Current Journal of Applied Science and Technology

39(48): 225-236, 2020; Article no.CJAST.66043
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Impact of River Valley Project in South Pennaiyar Catchment of Tamil Nadu, India

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Authors' contributions

The work was carried out by all the authors' through multi disciplinary approach. Author SM has collected and analyzed the data in respect of all engineering works. The authors OPSK and KK carried out the evaluation pertaining to production and productivity. Author BLD analyzed the economical viability of the project. Author VKT managed the literature review. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2020/v39i4831225
Editor(s):
(1) Dr. Pavel K. Kepezhinskas, PNK GeoScience, USA.
Reviewers:
(1) Iran Carlos Stalliviere Corrêa, Universidade Federal do Rio Grande do Sul, Brasil.
(2) Thiago Simonato Mozer, Universidade Federal Fluminense, Brazil.
Complete Peer review History: http://www.sdiarticle4.com/review-history/66043

Original Research Article

Received 25 October 2020
Accepted 30 December 2020
Published 31 December 2020

ABSTRACT

Aims: The impact of comprehensive interventions in erosion control, improving water availability, development of agro-forestry, sustainable management of natural resources, enhancement of agricultural productivity and socio-economic aspects of the farmers was studied. Assessment of effectiveness of watershed development programme, identification of major issues and lacunae in project implementation across the watersheds also has been studied.
Study Design: Multistage stratified sampling technique was adopted in selection of study watersheds (secondary sampling unit-SSU), farmers (primary sampling units-PSU) and structures for detailed surveys.
Place and Duration of the Study: The study was conducted in South Pennaiyar catchement in Dharmapuri, Salem, Villupuram, Vellore, Thiruvannamalai districts of Tamil Nadu. The study was conducted for three years period during 2012-14.

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Methodology: Sample based before and after project evaluation approach, employing budgeting techniques. By employing stratified random sampling method 15 study watersheds (SWS) were selected and the benchmark data collected by the project implementing agency (PIA) at the time of project planning were used for the study. All the collected data were analyzed through budgeting techniques or appropriate statistics. The cash flow table was developed which were further aggregated along with other miscellaneous costs of the project to generate total cost and benefit stream of the project.

Results: The evaluation study reveals that runoff reduction of 8 to 10 percent and soil loss varies in the range of 1.1 to 1.9 t $ha^{-1}yr^{-1}$ after the project compare to 4.1 to 4.9 t $ha^{-1}yr^{-1}$ before the project shows the reduction of 3 t $ha^{-1}yr^{-1}$. Gully control structures made their impacts in terms of arresting silts at the rate of about 10.1 cum yr^{-1} in one watershed and stabilized the gullies. Increased water table in the range of 0.32 and 0.93 m with increased duration of water availability in wells for more than 9 months and increased recuperation rate (1.8 to 6.5 per cent) were observed. An additional surface storage capacity of 26.4 ha - m per watershed was created due to watershed interventions. The Net Present value of the project is about Rs. 52,238 lakhs without considering intangible benefits. The economic soundness of the project is also amply indicated by BCR (1.65:1) and IRR (53%) and the whole investment made in the project can be recovered within seven years. The NPV of the project further improved by inclusion of monetary value of the nutrient due to reduced soil erosion. The value of NPV was more than Rs. 63,968 Lakhs with 1.72 BCR and 65.5 % IRR.

Conclusion: River valley project in South Pennaiyar catchment of Tamil Nadu is economically viable and recommended to be taken on priority for sustainable agricultural growth in the river / reservoir catchments.

Keywords: River valley project; surface runoff; South Pennaiyar catchment; watershed.

1. INTRODUCTION

Watershed is a special kind of common pool resource: an area defined by hydrological linkages where optimal management requires coordinated use of natural resources by all users [1]. The watershed programme is primarily a land based programme, which is increasingly being focused on water, with its main objective being to enhance agricultural productivity through increased in situ moisture conservation and protective irrigation for socio-economic development of rural people [2]. Watershed development activities have made significant positive impacts on various biophysical aspects such as soil and water conservation, soil fertility, changes in cropping pattern, cropping intensity, production and productivity of crops, water table and availability of water in wells [3,4,5]. Participatory watershed management help to define problems, set priorities, select technologies and policies, and monitor and evaluate impacts, raises new questions for watershed research, including how to design appropriate mechanisms for organizing stakeholders and facilitating collective action [6].

Understanding the economic, social and environmental impacts of watershed development means expanding the indicators to beyond numbers of farmers trained [7]. Quantitative and qualitative evaluation methods, which traditionally have been used separately, both have strengths and weaknesses, and comprehensive evaluation makes more effective [8,9]. Comprehensive assessment studies proved that the watershed programmes converted more waste land into agricultural land [10] and the watershed technologies are economically viable and ecologically sustainable [11].

Watershed development projects in India has a long history of development however, very limited studies were conducted to quantify the impact of watershed interventions on biophysical aspects [12,13]. The impact of IWD interventions on ecosystem services is not well understood and this has under estimated the impact of watershed management programs in the country. There is also increasing concern about downstream water availability due to watershed interventions in upstream areas especially in dry lands regions [13,14]. The watershed development activities implemented in the rainfed areas have significantly influenced the various biophysical aspects such as soil and water conservation, soil fertility, positive impacts on cropping pattern, cropping intensity, production and productivity of crops [15,16, 17,18,19,20,21,22]. Watershed interventions also helps in increased water table, perenniality of water in wells, water availability for cattle and other domestic uses [3]. Chen et al. [23] stated that a filter strip can significantly mitigate surface water pollution in agricultural watershed were the dominant sources of nutrients and sediment in the watershed. Land use and land cover changes at watershed level were increased in both the water body and forest areas and decrease in the dense vegetation, barren land and riverine sand areas [24]. The soil conservation measures taken in fields, effectively reduce onsite soil loss and sediment yield by integrated small watershed management [25]. However, application of integrated water resource management at river basins, it will vary according to the hydrological, socio-political, and economic conditions affecting each application and what work in one place may not work elsewhere [26]. Integrating the watershed approach with ecological risk assessment increases the use of environmental monitoring and assessment data in decision making [27]. Despite various assessment studies conducted at micro watershed level, the impact study at larger reservoir catchments are scanty and reported very limited elsewhere. Hence, the present study aims to evaluate the impact of watershed interventions implemented under River Valley Project (RVP) in 101 micro watersheds of South pennaiyar catchment of Tamil Nadu through random evaluation of 15 study watersheds. The impact of comprehensive interventions in erosion control, improving water availability, development of agro-forestry, sustainable management of natural resources, enhancement of agricultural productivity and socio-economic aspects of the farmers was studied. Assessment of effectiveness of watershed development programme, identification of major issues and lacunae in project implementation across the watersheds also has been studied.

2. MATERIALS AND METHODS

2.1 Study Area

The South Pennaiyar River Valley Project in Dharmapuri, Salem, Villupuram, Vellore, Thiruvannamalai districts of Tamil Nadu initiated under centrally sponsored soil conservation scheme for river valley projects during the fourth five year plan period with the objective to reduce siltation of Krishnagiri reservoir through reduction of runoff and recharge ground water aquifer for sustained water yield through watershed development approach. A total geological area of 33,652 ha was treated under 101 micro watersheds in south Pennaiyar catchments. Out of the total area, 10,590 ha treated area was covered under 15 watersheds in Dharmapuri, Vellore, Salem and Thiruvannamalai districts for evaluation under this study. The 15 watersheds selected for detailed impact analysis study those represents all the three Districts. The average slope of selected watershed ranged between 3 to 25% which is representative slope of the overall projects. A brief geographical description of study watersheds is presented in Table 1.

The mean annual air temperature is more than 22ºC and the difference between summer air soil temperature and mean winter soil temperature is less than 5ºC and hence the soil temperature regime of the area is iso-hyperthermic. The project area receives average annual rainfall of 852 to 1174 mm. The area consists of Archean rocks constituting of Charnokites, granites and basic intrusive rocks. Ferruginous quartzite, pink granites, laterite, limestone are found in the region. The area under the study comprises of red soils, black soils and mixed red and black soils. Out of 33,652 ha, red soils occupy an area of 23,623 hectare constituting 70.2%, black soils occupy an area of 538 hectare (1.6%) and mixed soils in area are of 6562 hectare (19.5%). Agriculture is the major land use (5901 ha), followed by forest (2692 ha), waste land (2169 ha) and least under other uses (738 ha). The watershed interventions namely Contour / field bund, Contour Staggered trenches, Loose boulders check dams, Silt detention tanks, Water harvesting structures, Percolation ponds, Horticulture plantation, Agro-forestry and Afforestation were planned and implemented.

2.2 Evaluation Methods

The impact evaluation study was conducted through sample based before and after project evaluation approach, employing budgeting techniques. By employing stratified random sampling method 15 study watersheds (SWS) were selected and the benchmark data collected by the project implementing agency at the time of project planning were used for the study. After collecting benchmark data the impact indicators were enlisted (direct or surrogate indicators) to capture the status of provisionary, regulatory supportive and cultural services provided by the

South Pennaiyar catchment system before and after the WSD program. Provisionary services include the status of the level of production of food crops, horticultural produce, livestock products, regulatory services indicate rainwater conserved, regulate flow of water in the watershed system. Soil conserved, vegetation coverage, induced ecosystem, supportive service indicators – land smoothening, bunding, water quality, application of farm yard manure etc. and cultural services includes infusion or diffusion of good land and water management practices, culture of maintaining and utilizing created assets on a sustained basis, social equity etc.

Multistage stratified sampling technique was adopted in selection of study watersheds (secondary sampling unit-SSU), farmers (primary sampling units-PSU) and structures for detailed surveys. SSU stratification was based on topographic sequence present in the project area namely watersheds located in upper reaches, middle reaches and lower reaches of the catchment. The numbers of SSU from each topo-sequence was in proportion to the number of treated watersheds subject to minimum of two watersheds from each topo-sequence as well as the priority category. Selection of PSU from each SWS was again stratified based onto topo-sequence in combination of socio economic variation present in the watershed and in proportion of number of households of different socio-economic stratum in different topo-sequence subjected to minimum two PSU from each socio-economic stratum and maximum 10 PSUs from each topo-sequence from each watershed making 30 PSUs from each watershed. Transect walk with Watershed Development Team (WDT) members and farmers were conducted to verify the present status of structural design (assets) created during the project period. A ten per cent of each type of structure subject to minimum one structure from each SWS was selected for detailed investigation.

All the collected data were analyzed through budgeting techniques or appropriate statistics. The cash flow table was developed which were further aggregated along with other miscellaneous costs of the project to generate total cost and benefit stream of the project. Down-stream benefits (external benefits) in the command area through saving of pond age area by arresting silt within the catchments was also estimated in similar manner and aggregated to form stream of additional benefits of the project. Cash flow table was discounted at 10 per cent discount rate being a high priority activity of environmental security had priority lending rate. Benefit-Cost Ratio (BCR), Net Present Worth (NPW), Pay Back Period (PBP) and Internal Rate of Return (IRR) were estimated. Sensitivity analysis with respect to cost and benefits was done for 10% increase in cost, 20% decrease in benefits in isolation as well as both together. Higher rate of decrease in benefits was selected owing to high dependency of farming system on low rainfall situation in the area. Horticulture plantation (mango, coconut, tamarind, etc.) trees had more than 30 years technical life was taken as period of analysis under the study. Average situation of past 10-years cost and benefit stream was taken for rest of the period to account future benefits and costs. The evaluation study was carried out during south-west and north-east monsoon period in each watershed to capture impact during both monsoon periods.

3. RESULTS AND DISCUSSION

Implementation phase for all the watersheds were completed during 2012-13. The impact evaluation study results of the fifteen study watersheds from South Pennaiyar catchment is presented under this chapter in details and divided into various sub sections as described below.

3.1 In Situ Soil and Water Conservation Measures

The impact of the contour / field funds was gauged from the increased yield level of various crops ranges from 1.3 to 14.5 per cent. Few of the pockets it was noticed that the crop diversification has been taken place after forming the contour bund. Nearly 10.4 per cent of the amount has been spent for this activity. In low rainfall areas contour bunds can increase sorghum yields by 30–90% with rainfall [28]. The dimensions of trench were 2.50 m length, 0.45 m width and 0.30 m height. Positive impact of the trenches was noticed from the higher growth rate of the plantations / horticultural crops which was found to be satisfactory.

Table 1. Geographical description of selected watersheds treated under river valley project in South Pennaiyar catchment

S. No	Watershed code	Longitude	Latitude	Villages	Total Area (ha)
1	$4C_1C_7b_3$	78º 07'E	12º43'N	Chinnagundhur, Krishnagiri, Devarakundhani, Edrapalli, Dananthikuppam	850
2	$4C_1C_7d_5$	78º6'E	12º47'N	BottiMaduvu,Jdipalle, Oddapalle, Karnataka	732
3	$4C_1C_6f_2$	78º14'E	12º32'N	Kompalli,Ragimaganapalli, Jujupalli, Polupalli, Kurubarapalli	928
4	$4C_1C_4p_7$	78º44'E	12º28'N	Pungampattu Nadu	791
5	$4C_1C_5n_7$	78º14'E	12º3'N	Periyur	798
6	$4C_1C_2n_6$	78º27'E	11º58'N	Malagapadi,Kokkarapatty,Erumaiyampatty	631
7	$4C_1C_2a_1$	78º34'E	12º08'N	Chinnapannimaduvu,Periapannimaduvu, Thambal	798
8	$4C_1C_1C_6$	78º4'N	12º8' N	Karimalaipadi,Melravandavadi,Andipatti,Thambunaickenpatty, Naradapattu	1490
9	$4C_1C_1j_3$	78º39'N	11º53' N	Vadakunadu, Athur, manipalayam, Aruvankadu, Chinnakalrayanvadakunnadu, maniyamandayam	580
10	$4C_1C_1d_3$	78º40'E	12º06'N	Runganavalasai,Periyapatti	870
11	$4C_1C_1p_5$	78º37'E	12º9'N	Melchengampadi,Kilchengampadi,Mondukuli,Andiyur,Kattevadichempatty,Theerathamalai	873
12	$4C_1C_1S_7$	78º34'E	12º03'N	Veppampatti,Veppampatti RF	927
13	$4C_1C_7a_3$	78º09' E	12º40' N	Bimandapalli,Gunttapalli, Kuppachiparai,B.G.Durgam,Beerapalli	836
14	$4C_1C_1t_3$	78º39'E	12º02'N	Elavampadi,Neeppadurai,Pungani, Kattamaduvu	1235
15	$4C_1C_1f_3$	78º40'E	12º02'N	Bairnaikampatty,Naripalli, Senrayampatty,Theerthamalai RF	479

3.2 Drainage Line Treatments

Loose boulders check dams (LBCDs) are mostly constructed in first order streams of upper reaches and found that about 70 per cent of these structures were found to be in good condition and functioning efficiently for the purpose it was constructed. Positive impact was gauged from the quantity of silt accumulated in the upstream side of the LBCDs. Similarly, LBCDs constructed in second order streams of middle reaches are found to be intact at 65 per cent. These structures help in stabilization of stream beds apart from reducing the velocity of water flow. After few years, these LBCDs act as water harvesting structures due to blocking of pores. Due to sediment deposition behind the structures constructed in the streams, the gully bed level is stabilized. Large number of the Gabion check dams (GCDs) were constructed in middle reaches and found that 90 per cent of these structures found to be good condition. The silt deposited behind *ex-situ* conservation measures of sample structures were estimated from SWS is presented in Table 2. Based on silt deposited behind selected check dams/ponds, soil loss was estimated to vary in the range of 1.1 to 1.9 t $ha^{-1}yr^{-1}$, which is very well within the permissible limit. The results are in line with the study conducted by Lenzi [29]. The silt accumulated behind check dams are being effectively utilized by beneficiaries which increase the soil fertility and enhances the growth of vegetation in the nearby region [30].

3.3 Water Harvesting Structures

Ninety per cent of the water harvesting structures (WHS) are functioning and were well maintained by the beneficiaries under the convergence of MNREGA scheme. Three to ten tube wells are being benefitted by each water harvesting structures. Positive impact of water harvesting structures could be gauged from decreased depth to ground water table ranges from 3 to 5 m during monsoon and 10 to 12 m during summer. The major crops cultivated near to these structures are tapioca, black gram and vegetables.

There are two to three silt detention tanks (SDTs) were constructed in series to trap the runoff water and silt in each watershed. All the SDTs constructed in lower reaches were found to be intact and serving the purpose for its constructed. Almost 95 percent of the SDTs are fully functional. Realizing the benefit local community decided to desilt these structures to be functional where they were completed silted up. Even the damaged structures had partly served their purpose as evident from gradient slope reduction and silt deposited behind the structure.

Table 2. Quantity of silt trapped in various structures in South Pennaiyar catchment

Watershed name	Water harvesting structures		Farm pond		Silt detention tank	
	No.	Silt deposition (cum)	No.	Silt deposition (cum)	No.	Silt deposition (cum)
Andipatti	1	14.89	1	---	1	15.62
Rungavalasai	2	39.10	2	4.00	2	28.46
Kurumapatti	-	-	-	-	1	8.79
Senrayampatty	3	64.24	2	18.47	8	94.58
Aruvankadu	2	46.21	2	12.34	5	60.12
Veppampatti	-	-	-	-	1	9.58
Elavampadi	1	25.16	-	-	1	6.45
Sattayampatti	3	67.30	4	32.15	7	79.58
Kokkarapatti	4	86.33	4	28.58	7	90.05
Nadur	2	35.17	5	37.29	10	105.42
Periyur	2	24.89	2	21.47	7	65.47
Chinnagummarur	1	48.23	-	-	1	9.16
Beemandapalli	3	52.54	4	19.24	8	95.16
Devaragundhani	2	30.26			9	87.58
Total	26	534.32	26	173.54	68	756.02

Detailed survey conducted for few farmers in these watersheds whose cultivable land close to WHS/SDT is presented in Table 3. It could be observed that slight increase in irrigated area around the water harvesting structures due to increase in ground water table, well yield/recuperation and duration of water availability in the wells. The irrigated area has been increased by 30% in the South Pennaiyar catchment after the implementation of the project. The area under irrigation has been increased in the entire watershed under the catchment. Among various watersheds in the catchment, the highest increase in area under irrigation (80%) was observed in Kokkarapatti watershed which was followed by Beemandapalli watershed (64%) and Nadur watershed (57%). Significant and quick impact of rain water harvesting structures on ground water recharge in Bundelkhand region was reported by Kumari et al [31].

3.4 Artificial Recharge Structures

Percolation ponds (PPs) formed important component of RVP watersheds works for augmenting groundwater recharge. The storage capacity of these PPs generally varies between 20 ha cm and 50 ha cm. The additional water storage created helped in raising water table in the open wells which bring additional area under irrigation. Surface water storage construction to collect runoff water during high rainfall events were found effective and capacity have increased considerably in the watersheds through construction of new water harvesting structures, percolation ponds in order to increase ground water recharge. A total 751.5 ha-cm water storage capacity has been created in 15 selected watersheds of South Pennaiyar. It reveals that area had high relevance of WHS in the area.

3.5 Impact on Surface Runoff

Based on data collected by the department in few selected gauging stations located in the treated watersheds it is clearly depicted that the runoff and sediment yield has been reduced drastically. Based on the runoff gauging data available at ponds/check dams, surface runoff was found to be 9 to 12.3 per cent of the rainfall for selected rainfall events. In general, most of the surface runoff was reduced as a result of in situ moisture conservation practices like contour bunds/field bunds, land leveling, etc., in the field and remaining runoff was stored beyond the structures constructed for storing surface runoff with in the watersheds. Soil loss was reduced from 4 to 1.2 tonnes ha^{-1} yr^{-1}due to *in-situ* moisture conservation measures and gully control structures.

Table 3. Disparity between irrigated and rain fed area in river valley project watersheds of South Pennaiyar catchment during pre and post project period

S. No.	Watershed name	Irrigated area (ha)			Rainfed area (ha)		
		Before project	After project	Percent change	Before project	After project	Percent change
1.	Andipatti	14	15	10	17	13	-22
2.	Rungavalasai	20	23	16	14	10	-27
3.	Kurumapatti	12	16	30	12	14	16
4.	Senrayampatty	9	11	17	22	20	-9
5.	Aruvankadu	4	4	0	24	23	-5
6.	Veppampatti	13	14	8	18	17	-6
7.	Elavampadi	16	20	25	14	9	-30
8.	Sattayampatti	15	18	19	23	19	-17
9.	Kokkarapatti	6	11	80	26	21	-19
10.	Nadur	6	9	57	29	25	-11
11.	Periyur	11	16	49	16	10	-36
12.	Chinnagummarur	6	8	36	7	6	-25
13.	Beemandapalli	5	8	64	26	22	-13
14.	Devaragundhani	15	21	42	13	8	-40
15.	Bottimaduvu	8	14	62	20	13	-37
	Total	161	208	30	280	231	-18

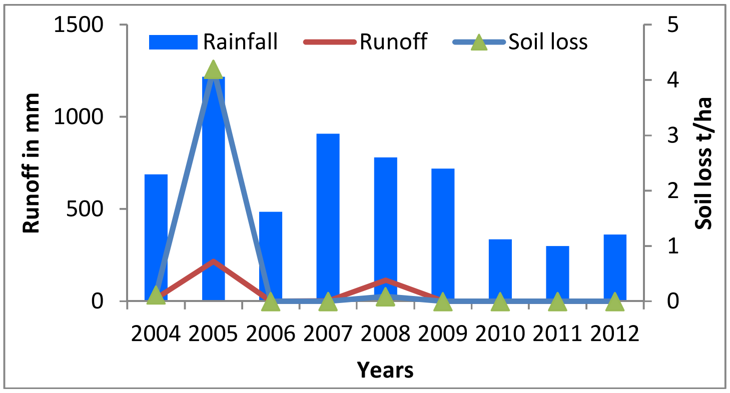

Fig. 1. Impact of RVP schemes on runoff and soil loss

Table 4. Impact of RVP watershed project in recuperation rate in South Pennaiyar

Watershed	Recuperation rate (m^3/hr)			Increase (%)
	Before	After	Increase	
Andipatti	0.82	0.85	0.03	3.50
Aruvankadu	1.10	1.17	0.07	6.53
Beemandapalli	0.96	0.99	0.03	2.86
Bottimaduvu	0.96	0.97	0.01	1.48
Chinnagummarur	1.90	1.95	0.05	2.86
Devaragundhani	1.80	1.88	0.08	4.35
Kokkarapatti	0.70	0.71	0.01	2.08
Nadur	0.70	0.74	0.04	6.18
Periyar	2.09	2.16	0.07	3.33
Rungavalasai	2.09	2.17	0.08	3.90
Sattayampatti	2.00	2.07	0.07	3.62
Senrayampatty	1.80	1.89	0.09	5.26
Veppampatti	2.00	2.07	0.07	3.66

3.6 Impact on Ground Water Resources

Impact of the interventions such as Water harvesting structures, percolation Pond, Silt Detention tank, contour bunding etc., on ground water was observed to some extent during field survey and discussion with the farmers. Impacts in term of increase in water table duration of water availability in wells with increase in well yield/recuperation under selected watersheds are presented (Tables 4 and 5). Raise in ground water table observed during the year 2014 in influence zone of water harvesting structures under SWS is presented. It was found that raise in water table varies from 0.10 m to as high as 0.86 m in different watersheds with average rise in water table varies from 0.20 to 0.46 m. The raise in water table was maximum in Aruvankadu watershed (0.51 m) and minimum of 0.20 m in Bottimaduvu watershed. Similarly, 2.54 m increase in ground water level was reported by Abraham and Mohan [32]. The difference in raise in water table was due to interventions taken in these watersheds and such as location of well or topo sequence of SWS and other factors.

The period to which water remains in the wells for productive purpose is an important aspect as watershed impact data of 162 wells in South Pennaiyar watersheds were studied. Forty seven per cent of the sample wells had water for more than 9 months during the evaluation period as compared to 41 per cent before the project period. The study clearly reveals the watershed management activities under RVP scheme in South Ponniayar had impacted positively in longevity of water availability in wells. The one another very positive aspect of the project was no drying or reduction in water availability in the wells situated at upper location/reaches of the SWS of the study area rather it increases there too. Recuperation rate after RVP project increased in the range of 2.08 to 8.18 per cent in different watersheds. The maximum recuperation rate was observed in Aruvankadu watershed and it was minimum in Bottimadavu watershed. The recuperation rate was influenced primarily attributed to location distance of wells from the location of water harvesting structure and quantum of water available in the structure besides quantum of rainfall in the watershed.

3.7 Impact on Land Use and Crop Productivity

Land use change in South Pennaiyar catchment shows that there was an increase in cropped area of about 54.7 ha (18.74%) after the implementation of the project. Although there was no change in the field crops area in the catchment as a whole, the area under field crops has been decreased and these areas were diverted to more remunerative vegetable cultivation. The reduction in area under field crop cultivation ranged from 0.9 % in Elavampadi watershed to 34.0 % in Veppampatti watershed. There was a steep increase in area under vegetable cultivation (143%) in the catchment as a whole after the implementation of watershed project due to the assured water supply which led to the more remunerative vegetable cultivation. The highest per cent of change in vegetable cultivation was notice in Chinnagummarur (375%) and Kokkarapatti (348%) watershed where vegetable cultivation before the implementation was less than a hectare. Maximum increased area under vegetable cultivation (6.6 ha) after the implementation was noticed in Nadur watershed. There was a decrease in area under pasture (39.5%). The change in land use.

3.8 Benefit Cost Analysis (BCA)

BCA of the project was done by considering 25 years project life at 10% discount rate and presented in Table 6. The Net Present value of the project is about Rs. 52238 lakhs without considering intangible benefits. The economic soundness of the project is also amply indicated by other criteria viz. BCR (1.65:1) and IRR (53%). The whole investment made in the project can be recovered within seven years. The values of the economic viability of the project improved by inclusion the monetary value of the nutrient saved by way of reduction in soil erosion. The value of NPV was more than Rs. 63968 lakhs with 1.72 BCR and 65.5 % IRR. The pay back also reduced by one year. All the criteria of economic evaluation indicate that such projects are highly economically sound be taken on priority for sustainable agricultural growth in the region.

Table 5. Number of wells and tube wells in different SWS after the project

Watershed	Name of the structure		Depth of water availability during summer (m)	Depth of water availability during monsoon (m)
	Well	Tube well		
Andipatti	12	27	3.36	34.55
Aruvankadu	7	35	5.33	36.67
Beemandapalli	10	28	3.13	12.63
Bottimaduvu	10	27	2.44	18.89
Chinnagummarur	9	25	2.89	29.44
Devaragundhani	9	18	4.22	15.33
Kokkarapatti	9	19	2.83	36.17
Nadur	14	28	4.42	31.77
Periyar	17	31	3.35	14.62
Rungavalasai	17	30	3.56	30.38
Sattayampatti	11	19	3.73	29.09
Senrayampatty	15	25	4.36	26.29
Veppampatti	22	32	3.41	31.68
	162	344	3.62	26.73

Table 6. Benefit cost analysis of south Pennaiyar watersheds at 10% discount rate

Evaluation criteria	Situation	
	Tangible benefits only	Tangible + nutrient saved
NPV (Lakh Rs.)	52238	63968
BCR	1.65:1	1.72:1
PBP (Years)	7	6
IRR (%)	53	65.5

4. CONCLUSION

Overall, the River valley project activities carried out in south Pennaiyar catchments from 2002 to 2012 in 101 micro-watersheds of Tamil Nadu state made number of tangible and intangible benefits in the region. Positive impact on natural resources in terms of increase in ground water recharge, silt detention, gully stabilization, increase *in - situ* moisture conservation, reduction in runoff and soil loss, reduction in silt carrying capacity to reservoirs, increase in irrigated area and people participation / institutional building were noticed. Production and productivity are also in increasing trend due to watershed activities in the south Pennaiyar catchment. The project has also made positive impact on socio-economic status of the beneficiaries in terms of increase in additional employment generation and additional income generation. The project has created awareness among the beneficiaries about importance of natural resources, watershed development programmes, advanced soil and water conservation technologies and production technologies for enhancing productivity. All the criteria of economic evaluation indicate that such projects are highly economically sound be taken on priority for sustainable agricultural growth in the region. Hence, the evaluation study conclude that such projects should be taken in the catchments of reservoirs on priority in a more concentrated and coordinated manner with active participation of local community, guided by technological requirement rather than the rigid government norms along with technical back stopping mechanism and withdrawal strategy.

ACKNOWLEDGEMENTS

Authors acknowledge the financial support granted by Agricultural Engineering Department, Government of Tamil Nadu, Chennai for conducting this impact evaluation study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/66043