JEB
Website : www.jeb.co.in
E-mail : editor@jeb.co.in

Journal of Environmental Biology

ISSN: 0254-8704 (Print)
ISSN: 2394-0379 (Online)
CODEN: JEBIDP

Comprehensive impact assessment of resource conservation measures in watershed of eastern region of India

M. Madhu*, B.S. Naik, Praveen Jakhar, H.C. Hombe Gowda, Partha Pratim Adhikary, K.P. Gore, D. Barman and G.B. Naik

ICAR-Indian Institute of Soil and Water Conservation, Research Centre, Koraput, Odisha – 763 002, India

*Corresponding Author E-mail: **madhupmd@gmail.com**

Publication Info

Paper received:
21 November 2014

Revised received:
14 October 2015

Re-revised received:
02 November 2015

Accepted:
12 December 2015

Abstract

A comprehensive study was carried out to assess the impact of watershed development activities in a tribal dominated watershed in the Eastern Ghats region of Odisha. The average potential soil erosion rate (PSER) in watershed for pre- and post-project period was estimated to be 30.24 t ha^{-1} yr^{-1} and 25.03 t ha^{-1} yr^{-1}, respectively. The average estimated runoff in the watershed decreased to 14.6% during post-project period from 24.4% in the pre-project period. Yield of all the crops increased by 3 to 15% with overall average increase of 9.14%. Maximum water productivity was observed in the upland paddy (0.45 kg m^{-3}) followed by maize (0.38 kg m^{-3}), lowland paddy (0.3 kg m^{-3}), red gram (0.18 kg m^{-3}) and ragi (0.17 kg m^{-3}). Water productivity of vegetables in watershed varied between 2.4 kg m^{-3} (beans) to a maximum of 5.7 kg m^{-3} (cabbage) of water. The average energy efficiency of rain-water (EERW) for the crops grown in watershed area was 5.53 MJ m^{-3} of rainwater which was equivalent to 1.32 kcal l^{-1} of rainwater. The average carbon sequestration potential was 2.12 and 3.4 t ha^{-1} yr^{-1} after 10 and 20 years, respectively worked out from the plantation area. The average human population carrying capacity (HPCC) of crops increased by 9.3% due to enhanced productivity of crops. The technical man days actually involved in different phases of watershed development was also worked out. All these indices showed positive ecological and economic impact of watershed development works and could be used as technical reference for further refinement and future assessment.

Key words

Bio-physical impact, Environmental impact, Impact assessment, Watershed management

Introduction

Livelihood security with a strong commitment to natural resource conservation is the foremost challenge of 21st century. Globally, 80% of agriculture are *rainfed* and contributes 60% of world's food basket. Over 120 million ha land area has been declared degraded (Maji, 2007) in India. About 60% of total arable land (142 M ha) in the country are rainfed, characterized by low productivity, low income, low employment with high incidence of poverty. To manage these lands for sustainable crop production and livelihood security of the people residing there, watershed approach is a viable option. The success of watershed management depends on stakeholder participation (Fadim and Baycan, 2015). Thus, views of local community should carefully be evaluated to enhance the success level in watershed management studies. Additionally, co-operation between the public and government agencies need to be improved (Yoganand and Gebremedhin, 2006).

Development of watershed/catchment is one of the most trusted and eco-friendly approach to manage rainwater and other natural resources, which has paid rich dividends in the rainfed areas and is capable of addressing many natural, social and environmental issues (Wani *et al.,* 2003). Management of natural resources at the catchment/

watershed scale produce multiple benefits in terms of increasing food production, improving livelihoods, protecting environment, addressing gender and equity issues along with biodiversity concerns (Joshi *et al.,* 2005) and is also recommended as the best option to upgrade rainfed agriculture to meet the growing food demand globally (Rockström *et al.,* 2007). There is considerable potential to bridge the yield gap between the actual and potential yield through adoption of improved resource management technologies. Several studies have highlighted appropriate rainwater management and utilization results in enhanced agricultural productivity (Wani *et al.,* 2003).

The eastern region of India constitutes about 63 % of the net sown area under rainfed, supporting a population of 290.8 million (Madhu *et al*., 2013). About 62.5% of total geographical area of Eastern region is degraded exclusively by water induced soil erosion, which in conjunction with salt-affected and acid soils works out to be 73.9%. The forest biomass is exposed to enormous pressure for securing the needs by the aboriginal people, posing great threat to biodiversity and environment of this region (Islam *et al*., 2015). The Government of India has adopted watershed management as a national policy to address the sustainable agricultural productivity in the *rainfed* areas (Joshi *et al.,* 2004).

Tribal participated resource conservation through watershed approach in the tribal dominated areas of Odisha was implemented by Central Soil and Water Conservation Research and Training Institute (CSWCRTI), Research Centre, Sunabaeda, Koraput, Odisha. Based on high Rainfed Areas Prioritization Index by National Rainfed Area Authority (NRAA) (2012), Koraput district stands at 110 position among the 167 top one –third districts in the country. The overall aim of the present study was to assess the productivity, resource use and environmental impact of watershed management activities in the tribal dominated watershed in Eastern India.

Materials and Methods

Study area : Lachhaputraghati watershed is located in Pottangi Tehsil of Koraput District in Odisha state with an area of 601.24 ha. The watershed is 20 km away from Semiliguda town and 45 km away from Koraput district head-quarters with an elevation range of 900 m to 1258 m above msl.

The climate of watershed is warm and humid with annual mean maximum and minimum temperature of 35.8° C and 7.6° C, respectively. The normal annual rainfall is 1452.2 mm received in 77 rainy days. About 81% of total rainfall is received during June to September (South-West monsoon). The average evaporation rate is 3.7 mm day^{-1}, maximum in May (6.2 mm day^{-1}) and minimum during the month of August (2.1 mm day^{-1}). Water balance showed that surplus water was available for agricultural use between May and October with a length of growing period is about 170 days.

Soil was red with sandy clay loam in texture, acidic in reaction, medium in organic carbon (0.69%), soil available nitrogen (288 kg ha^{-1}) phosphorus content (11.1 kg ha^{-1}) and high in potassium content (313 kg ha^{-1}). The land capability classification of watershed revealed that, maximum area was under class III (43.1%) followed by class VI (22.6%) and class VII (20%). The class II and IV account for 6.6 and 7.7% of the total watershed area, respectively. The area possessed lithology mainly composed of shale, slate and sand stones showing faults and fissures.

Out of the total geographical area of 601.24 ha, maximum area was under degraded forest (61%) followed by the cultivated area (20.15%), current fallow (11.5%), area under non-agricultural use (6.0%) and area under pasture land (1.4%). Tribal population accounted about 66% of total population of the watershed. Major occupation was agriculture and landless labours.

Resource conservation and livelihood activities : The watershed development activities taken in the watersheds were soil and water conservation measures in arable lands, water resource development, productivity enhancement activities, etc. Activities under resource conservation were vegetative filter strips, field bunding, hedge planting, stone bunding and trenching. Live check dams, brushwood check dams, loose boulders check dams, gabions and stream bank stabilization were the measures implemented for stabilization of gullies and drainage networks in the watershed. Water resources in watershed area were developed through farm ponds, jhola khundies, renovation of water harvesting structures and providing water convey systems. To improve the productivity of land measure, agri-horticulture systems, bamboo plantation, fuel and fodder tree plantation, silvi-pasture system and agronomic management practices were taken up in the watershed area.

Data collection and impact assessment : The study on impact analysis was based on the baseline data during 2008 and data monitored during the project implementation period till June 2013. Data on bio-physical parameters were collected through field visits, detailed resource survey, household survey, Participatory rural appraisal (PRA) techniques, meeting, interviews and Focus group discussion during pre-project and post-project implementation of the watershed project. The biophysical impact of various interventions in the watershed was assessed through different impact indicators (Table 1). Pre and post project approach

Table 1 : Impact indicators with their methodology

Impact Indicator	Methodology
Productivity impact indicators	
Crop Diversification Index (CDI)	Sikka *et al.(*2004)
Cultivated Land Utilization Index (CLUI)	Chuang (1973)
Crop Productivity Index (CPI)	Sikka *et al. (*2004)
Crop Fertility Index (CFI)	Sikka *et al. (*2004)
Watershed Productivity (WP)	Sikka *et al. (*2004)
Human population carrying capacity *(HPCC)*	Madhu *et al.* (2014)
Resource use efficiency indicators	
Water Use Efficiency (WUE)	Allen *et al*. (1998)
Energy Efficiency of Rain Water (EERW)	Madhu *et al.* (2014)
Environmental and economic impact indicators	
Surface Runoff	Estimated using curve number method. USDA-SCS (1972)
Potential Soil Erosion Rates (PSER)	Using USLE, Wischmeier and Smith (1960&1978)
Ground Water Table	Periodical measured in open wells
Induced Watershed Eco-Index (IWEI)	Sikka *et al.(*2004)
BCR & IRR	Gittinger (2004)
Technical man days at different phases of watershed development	Madhu *et al.* (2014)

was adopted for impact assessment. The post project impact assessment of investment in watershed activities in village was carried out to examine the efficiency of economic returns.

Energy efficiency of rainwater (EERW) : Energy efficiency of rainwater is the ratio of energy output (co-efficient) value of unit crop produce to energy co-efficiency of water. The energy co-efficient of water was taken as 0.63 MJ m^{-3} of water.

Carbon sequestration potential of plantation : Based on growth parameters of plantation, future attainable biomass were estimated for 10 and 20 years using allometric equation (Brown, 1997). The carbon content of plantation was calculated by multiplying their biomass value with 0.45, in general, this ratio is used for tropical trees.

Human population carrying capacity (HPCC) : The human population (adult) carrying capacity is the ratio of energy output from land use or production system to annual energy requirement of an adult. The annual energy requirement for an adult was calculated based on the daily energy requirement recommended by National Institute of Nutrition (NIN), Hyderabad (NIN, 2009).

Technical man days at different phases of watershed development : Actual scientific and technical staff involved at three different phases of watershed development was calculated based on the contribution of each staff associated in the project period which may provide base for policy maker to plan for implementation of resource conservation programme where technical man power is required.

Results and Discussion

A total of 45.4 ha area was increased under cereals, pulses and oil seed crops during the project period and increased area under horticultural crops to the extent of 24 ha (Fig. 1). Yield of all the crops increased in the range of 3 to 15% with the overall average increase of 9.14%. Due to increase in water availability and high market demand for vegetables, the area under vegetable cultivation increased by 30% over the pre-project period (from 31 ha to 40 ha). Crop diversification index (CDI) increased to 0.71 from 0.55 registering an increase of 30% (Table 2). A similar increase in productivity and CDI was also reported by Sikka *et al.* (2004 and 2014) under other watershed programmes. In another watershed of similar agro-climatic and socio-scenomic condition Dass *et al.* (2009) observed 44.12 % increase of CDI due to the implementation of watershed development programmes.

Crop productivity index (CPI) indicates the extent of crop productivity level in comparison to normal yield of crops as per the package of practices. Overall CPI increased from 0.547 during the pre-project period to 0.613 after the project, registering an increase of 12% in the productivity level of crops and it was partly due to distribution of inputs *viz.,* seeds and fertilizers. Dass *et al.* (2009) observed 45.39 % increase of CPI in another watershed development programme in Eastern India.

Cultivated land utilization index (CLUI) increased by 0.05 from 0.35 to 0.40 in the watershed areas as a result of large scale introduction of horticultural plantation in dry land

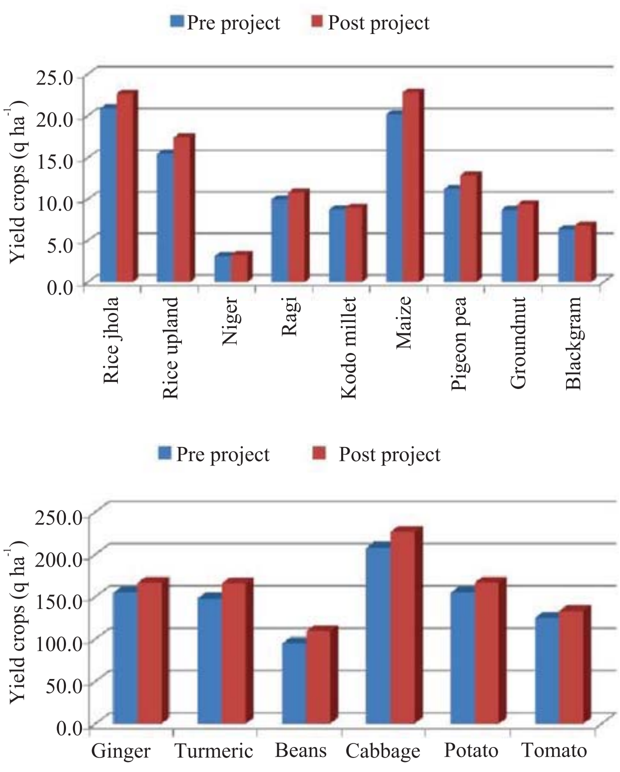

Fig. 1 : Yield of crops during pre and post project period

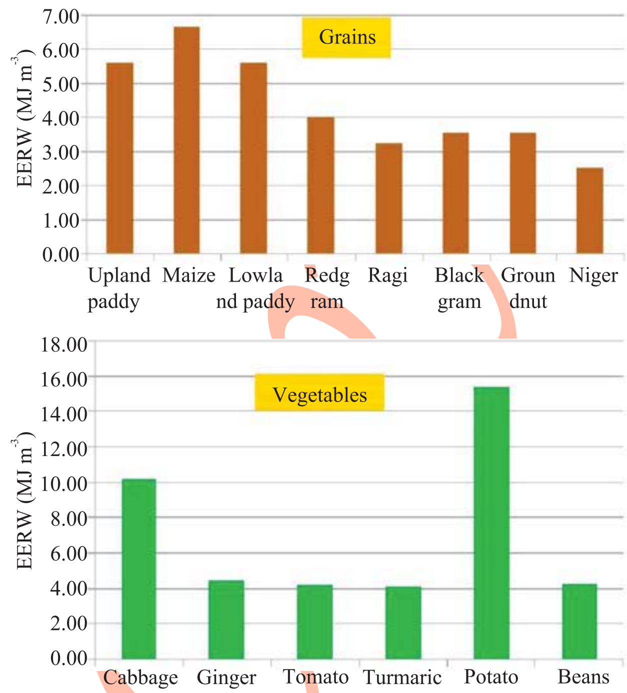

Fig. 2 : Energy efficiency of rainwater for grain crops and vegetables in the Lachhaputraghati watershed, Odisha

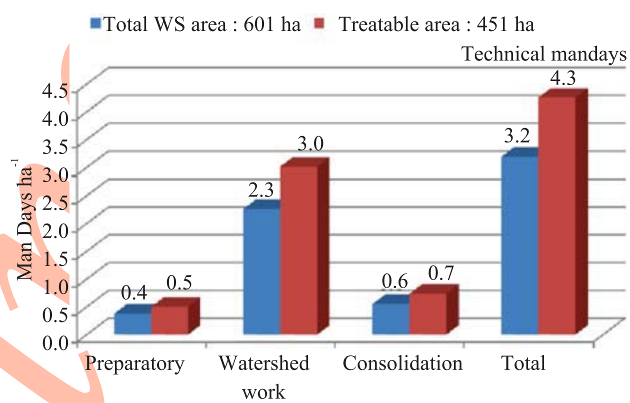

Fig. 3 : Technical man days at different phases of watershed development

and increased area under irrigation. Low CLUI during pre-project period was due to rainfed nature of crops and single cropping system. Watershed interventions have made some additional source of irrigation to boost the farming system. This indicated that irrigated area was put under intensive cultivation with high value commercial crops. Dass *et al.* (2009) observed an increase of CLUI from 0.14 to 0.21 in another watershed development programme in Eastern India.

Crop fertilization index (CFI) indicates the extent of crop nutrients (NPK) applied to crop in comparison to the recommended level of nutrients to that crop. Overall CFI increased from 0.21 during the pre-project period to 0.30 after the project, registering an increase of 43% in rate of nutrient application. In general, vegetable crops were fertilized more than grain crops due to better price for vegetable crops. This was partly due to distribution of inputs during the project period. Low CFI indicate that NPK consumption in the watershed areas was less than half of the recommended dose of nutrients to the crops. Under *rainfed* condition, due to uncertainty of rainfall the consumption of chemical fertilizer is low particularly in semi-arid region of India (Sikka *et al.,* 2004; 2014).

Watershed productivity (WP) indicates the overall productivity level in the watershed. Overall watershed productivity was expressed in equivalent yield of ragi. The overall WP increased from 4962 kg ha^{-1} of ragi during pre-project period to 6126 kg ha^{-1} after the project period (Table 2). This was mainly due to increased area under irrigation, slight increase in productivity of crops and diversification of crops towards vegetable crops. The increase in WP was 19% and this was attributed to increased area under vegetable cultivation, which were highly remunerative than any grain crops grown in the watershed. Deshpande and Reddy (1991), Dhyani *et al.* (2001), Shah (2001) and Joshi *et al.* (2004) reviewed different dimensions of watershed management and their studies focused on the positive impact of watershed management on cropping, agricultural productivity, employment generation and increase in income, amongst others.

The HPCC was lowest in niger (1.0) and maximum in potato (12.2). Among the cereals, paddy in low lying *jhola* land, upland paddy and maize had HPCC of 4.9 to 6.6 during the pre-project period and 5.5 to 7.2 during the post-project period (Table 2). The HPCC of vegetables varied between 2.2 (beans) and 12.2 (potato) during pre-project period and it increased to 2.4 and 13.1 during the post-project period due to increased productivity of crops. The average HPCC of crops increased to 4.4 during the post-project period from 4.0 during the pre-project period, and registered an increase of 9.3% due to enhanced productivity of crops through watershed activities.

Maximum Rain Water Use Efficiency (RWUE) was in upland paddy (4.49 kg ha^{-1} mm^{-1}) followed by maize (3.77 kg ha^{-1} mm^{-1}) and low land rice (3.00 kg ha^{-1} mm^{-1}) among the cereals. Among the pulses and oilseeds, RWUE was maximum in red gram (1.81 kg ha^{-1} mm^{-1}) and groundnut (1.48 kg ha^{-1} mm^{-1}). Among the vegetable crops, maximum RWUE was in the cabbage (57.4 kg ha^{-1} mm^{-1}) followed by ginger, turmeric and tomato, respectively (Table 3). In an another study, Adhikary *et al.* (2015) found that RWUE of cabbage was highest followed by cauliflower, ginger and turmeric. Similarly, water productivity of crops followed the same trend that of RWUE of crops. Gross returns per unit of water used was much higher to produce spices followed by vegetable crops as compared to that of cereals, oilseeds and pulses and thus farmers prefer to cultivate vegetables under assured condition of water availability. Due to watershed management programme, farmers have amalgamated their traditional knowledge with modern techniques and made their own integrated approach of crop production system based on RWUE (Adhikary *et al*, 2015). Similerly, micro-watershed treatments increased grain yield and rainfall use efficiency of wheat was reported by Sadur *et al*. (2009).

The Energy Efficiency of Rainwater **(**EERW) varied between 2.5 and 6.65 MJ m^{-3} of rainwater for grain crops and for vegetables it ranged from 4.23 to 15.35 MJ m^{-3} of rainwater. Maize (6.65), paddy (5.61), and red gram (4.01) among the grain crops and potato (15.35) and cabbage (10.21) among the vegetables have high EERW in the watershed areas (Fig. 2). The average EERW of all the crops in the watershed area was 5.53 MJ m^{-3} of rainwater which is equivalent to 1.32 kcal per liter of rainwater.

During the pre-project period, maximum area under Potential Soil Erosion Rate (PSER) was in the erosion class of >40.0 t ha^{-1} yr^{-1} (20.4%) followed by 15-20 t ha^{-1} yr^{-1} (18.2%) and 10-15 t ha^{-1} yr^{-1} (18.0%). This was due to the absence of suitable conservation measures and vegetation cover in the watershed (Table 4). However, during the post-project period, the percent area under high erosion classes (moderate to very high) decreased and these areas shifted towards lower erosion classes (very low and moderately low). This reduction in PSER from higher erosion classes to lower classes was attributed to various conservation measures taken in the watershed, which contributed towards reducing the length of slope by field bunding and decreased CP factors due to vegetation cover coupled with bunding and trenching. The average PSER in the watershed for pre- and post-project period was estimated to 30.24 t ha^{-1} yr^{-1} and 25.03 t ha^{-1} yr^{-1}, respectively. The average actual soil deposited in the trenches was 13.69 t ha^{-1}yr^{-1} soil that was retained on the site, otherwise this soil would have been deposited in the streams and water storage structures. Watershed treatment activities improve conservation of soil and moisture; improve and maintain the fertility status of soil and also reduce soil and water erosion (Sikka *et al.,* 2014; Palanisami and Suresh Kumar, 2009)

The estimated runoff for different land uses in the watershed varied from 14.7 to 29.9% and 7.3 to 15.4 % for the pre- and post-project period, respectively (Table 4). The maximum runoff was observed in *ragi* and upland paddy (29.9%) during pre-project period and it decreased to 15.4%

Table 2 : Productivity impact indicators in the tribal participated Lachhaputraghati watershed, Odisha

Indicators	Unit	Before (2008)	After (2012-13)	Change
i. Productivity of crops	%	9.14		
ii. Crop diversification index		0.55	0.71	30%
iii. Cultivated land utilization index		0.35	0.4	14.3%
iv. Crop productivity index		0.55	0.61	12%
v. Crop fertilization index		0.21	0.3	43%
vi. Watershed productivity (REY)	kg ha^{-1}	4962	6126	19%
vii. Av. Survival rate of mango	%	68		
viii. Human population carrying capacity				
Av. Energy output	Mj ha^{-1}	18296	20006	9.30%
Av. HPCC of land	Adult ha^{-1}	4	4.4	9.30%
Jhola land	Adult ha^{-1}	6.6	7.2	8.50%
Beda land	Adult ha^{-1}	4.2	4.6	9.70%
Padda & Donger land	Adult ha^{-1}	2.7	3	8.50%

Table 3 : Resource use efficiency impact indicators in the tribal participated Lachhaputraghati watershed, Odisha

Indicators	Before (2008)	After (2012-13)	Change
i. RWUE (kg ha^{-1} mm^{-1})			
Av. Cereals	2.14	2.35	9.9
Av. Pulses	1.47	1.63	11.2
Av.Food crops	1.95	2.15	10.2
Av. Oil seeds	1.04	1.11	6.9
Av. Vegetables	28.92	31.55	9.1
Av. Spices	23.44	25.71	9.7
Average for all crops	11.89	12.99	9.3
ii. EERW (MJ m^{-3})			
Av. Cereals	4.35	4.78	9.8
Av. Pulses	3.26	3.63	11.2
Av.Food crops	4.04	4.45	10.1
Av. Oil seeds	2.49	2.67	6.9
Av. Vegetables	7.15	7.78	8.7
Av. Spices	4.17	4.57	9.7
Average for all crops	4.71	5.12	8.7

Table 4 : Environmental impact indicators in the tribal participated Lachhaputraghati watershed, Odisha

S.No	Indicators	Unit	Before (2008)	After (2012-13)	Change
1	Potential soil erosion rate				
i	Arable	t ha^{-1} yr^{-1}	17.93	15.61	12.90%
ii	Non- arable	t ha^{-1} yr^{-1}	37.23	30.38	18.40%
iii	WS average	t ha^{-1} yr^{-1}	30.24	25.03	17.20%
iv	Soil retention capacity of trenches	t ha^{-1}	13.69		
2	Estimated runoff	%	14.68 to 29.92	7.3 to 15.4	
I	Av.runoff	%	24.4	14.6	40%
3	Water resources development				
i	Storage capacity created	ha-cm	93.91		
ii	Additional area under irrigation	ha	24.2		
iii	Av.water table depth	m	2.97	2.8	5.90%
iv	Av.depth of water in well	m	0.99	1.17	17.80%
4	Density of trees	trees ha^{-1}	7	14	7
5	Induced watershed eco-index	0.04	4%		
6	Carbon sequestration potential	Years	10	20	
i	C (t ha^{-1} yr^{-1})		2.12	3.40	
ii	C Credit (Rs. ha^{-1} yr^{-1})		2544	4080	

in the post-project period due to field bunding in degraded sloping lands. The average estimated runoff in the watershed decreased to 14.6% during post-project period from 24.4% in the pre-project period. The degree of decrement of runoff was higher in the crop lands as compare to the scrub and forest lands. This is because of intensive field bunding and other soil water conservation (SWC) measures taken up in the crop lands. The forests are traditionally low runoff producing lands and ample regeneration due to watershed interventions helped to further lowering down the surface runoff from these lands. The impact assessment studies conducted across regions have revealed that watershed development activities generate significant positive impacts in the environment and the treatment activities help in conservation and enhancement of water resources (Palanisami and Suresh Kumar, 2009).

A total of 93.91 ha cm^{-1} rainwater storage capacity was created and harvested in the watershed (Table 4) through different water harvesting structures. An additional area of 24.2 ha was brought under protective irrigation for cultivation of paddy and vegetables benefiting 177 beneficiaries in the watershed. The average water table depth raised by 0.18 m (5.9%) and the depth of water storage in the well increased by 0.17 m (17.8%) during the post-project period as compared to pre-project period. Rise in water table and depth of water storage in well was attributed to increased base flow due to soil and water conservation measures in the watershed areas (Schilling *et al.*, 2008).

The maximum carbon sequestration potential was from energy plantation followed by miscellaneous plantation, bio-diesel and agri-horticulture plantations. A total of 391.24 and 1114.65 t of carbon sequestration potential were estimated over 10 and 20 years, respectively in the watershed areas. The average carbon sequestration potential was workout to 2.12 and 3.4 t ha^{-1} yr^{-1} after 10 and 20 years, respectively from the plantation area in the watershed. Estimating carbon credit at a carbon price of USD 20 t^{-1} of C3 (Atkinson *et al*., 2006), it worked out to USD 42.8 (Rs.2544/-) and 68 (Rs.4080/-) ha^{-1} $year^{-1}$ after 10 and 20 years, respectively (1 USD=Rs. 60/-).

The productive life of watershed project was assumed up to 20 years. The Benefit Cost Ratio at 10% discount rate was found to be 1.16:1 and Internal Rate of Returns was worked out to be 19.5% of arable land. This reveals that BCR and IRR for arable and non-arable lands suggest the economic viability of the project (Table 5). The financial analysis of impact of watershed development indicated that the return to public investment such as watershed development activities were feasible (Palanisami and Suresh Kumar, 2009).

The technical man days at watershed work phase was 2.3 and 3.0 man day ha^{-1} (71% of the total man days) for total and treatable area in the watershed, respectively (Fig. 3). The technical man days accounts for only 12 and 17% of total man day ha^{-1} during preparatory and consolidation phase of watershed, respectively. Technical man days was slightly higher during consolidation phase due to completion of pending works coupled with data collection and analysis for impact evaluation.

A comprehensive impact assessment of participatory watershed development for resource conservation and increasing livelihoods of poor community revealed a greater success. The result showed positive impacts on productivity, resource use and environmental impact indicators. As community play a vital role in sustainable use of ecosystem resources and restoring environmental degradation, technical skilled manpower required for watershed project on unit area basis must be considered in policy guideline for effective implementation and greater environmental impacts.

Acknowledgments

The authors are thankful to the watershed association and watershed committee for their active cooperation, and to the Ministry of Agriculture, Government of India for funding under Macro Management of Agriculture (MMA), National Watershed Development Project for Rainfed Areas (NWDPRA).

References

Adhikary, P.P., M. Madhu, J. Dash, D.C. Sahoo, P. Jakhar, B.S. Naik, H.C. Hombe Gowda, G.B. Naik and B. Dash: Prioritization of traditional tribal field crops based on RWUE in Koraput district of Odisha. *Ind. J. Tradit. Knowl.*, **16**, 88-95 (2015).

Allen, G.R., S.L. Pereira, D. Raes and M. Smith: Crop evapotranspiration: Guidelines for computing crop water requirements. Food and Agricultural Organization of the United Nations, FAO-56. Rome, p. 300 (1998).

Atkinson, G. and H. Gundimeda: Accounting for India's forest wealth. *Ecol. Econ.*, **59**, 492-476 (2006).

Brown, S.: Estimating biomass and biomass of tropical forest: a primer. FAO Forestry Paper No. 134, Rome: Food and Agriculture Organization, p. 55 (1997).

Chuang, F.T.: An analysis of change of Taiwan's cultivated land utilization in recent years. Rural Economic Division JCRR Rep. 21, Taipei, Taiwan (1973).

Dass, A., S. Sudhishri, U.S. Patnaik and N. Lenka: Effect of agronomic management in watershed productivity, impact indices, crop diversification and soil fertility in Eastern Ghats of Odisha. *J. Soil Water Conser.*, **8**, 34-42 (2009).

Deshpande, R.S. and V. R. Reddy: Differential impact of watershed based technology: Some analytical issues. *Indian J. Agric. Econ.*, **46**, 261-269 (1991).

Dhyani, B.L., J.S. Samra, R. Babua and N. Kumar: Environmental payoff integrated watershed management programme in Garhwal Himalaya- A case study of ORP Fakot. *J. Soil Water Conser.*, **45**, 141-147(2001).

Fadim, Y. and T. Baycan. Stakeholder participation to watershed management: A case study from Beysehir Lake basin. *J. Environ. Biol.*, **36**, 221-228 (2015).

Gittinger, J.P.: Economic analysis of agricultural projects. Economic Development Institute. The World Bank. http:// www.stanford.ed/ group/FRI/Indonesia/document/gittinger/output/title.htm.21 1984 (2004).

Islam, M.A, S.M.S. Quli, R. Rai, A. Ali and S.A. Gangoo: Forest biomass flow for fuel wood, fodder and timber security among tribal communities of Jharkhand. *J. Environ. Biol.*, **36**, 221-228 (2015).

Joshi, P.K., A.K. Jha, S.P. Wani, J. Laxmi and R.L. Shiyani: Meta-analysis to assess impact of watershed program and people's participation. Research Report 8, Comprehensive Assessment of watershed management in agriculture, International Crops Research Institute for the Semi-Arid Tropics and Asian Development Bank, p. 21 (2005).

Joshi, P.K., B. Pangare V. Shiferaw, S.P. Wani, J. Bouma and C. Scott: Socioeconomic and policy research on watershed management in India: Synthesis of past experiences and needs for future research. Global Theme on Agroecosystems Report no. 7. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics, p. 88 (2004).

Madhu, M., P. Jakhar, P.P. Adhikary, H. Gowda, V.N. Sharda, P.K. Mishra and M.K. Khan: Natural resource conservation emerging issues and future challenges. Satish Serial Publishing House, 403, Express Tower, Azadpur, Delhi, india, p. 984 (2013).

Madhu, M., B.S. Naik, P. Jakhar, H.C. Hombe Gowda, P.P. Adhikary and K.P. Gore: Impact assessment of Integrated watershed development in Lachaputtraghati Watershed, Koraput, Odisha, *Technical Bulletein*, p. 49 (2014).

Maji, A.K.: Assessment of degradation and wastelands of Indian. *J. Ind. Soc. Soil Sci.,* **55**, 427-435 (2007).

NIN: Nutrient Requirements and Recommended Dietary Allowances for Indians. A Report of the Expert Group of the Indian Council of Medical Research, National Institute of Nutrition, Indian Council of Medical Research, Hyderabad – 500 604, p. 334 (2009).

NRAA: Prioritization of Rainfed Areas in India. *National Rainfed Area Authority*, Government of India, New Delhi, Study report 4. p. 100 (2012).

Rockström, J., N. Hatibu, Y. Theib, Oweis and S.P. Wani: Managing water in rain-fed agriculture. In: Water for food, water for life: A comprehensive assessment of water management in agriculture (Ed. D. Molden). London, UK: Earthscan and Colombo,Sri-Lanka: International Water Management Institute pp. 315-348 (2007).

Sadur, R., S.K. Khalil, A. Rehman, Amanullah, A.Z. Khan, N.H. Shah: Micro-watershed enhances rain water use efficiency, phenology and productivity of wheat under rainfed condition. *Soil Tillage*., **104**, 82-87 (2009).

Schilling, K.E. and M. Helmers: Effects of subsurface drainage tiles on stream flow in Iowa agricultural watersheds: Exploratory hydrograph analysis. *Hydrol. Proc.,* **22,** 4497–4506 (2008).

Shah, A.: Who benefits from participatory watershed development? Lessons from Gujarat, India, IIED Gatekeeper Series 97 IIED, London (2001).

Sikka, A.K., M., Madhu, Subhashchand, V. Selvi, D.V. Singh, P. Sundarambal and K. Jeevarathanam: Participatory watershed management for sustainable development in Salaiyur watershed, Coimbatore, Tamil Nadu,CSWCRTI, Research Centre, Udhagamandalam, p. 96 (2004).

Sikka, A.K., M. Madhu, Subhash Chand, D.V. Singh, V. Selvi, P.Sundarambal, K. Jeevarathanam and M. Murgaiah: Impact analysis of participatory integrated watershed management programme in semi-arid region of Tamil Nadu, India. *Ind. J. Soil Cons.,* **42**, 98-106 (2014).

Palanisami, K. and D.S. Kumar: Impacts of watershed development programmes: Experiences and Evidences from Tamil Nadu. *Agricul. Econ. Rese. Rev.,* **22** (Conference Number): 387-396 (2009).

USDA-SCS, SCS: National Engineering Handbook, Section 4, Hydrology. Chapter 10, Estimation of Direct Runoff From Storm Rainfall. U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C.,pp. 10.1-10.24 (1972).

Wani, S.P., P. Pathak, L.S. Jangawad, H. Eswaran and P. Singh: Improved management of vertisols in the semi-arid tropics for increased productivity and soil carbon sequestration. *Soil Use Manage.,* **19**, 217-222 (2003).

Wischmeier, W.H. and D.D. Smith: A universal soil-loss equation to guide conservation farm planning. *Trans. Int. Congr. Soil Sci.,* 7th, pp. 418-425 (1960).

Wischmeier, W.H. and D.D. Smith: Predicting Rainfall Erosion Losses: A Guide to Conservation Planning. Agriculture Handbook No. 537.USDA Agricultural Science Handbook. Washington, DC, p. 58 (1978).

Yoganand, B. and T.G. Gebremedhin: Participatory watershed management for sustainable rural livelihoods in India. ResearchPaper,theSouthernAgriculturalEconomicsAssociationAnnualMeeting,Orlando,Florida, pp.1-18 (2006).