)	44272	13310	13310	12600	5100	5150	44450	117000	13000	268192
Present value	40992	11411	10566	9261	3470	3245	27386	50060	4130	163956

cost analysis. The value of nutrients, thus, saved through bamboo plantation was estimated to be Rs 2126 – 5555/ha.

Social/economic Analysis

The present silvicultural practice has suggested harvesting of one-third matured bamboo clumps from the 7th year onwards (Kurothe *et al.,* 2002-03). The adoption of recommended bamboo harvest cycle not only yields bamboo poles but also sequester carbon in the soil. The soil carbon having the value of Rs 41000/ha adds to the total benefits in the 20th year. A social discount rate of 5.9 per cent was used. On including the intangible benefits of soil organic carbon under the bamboo plantation, the benefit cost ratio increased to 1.98 (Table 9) with an economic rate of return of 19.3 per cent.

Conclusions

Deep and narrow gullies are recommended to be brought under permanent vegetation of grasses and trees. Bamboo plantation for productive and protective utilization of such degraded lands is not only a profitable option for local stakeholders but also an economically viable policy option for funding agencies and government and non-government agencies. The analysis carried out using data from the three major ravine systems suggests a cash outflow ranging from ₹ 30,550/ha to ₹ 48,000/ha from the 7th year onwards to individual stakeholders in the region and accrual of additional benefits to the society at large in terms of improvement in soil health (valued at ₹ 41,000/ha) and soil conservation with an average value of ₹ 3840/ha. The bamboo harvest cycle would continue for a long time in ravines if a recommended practice of harvesting one-third culms per clump is followed. The soil carbon build-up would enhance with the age of plantation due to litter fall. Based on the evidence in Mahi ravines, this conservative value of enhanced soil carbon adds up to a net present value of benefits of ₹ 351100/ha to the economy against the net present value of costs valued at ₹ 163956/ha.

About 98000 ha of degraded ravine lands, particularly the deep gullies in Gujarat alone which are devoid of vegetation, can be put under bamboo plantation for productive and protective utilization. The cost of bamboo plantation could be a constraint to small and medium stakeholders located in the vicinity of the ravine lands. The wasteland development programme of the government would be an appropriate mechanism to address this problem. It is suggested that high cost of establishment could be met through financial incentives to the group/ village community on a collective basis and such policy instruments can be converged with land base schemes of central and state governments like MGNREGA or some other similar schemes. The large-scale bamboo plantation could be undertaken with assistance from such schemes and the remaining cost of plantation could be paid by the group/ village society towards environmental services provided by the locational bamboo ecosystems.

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