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(Received : July 2001; Revised : November 2001)

Madras Agric. J. 88 (10-12) : 673-677 October-December 2001
https://doi.org/10.29321/MAJ.10.A00400

Techno – economics of watershed management - A case study

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Abstract: The Vagpura watershed in Jhadole Tehsil of Udaipur District, Rajasthan was undertaken for preparing an economical design plan of conservation measures and estimating benefit cost ratio. For the proposed watershed, location and site specific soil and water conservation measures like contour bunding, stone wall terracing, contour furrows, pasture development, grass waterway, diversion channel, earthen embankment reservoir for water harvesting are recommended. Cost analysis of the proposed measures resulted that; total cost for development of watershed comes out to be Rs. 3469 per hectare. Benefit cost ratio analysed by economical and financial evaluation methods was found to be 1.6:1 and 1.38:1 respectively. *(Key words: Water shed, Conservation measures, Water harvesting)*

Rajasthan State is the second largest state of Indian union covering 34.3 million ha of land and forest area occupies only about 9 per cent of geographical area of the State. The Aravelly system as a whole covers 32.69 per cent of total area of the State. About 8 milloin ha of hilly tracts bear some kinds of forest growth which now have become most degraded due to over exploitation, and incident of grazing and shifting cultivation (Sharma, 1990). Patil and Sahane (1969) and Gawand *et al.* (1974) have observed appreciable increment in ground water recharge from contour bunded fields. To ensure an ecological balance and economic security, an integrated approach of watershed basis is considered essential. Different techniques like crop production, soil and water conservation, water management, pasture development, afforestation etc. therefore need to be simultaneously adopted on watershed basis so that the efficiency of use of natural resources as well as applied inputs become high (Pandey and Kiran 1991). Singh *et al.* (1992) have evaluated the potential of severely eroded 'Thakarda' watershed in terms of conservation and development resources and increase in productivity through watershed management programme. They reported that the yield of wheat and maize increased from 7.5 q ha^{-1} to 21.6 q ha^{-1} and 5.0 q ha^{-1} to 14.35 q ha^{-1} respectively. Watershed development treatments are economically viable in south Rajasthan as the investment made in the project received in four years from increased crop production (Prasad *et al.* 1997).

The Vagpura watershed covering an area of 179.60 ha was selected in Jhadol Tehsil of Udaipur district to prepare a development plan and to conduct benefit cost ratio analysis on watershed basis. Contour Bunding (CB) has been

proposed for cultivated fields. Stone Wall Terraces (SWT) and Puerto Rico Terraces (PRT) have been proposed to conserve the soil and moisture in the watershed area. Contour furrows are proposed for plantation along the contour for retaining moisture and reducing velocity of the flowing water. Stone fencing wall may protect grasses and plantation. Earthen Embankment Reservoir (EER) will serve as runoff storage structure that primarily be used for giving life saving irrigation to the nearby fields and also for domestic uses as and when needed.

Materials and Methods

Characteristics of the selected watershed

The watershed is situated at a distance of 5 km from Udaipur city in south-west corner of Udaipur Jhadot road and lies at 73°0'and 74°35'East longitude and 23°40'and 25° 30' North latitude. The area comes under semi-arid to sub-humid climate. The annual rainfall during monsoon is uneven and erratic. Mean annual maximum and minimum temperatures of the area are 366°C and 16.1°c respectively. During months of monsoon the relative humidity in the area is about 68 per cent and during the month of March and April this goes below 30 per cent. The area constitutes the rolling topography. The general slope direction is south to north.

As per standard land capability classification the watershed was divided in to four land use capability classes II, III, IV and VI covering an area about 32.1, 109.5, 13.6 and 14.7 ha respectively. The soils are shallow to moderately deep, excessively drained, brown to dark brown, medium texture and located on gentle slope uplands. The pH of the soil is neutral to slightly alkaline. Organic matter and available nitrogen are usually low and are non-calcareous having moderately rapid permeability with enough water holding capacity. Rocks present in the area belong to Aravally and PostAravally system. Quartzite gravel is very common in the area.

Topographical survey was conducted to prepare the contour map. Soil and revenue maps were collected from concern Governement departments of the district. Socio economic status of the farmers was analysed by conducting benchmark survey of the watershed. Design plan of the watershed was prepared keeping hydrological and engineering design criteria for the conservation structures in to consideration. The cost estimation was done and finally benefit cost ratio was analysed for proposed measures.

Contour Bunding (CB)

The general design (height of the bund 0.75m, top width of the bund 0.40m, and bottom width of the bund 2.65m) was adopted for their construction. Total length of contour bund of 1544.00 m length covering an area of 68.75 ha has been proposed. Ramp cum waste weir and stone pitched outlets were designed as water surplushing arrangement from contour bunds. Lateral bunds have been proposed with contour bunds at about every 250 m distance and are extended up to 0.30 m height from the main contour bunds to guide the water in the contour bunds. (Fig.1).

Stone Wall Terraces (SWT)

The general design (height of SWT 1.00 m, top width of SWT 0.4 m, bottom width of SWT 1.40 m and depth of foundation 0.20 m) was adopted for construction. The total length of the measures proposed was 7454.00 m in length covering an area of 81.82 ha (Fig.2).

Puerto Rico Terrace (PRT)

In the region, Puerto Rico Terrace is most popular and widely adopted conservation measure since a good amount of cultivated land exists in the valleys. With the help of this measure double cropping is also possible during good rainy years. This structure has been proposed where slope is greater than 4 per cent, as bunding is not suitable for this situation. Total length of PRT comes to be 3144.00 m covering an area of 11.08 ha. (Fig.3).

Diversion Channel (DC)

It is an individual designed channel constructed across the slope for the purpose of intercepting surface runoff and disposing in to a safe outlet. This is used to protect down stream land from overflow located just above the croped land area. The cross section of the diversion channel was taken at three points i.e. A, B, and C with trapezoidal section. Designs adopted at point A, B and C were top width 3.87 m, bottom width 3.00 m, depth of flow 3.50 m and side slope 1:1, top width 3.80 m, bottom width 3.00 m, depth of flow 3.50 m and side slop 1:1 and top width 6.80 m, bottom width 3.00 m, depth of flow 0.4 m, and side slope 1:1 respectively. (Fig.4).

Earthen Embankment Reservoir (EER)

An earthen embankment reservoir was proposed to harvest the runoff along with a provision of waste weir for safe disposal of excess runoff. The harvested water will not only be used for life saving/supplemental irrigation but will also help in augmenting the ground water recharge.

Table 1. Proposed measures with area, total cost and cost per ha

Proposed Measures	Area (ha)	Cost (Rs)	Survey @Rs.30/hr	Total cost (Rs)	Cost/ha (Rs)
CB	68.750	181122.00	2062.50	183185.00	2664.51
SWT	81.827	286540.00	2454.81	288995.00	3531.78
PRT	11.080	30804.00	332.40	31136.00	2810.11
ACPD	2.146	21242.00	64.38	21306.00	9928.24
EER,GWW,DC	6.201	98252.00	186.03	98438.00	15874.70
				Total	623060.00

Table 2. Return before and after execution of different measures and their economical evaluation.

Proposed Measures	Return before execution of the project (Rs)	Return after execution of the project (Rs)	Net incremental income (Rs)	Present worth of total cost (Rs)	Present worth of net incremental cost (Rs)	Benefit Cost Ratio
CB	119867.80	181005.00	61137.00	284762.00	379830.00	
SWT,EER, GWW, DC	159590.00	263834.00	104234.00	599056.00	647580.00	
PRT	162238.50	25576.10	9338.00	48371.00	58012.00	
ACPD	-	-	-	36561.00	37921.00	
			TOTAL	968750.00	1123343.00	1.16:1

Table 3. Financial evaluation of total project

Proposed Measures	Capital cost (Rs)	Total amount of interest @12% (10 yrs.) (Rs)	Capital cost including interest (Rs)	Total cost including repair and maintenance charges 10 yrs. (Rs)	Benefit including subsidy, 10 yrs. (Rs)	Benefit Cost Ratio
CB	183185.00	109911.00	293096.00	439648.00	675308.00	
SWT, EER, GWW, DC	387433.00	232462.00	619894.00	929838.00	1210850.00	
RT	31136.00	18682.00	49818.00	74730.00	103051.00	
CPD	21306.00	19175.00	40481.00	68179.00	79806.00	
			TOTAL	1512395.00	2087015.00	1.38:1

ACPD - Afforestation Cum Pasture Development
CB - Contour Bunding
DC - Diversion Channel
EER - Earthen Embankment Reservoir
GWW - Grass Water Way
PRT - Puerto Rico Terrace
SWT - Stone Wall Terracing

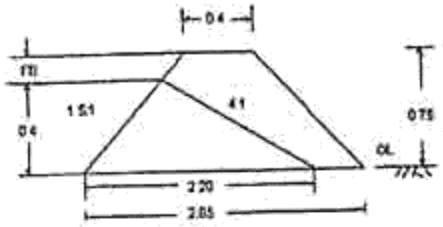

Fig 1. CROSS SECTION OF CONTOUR BUND
SCALE: 3CM = 1M HORIZONTAL
4CM = 1M VERTICAL

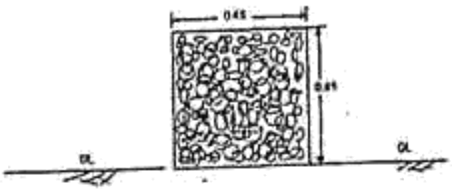

Fig-3. CROSS SECTION OF PUERTO RICO TERRACE
SCALE: 1 CM = 0.1 M HORIZONTAL
1 CM = 0.1 M VERTICAL

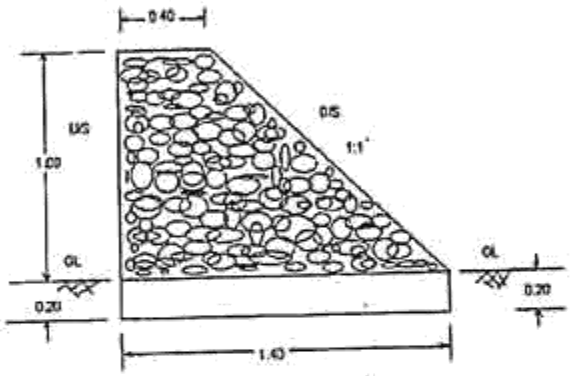

Fig-3. CROSS SECTION OF LOOSE STONE WALL TERRACE
SCALE: 5 CM = 1 M HORIZONTAL
5 CM = 1M VERTICAL

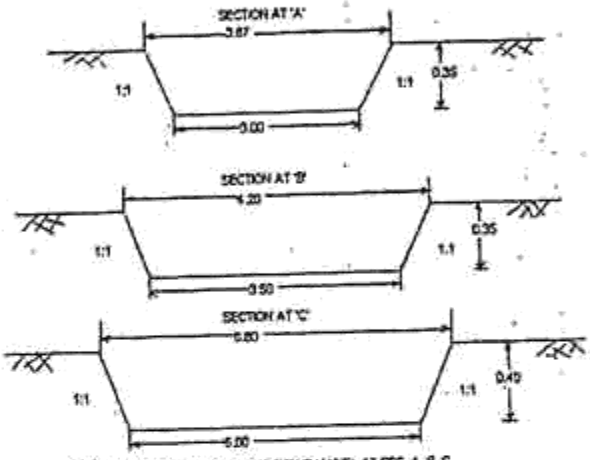

Fig-4. CROSS SECTION OF DIVERSION CHANNEL AT SEC. A, B, C
SCALE: 2 CM = 1 M HORIZONTAL 1 CM = 0.2 M VERTICAL

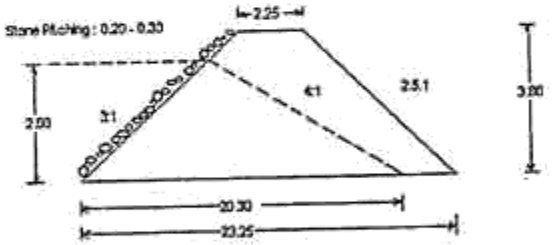

Fig-5. CROSS SECTION OF EARTHEN EMBANKMENT RESERVOIR
SCALE: 1 CM = 2 M HORIZONTAL
1 CM = 1 M VERTICAL

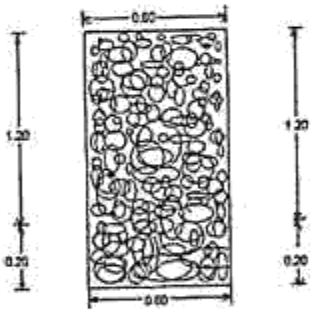

Fig-7. CROSS SECTION OF LOOSE STONE FENCING WALL
SCALE: 6 CM = 1 M HORIZONTAL
6 CM = 1 M VERTICAL

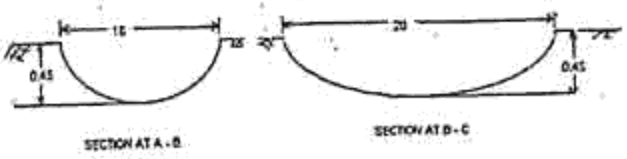

Fig.6 PARABOLIC CROSS SECTION OF GRASS WATERWAY
SCALE: 1 CM = 2 M HORIZONTAL
1 CM = 0.2 M VERTICAL

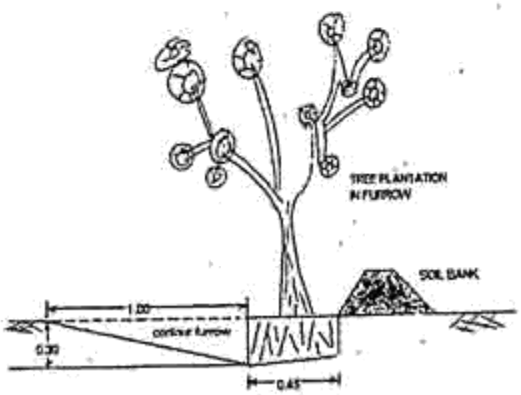

Fig-8. CROSS SECTION OF CONTOUR FURROW
SCALE: 5 CM = 1 M HORIZONTAL
5 CM = 1 M VERTICAL

Design details include catchment area 36.20 ha, submergence area 5.35 ha, total storage capacity 6.20 ha m, length 320.00 m, height 3.8 m, top width 2.25 m, upstream slope 3:1, downstream slope 2.5:1, length of waste weir 10.8 m and height of waste weir 3.8 m. (Fig.5).

Grass Water Way (GWW)

The design adopted for parabolic cross section at section A-A was top width 16.00 m, depth of channel 0.45 m, and at section B-C was top width 20.00 m, depth of section 0.45 m. The total length of grass water was 170.00 m. (Fig.6).

Afforestation Cum Pasture Development (ACPD)

A good amount of land in the watershed can best be put under afforestation with suitable water conservation/in-situ rainwater conservation measures.

Loose Stone Fencing Wall

This measure has been proposed to protect the plantation and grass from damage due to cattle grazing and reducing the velocity of flowing water. The dimensions of the structure are height 1.20 m, top width 0.60 m, bottom width 0.60 m and depth of foundation 0.20 m. The total length of structure comes to be 1980.00 m covering an area of 2.146 ha. (Fig.7).

Contour Furrow

To cerates small moisture regime for grasses by reducing the velocity of flowing water, this measure has been proposed. The general dimension adopted is width 1.00 m, depth of outword end 0.30 m, spacing 15 m. Total length of contour furrows come to be 2858.00 m covering an area of 2.146 ha. (Fig.8).

Results and Discussion

To work out return before and after execution of the individual measures crops like paddy, maize, jowar, urd, sugarcane, cotton in *kharif* and wheat, gram, barley, sarsoon in *rabi* have been considered for economic analysis. Stone wall terrace, earthen embankment reservoir, diversion channel and their related components like area, cost etc. were grouped together. Finally present worth of total cost and present worth of incremental cost have been worked out for the total project giving benefit cost ratio 1.6:1 on the basis of economical evaluation (Table 2). While analyzing economical evaluation, land class II, III and IV have been considered for crop production whereas afforestation cum pasture development work was proposed on class VI land. The benefit from the tree has not been considered for economic analysis, since the income was possible after only 15 years under the existing conditions. To work out financial evaluation of the project total amount including interest @12 per cent paid by the cultivators has been considered. Then total cost of the project including repair and maintenance charges and benefit including subsidy have been analysed for ten years life of the suggested measures. The benefit cost ratio by financial evaluation comes to be 1.38:1.

The economic and financial evaluation was done for the development and management of a micro watershed representing the area of hilly range. Existing crop yield will certainly be increased after execution of proposed engineering and agronomical measures. Total cost of watershed development and cost per ha estimated to be Rs. 6,23,060 and Rs.3469 respectively. Considering the investment life of the project as ten years and discount rate of 10 per cent, the benefit cost ratio worked out to be 1.6:1 and 1.3:1 by economical and financial evaluation respectively. Thus suggested measures will not only increase crop productivity but also help in improving socioeconomic status of the farmers of the region.

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(Received: June 2000; Revised: November 2001)