

Assessment of Mastihalla Watershed in Bellary District of Karnataka State, India

Biswajit Mondal*, S.L. Patil, N. Loganandhan, K.K. Reddy and K. Channabasappa

Central Soil and Water Conservation Research and Training Institute, Research Centre, Bellary 583 104, India

Abstract: An attempt has been made to assess the long-term impact of watershed development programme in Mastihalla watershed of Bellary district in Karnataka State, and to project the period during which incremental benefits of watershed development programme are likely to accrue. The evaluation was based on the data collected through household survey in the watershed. Various indicators as production/economic benefits, social impact, employment generation and environmental impact were assessed. The study revealed that with adoption of soil and water conservation measures and improved package of practices, productivity of different crops in the watershed increased over pre-project period by 12-53%. The economics of soil conservation on watershed-basis reveals viability of the programme. The benefit-cost ratios for agriculture as a whole were 3.0, 2.8 and 2.5 with 10, 15 and 20% discount rates for 15 years' benefit flow and 3.7, 3.5 and 3.2 considering the project life as 20 years at the same discount rates. Payback period was 8 years and the internal rate of return was 53-62%, which was much higher than the market rate of interest. Sensitivity analysis indicated that the economic parameters were stable considering the fluctuations in costs and benefits. The watershed development programme in rainfed areas increased the crop productivity, which ultimately increased the income of the resource-poor farming communities and induced favorable environmental and social impacts in this region.

Key words: Watershed, benefit-cost ratio, rainfed agriculture, employment generation, environmental impact, social benefits.

Watershed management is a holistic approach to optimize the land use, water and vegetation in an area. It mitigates drought, moderates floods, prevents soil erosion and improves availability of water, fuel, fodder, etc. on a sustained basis. The formulation of integrated watershed development programme since the mid-1980's was the manifestation of such realization (Shah, 1998). People's participation is a key to success of watershed programme (Rama Rao *et al.*, 2007). In order to justify investment in watershed development, evaluations were conducted to assess the impact and economic viability of watershed development projects in different regions of the country (Math, *et al.*, 1997; Kerr *et al.*, 2000; Diwate *et al.*, 2002). Most of the studies were conducted either during or just after the completion of the projects. Past experiences suggest that benefits from few components of the watershed treatment accrued for longer periods. Rama Rao *et al.* (2005) attempted an *ex-ante* assessment of returns to investment in soil and water conservation research considering the incremental yield gains for 15-years. Ashok and Ramasamy (2002) studied the economics of soil conservation measures in

Kambainallur watershed and observed the negative benefit-cost ratio even after five years of implementation of the programme. The benefit-cost ratio increased to 1.35 and 3.07 after 10 and 18 years, respectively.

The present study estimates the long-term benefits of watershed development programme by projecting the period during which incremental benefits are likely to accrue in Mastihalla watershed in Bellary district of Karnataka State, India.

Materials and Methods

Mastihalla watershed is located in Sandur taluk of Bellary district in Karnataka State, India. The mean annual rainfall (24 years' average) is 817 mm, with a bimodal distribution, the first peak in June (onset of south west monsoon) and the second peak in September (onset of north east monsoon). The uniform distribution of rainfall from June to October results in assured kharif crops in the normal rainfall years. The soils of watershed are red sandy loam with soil depth varying from 0.3 to 1.0 m. The slope of arable lands varied from 0.5 to 3.0% and that of non-arable lands from 3.0 to 7.0%. The major crops include sorghum, maize, finger millet, pearl millet, groundnut and

*E-mail: bisumondal@rediffmail.com

sunflower. The watershed was especially selected to conserve rainwater, to control erosion in the arable lands and to increase crop productivity (Table 1).

Mastihalla watershed was implemented under National Watershed Development Programme for Rainfed Areas (NWDPA) during 1997-98 to 2001-02 with 90% Central Government funds and 10% State Government funds during IX Five Year Plan period. The Project Implementing Agency was Department of Agriculture and Department of Watershed Development, Karnataka State. There are 5 revenue villages within the watershed geographical area of 10,200 ha with treatable area of 6885 ha.

Based on the total number of land holdings and their distribution in the watershed, fifty farmers were selected following simple random sampling technique representing marginal (9 farmers), small (17 farmers), medium (14 farmers) and large (10 farmers). Primary data were collected by personal interview of the selected households on the socio-economic conditions of the farm families and the farming activities with the help of pre-tested interview schedule. Benchmark survey details, general cropping pattern, expenditure on arable and non-arable land treatments, etc., were collected from secondary sources.

Analytical procedures, evaluation criteria and technique

The study was subjected to pre-project and post-project analysis approach. Changes in the watershed area were assessed by comparing the agro-economic data of the beneficiaries collected before (1997-98) and after (2004-05) the implementation of the project. To avoid the price effect over time and the inconvenience in fixing price in future, it was analyzed for whole watershed using 2004-05 price levels of input in production and output. The input-output data was projected considering the average of 3 years i.e. 2002-03, 2003-04 and 2004-05. An allowance for 20-25% decrease in yields due to drought was made for rainfed and tank-irrigated crops. Allowance was also made for annual repair and maintenance from sixth year onward at 5% of the total expenditure incurred on soil and water conservation structures.

For economic analysis, additional net return over pre-project period was considered. Economic viability was worked out in terms of discounted cash-flow techniques i.e. Benefit-Cost Ratio (BCR),

Pay-Back Period (PBP), Net Present Value (NPV) and Internal Rate of Return (IRR) (Kahlon and Singh, 1984). Variable discount rates of 10, 15 and 20% were considered for conversion of expenditure to 2004-05 prices in different activities of watershed development program. The analysis considered the expected project life as 15 and 20 years. Sensitivity analysis was carried out to examine the effect of fluctuations in benefits, costs, discount factor and anticipated project life on the BCR.

Results and Discussion

The evaluation was conducted covering three indicators: (a) production or economic benefits, (b) social impact/employment generation, and (c) environmental impact (Gregersen *et al.*, 1987; Ram Babu, 1985; Dhyani *et al.*, 1993; Reddy *et al.*, 2003).

Economic analysis of production activities

Changes in productivity of different crops: With the adoption of package of practices and rainwater conservation measures at terrace and inter-terrace level, the productivity of major crops in the watershed increased over pre-project period. The yield of cereals, pulses and oilseeds increased during post-project period by 45, 53 and 31%, respectively, over pre-project period in rainfed areas (Table 2). In irrigated areas it was 19, 12 and 16%, where vegetable production increased by 18%. The yield increase in these selected crops was attributed to watershed development program.

Incremental monetary returns

Assessing the economic viability in terms of monetary benefits is an essential part of the project evaluation (Kahlon and Singh, 1984). The economic analysis was carried out for rainfed and irrigated crops separately and for whole agriculture.

Rainfed agriculture: Under rainfed conditions, the major crops were sorghum, maize, finger millet, pearl millet, groundnut, sunflower, mango, etc. For economic analysis the incremental benefit flow from rainfed crops and capital expenditure on account of soil and water conservation measures in rainfed areas were considered. The BCR was 3.4, 3.1 and 2.9 at the discount rate of 10, 15 and 20%, respectively, considering the expected project life as 15 years, while it was 3.8, 3.7 and 3.4 considering the expected project life as 20 years (Table 3). The PBP in all the above-mentioned discount rate was only 7 years. In the rainfed agriculture, the NPV ranged from Rs. 7,300 to Rs. 7,900 for 15 years and from Rs. 9,610 to Rs.

10,070 for 20 years project life, respectively, at 10 and 20% discount rates. Nearly 61 and 69% IRR was observed for 15 and 20 years project life, and it was higher than the market rate of interest. These results indicate that conservation measures adopted in the rainfed areas in the watershed program were economically viable.

Irrigated agriculture: In addition to the 16 existing wells in the watershed during pre-project period (1997-98), 32 more wells were added in 2002-03, followed by 11 and 3 during 2003-04 and 2004-05, respectively. The increase in the number of bore wells increased the area under well irrigation (126 ha during post-project period from 27.4 ha during pre-project period). Six tanks existed in the watershed with a command area of 176 ha. However, during post-project period tank irrigation failed for first two years and was attributed to severe drought leading to low runoff inflow to the tanks. The crops grown in the irrigated area include groundnut, sunflower, cowpea, vegetables, sorghum and paddy.

For economic analysis the net additional benefit flow from irrigated crops and capital expenditure on account of bore wells and command area developments in irrigated areas were considered. The BCR observed were 2.5, 2.2 and 2.0 at 10, 15 and 20% discount rate considering 15-year project life; was 3.5, 3.2 and 2.8 for 20-year project life. BCR for rainfed crops was higher under the two project lives because of higher initial investment on leveling and cost of wells. However, the NPV was higher than that observed in rainfed situation and varied from Rs. 31,120 to Rs. 38,330 with 15 years and Rs. 59,320 to Rs. 65,980 with 20 years' benefit flow, respectively, at different discount rates. The PBP were 9, 10 and 11 years under 10, 15 and 20% discount rates, respectively. The IRR was 43 and 55%, respectively, considering the anticipated project life as 15 and 20 years.

Whole agriculture: In addition to assessing the benefits from rainfed and irrigated agriculture separately, the performance of whole agricultural enterprise was examined by pooling the data of

Table 1. Soil and water conservation measures and production enhancement activities at Mastihalla watershed

Measures/activities	Unit	Achievement
Field activities		
Arable land		
Gully control measures	Number	711
Vegetative filter strips	Running metre	1076
Contour vegetative hedges (3% slope)	ha	300
Non-arable land		
Gully control measures	Number	30
Drainage line treatment		
Upper reaches		
Gully bank stabilization	Running metre	1900
Loose boulder checks	Number	383
Dug out sunken ponds	Number	15
Middle reaches		
Loose boulder checks	Number	145
Lower reaches		
Check dams	Number	17
Production enhancement activities		
Arable land		
Crop demonstrations	Number	168
Agroforestry (boundary plantation)	Number of plants	9652
Dryland horticulture	Number of plants	6990
Homestead garden	Number of plants	300
Non-arable land		
Grass seeds/seedlings	ha	370
Planting of trees	Number of plants	12500

Table 2. Changes in productivity of major crops (kg ha⁻¹)

Particulars	Pre-project (1997-98)		Post-project (2004-05)	
	Rainfed	Irrigated	Rainfed	Irrigated
Cereals	944	2322	1364 (45)	2773 (19)
Pulses	422	750	647 (53)	839 (12)
Oilseeds	548	1017	720 (31)	1178 (16)
Vegetables	—	4841	—	5724 (18)

Figures in parentheses indicate per cent change over pre-project period.

both the sectors (Table 3). Optimum use of water resources through management produced a desirable BCR with shorter PBP. The BCR for whole agriculture were 3.0, 2.8 and 2.5 at 10, 15 and 20% discount rate with 15-year benefit flow and it was 3.7, 3.5 and 3.2 with 20-year project life. The NPV ranged from Rs. 9,170 to 10,280 for 15 years and Rs. 13,510 to Rs. 14,450 for 20 years project life, respectively, at 10, 15 and 20% discount rate. The PBP was 7 to 8 years and the IRR ranged from 53 to 62%, which was higher than the market rate of interest. In arable lands, in addition to the grain and biomass production, increased tree plantation/survival and grass production was observed.

Whole project: While calculating the various economic indicators, the expenditure on conservation works in non-arable lands, livestock sector, etc., were included in the project costs. The BCR for the whole project was 2.7, 2.4 and 2.1 at 10, 15 and 20% discount rate, respectively, with 15-year net additional benefits, whereas, it was 3.3, 3.0 and 2.7 for 20-year period. Other details are given in Table 3. This analysis indicates that implementation of watershed development program in rainfed areas of semi-arid region was economically viable. Similar findings have also been reported by earlier researchers (Agnihotri *et al.*, 1989; Arya *et al.*, 1994; Kumar *et al.*, 1999; Rama Rao *et al.*, 2005).

Sensitivity analysis

The sensitivity of the watershed development program was analyzed by considering 10% fluctuations in costs and benefits and their impact on BCR. The BCR varied from 2.11 to 2.84 at 15% discount rate for 15-year period in rainfed agriculture under 10% increase in costs and 10% decrease in benefits. The BCR varied from 1.43 to 2.16 at 15% discount rate for 15 year period for whole project. Thus, the economic parameters were found stable even beyond 20% discount rate. The variation in increased cost and decreased production did not have impact on the BCR, i.e. 2.33 in rainfed agriculture and 1.67 in whole project. This clearly indicates the economic worthiness of the program in the watershed. Similar results were also reported by Selvarajan *et al.* (1992).

Employment generation

Rural labor is a part of soil and water conservation in a watershed development program. Natural resource conservation activities result in additional labor employment. Bunding, construction of water harvesting and gully control structures and plantation of trees require labor (Math *et al.*, 1997; Mishra and Mondal, 2006). The additional employment created through these measures was to the extent of 18,026 man-days in the watershed. In addition, for lay out of fields

Table 3. Economic analysis of conservation works under different discount rates

Sector	Discount rates									IPR
	10%			15%			20%			
	BCR	NPV\$	PBP	BCR	NPV	PBP	BCR	NPV	PBP	
Rainfed agriculture	3.4*	7.9*	7	3.1*	7.6*	7	2.9*	7.3*	7	61.2*
	(3.8)**	(10.1)**		(3.7)**	(9.9)**		(3.4)**	(9.6)**		(68.5)**
Irrigated agriculture	2.5*	38.3*	9	2.2*	35.1*	10	2.0*	31.1*	11	42.5*
	(3.5)**	(66.0)**		(3.2)**	(63.1)**		(2.8)**	(59.3)**		(54.6)**
Whole agriculture	3.0*	10.3*	7	2.8*	9.8*	8	2.5*	9.2*	8	53.4*
	(3.7)**	(14.5)**		(3.5)**	(14.1)**		(3.2)**	(13.5)**		(62.3)**
Whole project	2.7*	9.7*	8	2.4*	9.0*	8	2.1*	8.2*	8	46.1*
	(3.3)**	(13.8)**		(3.0)**	(13.3)**		(2.7)**	(12.5)**		(54.2)**

* Anticipated project life: 15 years; ** Anticipated project life: 20 years; \$: Rs. in '000 ha⁻¹.

Table 4. Changes in land use and cropping pattern in two periods (area in ha)

Particulars	Pre-project			Post-project		
	Rainfed	Irrigated	Non-arable	Rainfed	Irrigated	Non-arable
Land use	3340	213	6564	3326	283	6508
Cropping pattern						
Cereals	2212	134	—	2137	143	—
Pulses	74	2	—	76	2	—
Oilseeds	1054	90	—	1209	163	—
Vegetables	—	8	—	—	17	—
Horticulture	—	—	—	10	2	—

with *in situ* rainwater conservation measures and increased crop production in the arable lands, the additional man-days of 15,433, 46,939 and 65,376 were created during 2002-03, 2003-04 and 2004-05, respectively. On the whole, employment of 10 additional man-days per ha per year was created during the three years of the project period.

Environmental impacts

Management of natural resources on watershed basis reduced the deterioration of soil health. Reclamation of marginal area in the watershed increased the cultivable area by 56 ha with corresponding decrease in area under rainfed cultivation and non-arable lands and increase in area under irrigation (Table 4). Watershed program resulted in a shift from long-duration cereal crops to short duration, profitable and erosion-resisting pulses and oilseeds, especially groundnut and sunflower. Under irrigation, vegetable cultivation increased in 9.9 ha area. The cropping intensity increased from 101% (pre-project) to 106% (post-project) with implementation of watershed program. Horticulture plantation was introduced in 10 ha rainfed (mango) and 1.7 ha irrigated area (banana).

Other visible impacts of the watershed program at Mastihalla included:

1. The soil and water conservation measures prevented encroachment of gullies to the agricultural land and increased *in situ* rainwater conservation, which resulted in increased crop productivity and economic value of land.
2. Conservation practices reduced the soil loss from 5.0 t ha⁻¹ to 2.9 t ha⁻¹ and increased soil water in the profile.
3. Increased crop productivity resulted in residue incorporation and availability of farmyard

manure with improved soil physico-chemical and biological properties.

4. The productivity of rainfed crops increased by 31% in oilseeds and 56% in pulses. In the irrigated area crop productivity increased by 12% in pulses and 19% in cereals.
5. Conservation measures recharged the groundwater and increased the number of borewells from 16 (pre-project) to 46 during post-project period, which increased the irrigated area from 24 to 126 ha, in addition to the increased crop yield. This also resulted in increased employment generation.
6. With the growth of trees, on-site soil properties, water conservation and fuel and fodder availability will also increase.

Social and off-site benefits

Implementation of watershed program increased the income of the households (Table 5). The income of marginal farmers increased from Rs. 5,864 (pre-project) to Rs. 9,863 (post-project), i.e. an increase of 68%, whereas the increase in income of large holding (>4.0 ha) was 35%, i.e. from Rs. 51,075 (pre-project) to Rs. 68,929 (post-project). The per capita net income increased from Rs. 1,882 to Rs. 2,895 during this period and was 54% higher over pre-project period. Kumar *et al.* (2006) found similar results in Chhajawa watershed, where income of the farmers was 57% higher than those outside the treated watershed.

Animal husbandry

The increase in animal population was to the tune of 54% during post-project period as compared to pre-project period. The increase was 54% in cows, 62% in buffalos and 51% in bullocks. Milk production also increased from 2.01 to 4.73 lakh

Table 5. Changes in annual income (Rs.) of individual families under different size of land holdings

Size of holding (ha)	Pre-project	Post-project			
		2002-03	2003-04	2004-05	Post project average
< 1.0	5864	7921	10973	10694	9863 (68)
1.01 to 2.0	14231	15664	22506	22839	20336 (43)
2.01 to 4.0	27939	32900	42811	45830	40513 (45)
> 4.0	51075	55961	73332	77495	68929 (35)
Changes in per capita net annual income					
Average	1882	2143	3199	3344	2895 (54)

Figures in parentheses indicate per cent changes over pre-project period.

liters per year in cows and from 2.40 to 5.07 lakh liters per year in buffaloes.

In addition to increase in income and economic status of the rural people, the other visible impacts of the watershed program on socio-economic parameters were:

- Watershed associations like Sri Anjaneya Jalanaya Sangha and Malayabika Jalanaya Sangha and user groups like Sri Valmiki Maharishi Sangha were formed. In addition, SHG's like Sri Shakthi group and Bharni Chetana Kendra were also established to participate in soil and water conservation activities.
- Activities like seed treatment, fertilizer application, plant protection measures and dairy management were found more effective in adoption due to realization of immediate benefits as compared to bunding, water harvesting structures and dryland horticulture, which are beneficial only in the long term.
- Due to the creation of additional man-days through various watershed activities seasonal migration of nearly 50% of the labor force and 10% of the land owners were reduced in the watershed.

Conclusions

Watershed management program conserved the rainwater and reduced the soil loss and recharged the groundwater, increased the borewells and increased the yields of rainfed and irrigated crops. Gross cropped area increased in addition to shifting in cropping pattern towards more remunerative and erosion-resisting pulses and oilseed crops. The program resulted in employment generation for the local population. It also increased the animal population by 54% and milk yield from 4.41 to 9.80 lakh liters per year. Optimum use of water resources with watershed management program

increased the BCR with shorter PBP. This indicates the economic viability of the watershed program. The variation in terms of increased cost and decreased production did not have much impact on the BCR, confirming the economic worthiness of the program in the watershed.

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