Vol. 48, No. 2, pp 139-148, 2020
Indian Journal of Soil Conservation

Ecosystem services from participatory integrated micro-watershed development project in Indian north western Himalayas: part-I

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ARTICLE INFO

Article history:
Received : August, 2019
Revised : July, 2020
Accepted : August, 2020

Key words:
Ecosystem
Ecosystem services
Legitimacy
Integrated watershed development
Boundary work

ABSTRACT

Ecosystem services (ES) of a participatory integrated watershed (370 ha) management project, namely Bhaintan of Indian North Western Himalayas (INWH), assessed from a set of 38 years data revealed that there was a simultaneous improvement in all the ES indicators in implementation (1975-1986) and post implementation (1987-2013) periods over the pre-project period. Improvement occurred in provisioning services in terms of rice equivalent production (4 times), milk production (7.4 times), and fruit production (from negligible to 6.4 times) and dependency on reserve forest reduced for fodder (55% points) and fuel (60% points). Cultural services improved in terms of cash income (62%) and asset value (4.6 times). Reduction in Gini-concentration ratio from 0.68 to 0.20 revealed a significant reduction in income disparity within the farming community. A significant reduction was observed in regulating services in form of reduction in runoff (69%) and soil loss (82%). Improvement in the ES is attributed to diversified farming system adopted by the farmers, high cohesiveness in the farming society, and immigration of outmigrated youth. The paper concludes that participatory integrated watershed development project Bhaintan showed a significant change in all ES indicators towards desired directions, which indicates that integrated watershed management programme planned with appropriate boundary work, and implemented with proper communication, translation, and mediation results in improvement in watershed ecosystem, and consequently the ES. Even an intensive landuse pattern resulting in tradeoff among ES can be changed to complementary relationship through proper integration of structural, production and social measures in the watershed with legitimacy.

1. INTRODUCTION

Ecosystem services (ES) are described as sum of provisioning, regulating, supportive and cultural benefits that human population derives directly or indirectly from an ecosystem for its well being (Costanza *et al.,* 1997; Boyd and Banzhaf, 2007; MA, 2005a,b; TEEB Foundation, 2010). But, anthropocentric activities, primarily for higher level of provisioning services, have adversely affected the other three ES (Tengberg *et al.,* 2012; Jax *et al.,* 2013). Thus, there is a strong belief that there is a trade-off among these ES; and, it is guided by the land-use (Raizada *et al.,* 2008; Martin-Lopez, 2013). If this landuse pattern continues for a long run, it will result into negatively sloped total ES function (Braat and de Groot, 2012; UNEP, 2010; Lalika *et al.,* 2015a,b; Geneletti *et al.,* 2016; Mandle *et al.,* 2015).

Tallis and Kareiva (2006) reviewed the Millennium Ecosystem Assessment (MA) scenario analyses approaches (models). They considered river basin as an ideal unit for assessment of ES where four independent models (IMPACT; IMAGE; WaterGap, and Eco-path with Ecosim) may be integrated, and impact on majority of ES may be estimated. They further emphasized on assessment of ES at smaller scale based on diverse live demonstrations of improved human well-being as a result of improved ecosystem management. A large number of studies in India have shown that integrated watershed management projects are more appropriate for balanced development than sectoral or commodity approach (NRAA, 2011; Dhyani *et al.,* 2006; Joshi *et al.,* 2005; Raizada *et al.,* 2008). Similar findings were also observed in other parts of the world (Howe *et al.,* 2014; Geneletti *et al.,* 2016; Esmail and Geneletti, 2017). An attempt was made in this study to quantify all the four ES from one of the oldest micro-watershed (370 ha) management project, Bhaintan, from Indian north-western Himalayas (INWH) to demonstrate the efficiency of participatory integrated watershed approach for simultaneous improvement of all ES over the years.

2. MATERIAL AND METHODS

Study Area

Bhaintan watershed (370 ha) is located at 78^{0}20'-78^{0} 22'E and 30^{0}13'-30^{0}15'N (Fig. 1). Its elevation varies from 650 m to 2015 m above mean sea level (AMSL) with average slope of 72%, and has all four types of land ownerships (private, community, government and civil soyam) having all possible land uses (agriculture, horticulture, forestry and agroforestry). Livestock is an integral part of INWH farming systems (Anonymous, 1978), which is also of Bhaintan watershed.

Watershed development boundary work was initiated by a multi-disciplinary team of Scientists from ICAR-Indian Institute of Soil and Water Conservation (formerly Central Soil and Water Conservation Research and Training Institute; CSWCRTI) in 1974-75. Seed money of US$ 50,000 was provided by Ford Foundation (USA) for the project for a period of five years. Expenditure of bulk of seed money (57%) was on project activities, primarily focusing upon demonstrations of improved production technologies coupled with required soil and water conservation (SWC) measures. These activities were continued till 1986 from budget of ICAR-IISWC (formerly CSWCRTI). As boundary work is a dynamic process, hence technical backstopping and monitoring of watershed responses were continued till 2013. During this period, three attributes, namely project objectives, participation and accountability were ensured from all the project partners.

Monitoring

All interventions pertaining to crop, horticulture, and pasture development were monitored through simple random sampling technique by adopting with and without project approach, and evaluated through budgeting method till 2013. Landuse budgeting along with crop varieties were suitably integrated for estimating agricultural production (food, fruit and fodder). Complete enumeration of farmers was performed at appropriate time intervals to estimate income, out migration and livestock production. Rainfall data were monitored with IMD standard rainfall recording equipment. Runoff and soil loss data were monitored at the watershed outlet through a runoff gauging station of United State Department of Agriculture (USDA) standard. Concurrent evaluation results were utilized to modify the project interventions with legitimacy, and most adoptable efficient technologies were upscaled. After 1986, project interventions on livestock improvement, drainage line treatment, water harvesting structures, landslide control measures and crop demonstrations of latest varieties and integrated pest management were undertaken by convergence of other organizations / programmes like Integrated Rural Development Programme, Border Road Organization, state agricultural universities and concerned state line departments. Thus, technical backstopping and monitoring of watershed responses were continued till 2013. This period (1987-2013) was also utilized to understand the dynamic change-chain process in real farm situation. Different land based watershed interventions implemented during two periods of the project *i.e.* implementation period 1975-1986 (IP) through project budget and post implementation period 1987-2013 (PIP) by the farmers, either from private sources or through material and skilled labour support through convergence of other schemes of the governments, are presented in Table 1.

Analytical Tools

The present study has followed MA-2005 and Fisher *et al.* (2009) approach in developing suitable indicators for ES based on data availability. The concept of ES related indicators presented by MA-2005, Simpson (1949); Shanon and

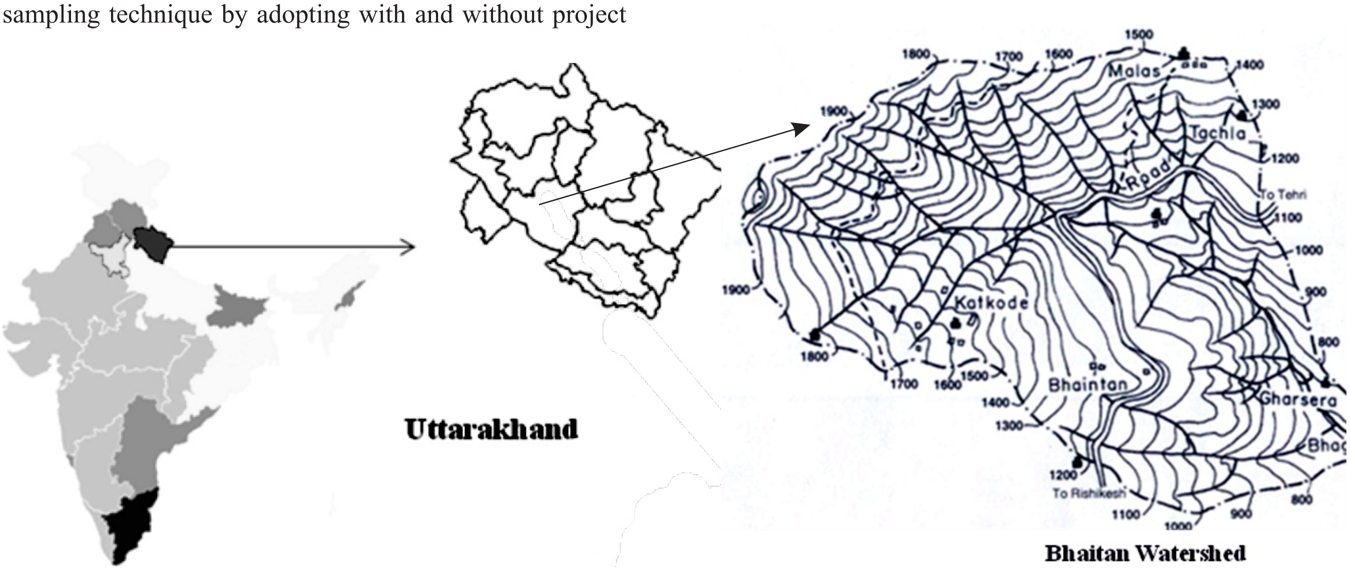

Fig. 1. Location of the watershed

Table: 1
Watershed interventions implemented during two periods of Bhaintan watershed project

Interventions	Unit	1975-1986 (IP)	1987-2013 (PIP)
Cement lined tank (each having 20 cum to 60 cum capacity)	Number	7	6
Cement lined channel	Metre	2316	2489
Irrigated terrace renovation	ha	7.9	0
Conversion of rainfed terraces into irrigated	ha	12.8	5.5
Renovation of rainfed terraces	ha	20.0	12.5
Horticultural plantation	ha	21.2	9.1
Grass land developed	ha	1.5	72.0
Fuel-fodder plantation	ha	22.4	3.6[@]
Gully plugs	Number	66	138

[@]*excludes the naturally regenerated tree area; Crop demonstrations >5000 number (total)*

Wiener (1963); Hill (1973); Hayo *et al.* (2002); Dhyani *et al.* (1997, 2015); Dhyani and Samra (2004); Joshi *et al.* (2005); Sharda *et al.* (2012) were utilized to finalize the appropriate indicators that can be estimated with available data set from a watershed. All primary and secondary data available from project records and reports were utilized for quantification of ES from Bhaintan watershed. The indicators estimated under each group of ES from the project are presented in Table 2.

Assumption and statistics used for estimation of some of the indicators, except those which are common in use with easily understandable results, are presented in Table 3. The indicators that were estimated every year of IP and PIP were averaged for respective periods. The average figure is presented accordingly. Estimates of some ES indicators were made during pre-project period (PP) and at irregular intervals afterwards (in IP and/or PIP). Therefore, they are point estimates only. Data for estimating vegetation diversity or richness indices were estimated by adopting with and without project approach; data were collected from Bhaintan (treated) watershed and adjacent Agar (non-treated) watershed in 2009 only. Thus, results are based on a mixed set of data over 38 years and trans-disciplinary methodologies of ES estimation. Therefore, the data analysis methodology followed in the study is "Toolkit Method".

3. RESULTS AND DISCUSSION

The results from the study are presented in four sections based on type of ES. Section 3.1 presents impact of the project on provisioning services; changes in regulatory services are presented in Section 3.2; Section 3.3 depicts the level of cultural service indicators at different periods; and, lastly Section 3.4 provides the changes in indicators belonging to supportive service group of ES.

3.1 Provisioning Services

The group includes those products or services which are either consumed / utilised by humans or their livestock directly to satisfy their immediate wants. Rice equivalent

Table: 2
Ecosystem services and indicators estimated

S.No.	ES group	Service	Indicator(s)
1.	Provisioning services	Food production	Rice equivalent production from field crops, mango equivalent production from horticultural crops, and milk production
		Fodder and fuel availability	Dependency on forest for fuel and fodder based on requirement met from reserved (government) forest
		Water availability	Average gross irrigated area
2.	Regulating services	Water regulation	Conserved rainwater, reduction in runoff peak, drinking water quality
		Erosion control	Reduction in soil loss
		Climate regulation	Climate resilience ratio in terms of rice equivalent production and farm income, sequestrated carbon, crop diversification index
3.	Cultural services	Economic benefit and income equity	Net farm income, Gini concentration ratio
		Social relations	Community organizations, group activity, out migration status and women empowerment
		Living standard	Family asset value index at constant price, food security
		Knowledge system	School enrolment ratio
		Educational value	Change in attitude and visitors visited
4.	Supportive services	Photosynthesis	Cultivated land utilization index, cropping intensity, forest diversity indices and forest cover pattern
		Nutrient cycling	Availability of N, P_2O_5 and K_2O, availability of compost
		Water quality	Water quality rating
		Bio-diversity	Vegetation diversity index, crop diversification index

Table: 3
Indicators, assumptions and statistics

S.No.	Indicator	Assumption	Statistics
1.	Rice equivalent total crop production (REP)	Higher REP reflects higher provisioning services and food security	$REP = \Sigma (y_i * p_i) / p$ ...(1) Where, y_i is production of i_{th} crop, p_i is price of i_{th} crop, p_r is price of rice (Sample size varied from 32 to 105 across the years as per the area under a particular crop)
2.	Mango equivalent fruit production (MEFP)	Higher MEFP reflects higher provisioning services and nutritional security	$MEFP = \Sigma (y_i * p_i) / p_m$ ... (2) Where, y_i is production of i_{th} fruit crop, p_i is price of i_{th} fruit crop, p_m is price of mango (based on complete enumeration)
3.	Dependency on reserve forest for fuel and fodder (FD)	Reduced dependency on forest will improve forest flora and thereby improve forest ES	$FD = \frac{\text{Fodder / fuel collected from forest}}{\text{Total fodder / fuel demand}} * 100$ ...(3) (Sample size varied from 81 to 132 across the years)
4.	Climate resilience ratio (CRR) in farm income / production (CRR)	Higher CRR indicates more stable income / production system and an indicator of sustainable development	CRR = AFI / FIAB ...(4) Where, AFI is average farm income / production in normal year and FIAB is farm income/production in climatically abnormal year as declared by the government *i.e.* 1987 (drought) and 2013 (high rainfall)
5.	Gini concentration ratio (GCR)	Lower GCR reflects more economic equity and likely results into a more cohesive society	$GCR = 1 - \Sigma p_i (q_i + q_{i-1})$ ... (5) Where, p_i is proportion of population in i_{th} class and q_i is cumulative proportion of income up to ith class
6.	Asset value index at constant price (AVI)	Higher AVI reflects higher living standard and good life	$AVI = \sum_{i=1}^{n} A_i * V_i$ ...(6) Where, A_i is the number of i_{th} asset and V_i is value of i_{th} asset at constant price (2010)
7.	School enrolment ratio of children below 16 years of age (SER)	Higher SER means future generation is more educated and will be capable of making well informed decisions	$SER = \frac{\text{School going children of 15-16 age}}{\text{Total children of 5-16 years age}}$ ...(7)
8.	Women empowerment (WE)	Women in INWH perform majority of farm operations and face real challenges. Higher value of WE will prompt women to participate in WSD programme	$WE = \frac{\text{Women >30 years of age involved in household decisions and are satisfied}}{\text{Total women > 30 years of age in the watershed}} * 100$ ...(8)
9.	Out migration percentage (OM)	Reduced out migration indicates that male members will be with family and they feel secure *i.e.* good life and more care of watershed's natural resources	$OM = \frac{\text{Number of seasonal working male population out migrated}}{\text{Total male working population}} * 100$ ...(9)
10.	Cultivated land utilization index (CLUI)	Higher CLUI indicates the land is under vegetative cover and more provisioning services are expected with less rainwater induced soil erosion	$CLUI = \sum_{i=1}^{n} a_i d_i / (A*365)$ ...(10) Where, n is the total number of crops, a_i is area occupied by i_{th} crop, d is the total number of days that the i_{th} crop occupied the area, and A is total cultivable land
11.	Soil organic carbon (SOC)	High soil organic carbon status indicates more carbon sequestration.	$SOC = (\%C * BD(t\ kg^{-1}) * Depth(m) * 10^4) / 100$ ...(11) Where, C is percent organic carbon, BD is bulk density
12.	Species diversity (H')	Higher diversity is an indicator of presence of multi storey forest vegetation leading to conservation of more rainfall and less soil erosion.	$H' = \sum_{i=1}^{s} [(N_i / N) \ln (N_i / N)]$ ...(12) Where, N_i is number of individuals belonging to i_{th} species in the sample and N is total number of individuals in the sample
13.	Species richness index (H_o)	Higher richness index is an indicator of improvement in forest flora condition.	$H_o = S$ ...(13) Where, S is total number of species in the sample
14.	Equity index (E_5)	Higher value of the equity index indicates the species are evenly distributed and all the three levels of canopy covers are present, which is a sign of good vegetation cover representing good ecosystem health.	$1/\lambda\ E5 = E^{H'} - 1$ ...(14) Where, H' and λ are Shanon-Wiener (1963) and Simpson (1949) Diversity Indices, respectively. $N_i(N_i - 1)\ \lambda = \sum_{i=1}^{s} N (N-1)$ ... (15) Where, N is total individuals in the population and N_i is the number of i_{th} species in the population.

production was estimated of each food crop, following Ghosh *et al.* (2015) and Bhattacharya *et al.* (2010), by multiplying its physical output by ratio of its price to rice price. Total rice equivalent production from watershed increased by more than 4.5 and 8.8 times as compared to PP during IP and PIP, respectively (Table 4). This is attributed to an increase in gross irrigated area by 1.8 times, more than 100% increase in crop diversification (decisively, off season vegetable cultivation which is 'niche' of the region), 90% increase in cultivated land utilization index, and marginal (8%) increase in availability of compost along with 1.8 time increase in conserved rain water. More water availability after rainy season (July-September) and cultivation of short duration crops increased gross irrigated area over PP by more than 100% and 300% during IP and PIP, respectively. Similar results were observed in Khootgad and Upper Koshi watersheds, Langha project from INWH region (Dhyani *et al.,* 2006, 2009 and 2015) and other watershed projects in the country (Bhardwaj and Dhyani, 1994; Kerr *et al.,* 2000; Joshi *et al.,* 2005; NDC, 2006; Khola *et al.,* 2012; Khola *et al.,* 2017a,b). Mango equivalent fruit production (MEFP) was also estimated by following the above approach using mango as a reference fruit crop for horticultural produce. MEFP also made a significant improvement over PP production by more than 200 times. This was mainly contributed by citrus plantation, though it is not a 'niche' crop of the region. Total milk production from the watershed increased over PP by 2.3 and 7.4 times during IP and PIP, respectively, which was attributed to some economically well off farmers who replaced their sheep and goats by improved cow or buffalo breeds and became member of newly established milk cooperative society (ANCHAL) in the district during IP. Consequently, farm income increased by 136 times than PP level. Similar findings were reported by Dhyani *et al.* (2006, 2009, 2015). Thus, food deficit watershed in PP changed into one having surplus food production of cereals, vegetables, milk and fruits during PIP. Consequently, the poorly fed human population before the project became nutritionally secure after the project. Reserve forest area located at all locations (top, middle and bottom) of the watershed was eased from biotic pressure i.e. dependency on forests for fodder and fuel reduced from 60% and 80% in PP to 5% and 20% during PIP, respectively. Consequently, natural regeneration invigorated the reserve forest as well as waste lands within the watershed, enabling them to deliver intended ES in due course of time (GoI, 2011).

3.2 Regulating Services

The group includes services which reflect capability of watershed to cope with exigencies such as climatic aberrations (drought or excessive rainfall) which are exogenous for human beings. Studies conducted by Singh *et al.* (2010) and Kumar *et al.* (2008) revealed that the Himalayan region is warming probably at a higher rate (0.74^{0}C and 0.18^{0}C, respectively) than the global average. INCCA (2010), Cline (2007) and Aase *et al.* (2009) have highlighted the negative impact of climate change due to global warming on agriculture. Therefore, the Himalayan region needs to develop adaptation mechanisms and cropping strategies to sustain livelihood of people of the region (Saxena *et al.,* 2004). Participatory integrated watershed management is a sustainable solution for such predicaments. Table 5 depicts the value of some of the indicators which reflect resiliency of Bhaintan watershed against climatic odds.

Annual average rainfall in the watershed is about 1900 mm and varies from 1379 mm to 2590 mm. About 76% to 80% of annual rainfall is received during July to September. It was estimated that pre-project land use system was able to conserve only 58% of total annual rainfall and 42% was lost from the watershed as runoff. After the interventions, the developed watershed was able to conserve about 72% of total rainfall during IP and 87% during PIP. This is about 14% and 29% points higher than PP level, respectively. July and August months receive maximum rainfall, and some them are high intensity rainfall events, thus resulting into high runoff and soil loss. However, considering only rainy season (July to September) rainfall, the rain water conservation values were 32%, 40% and 72% during PP, IP and PIP, respectively. It indicates that rainy season rain water conservation efficiency of watershed over PP improved by 8% points during IP and 40% points during PIP. Hydrograph analysis showed a gradual decrease in runoff peak during three periods of project indicating a steady release of conserved rain water from the watershed, and possible reduction in flood plain area. A significant steady decrease in soil loss was also observed from the watershed over study period (11.2 t ha^{-1} in PP to 2.7 t ha^{-1} during IP and < 2 t ha^{-1} in PIP). Reduction in runoff and soil loss is attributed to

Table: 4
Level of provisioning service indicators during three periods of project

S.No.	Indicator	Measurement unit	PP (1974-75)	IP (1975-1986*)	PIP (1987-2013*)
1.	Rice equivalent total food production	t	72.69	398.6	714.2
2.	Mango equivalent total fruit production	t	Negligible	6.4	232.1
3.	Total milk production	kilo litre (kl)	56.6	184.8	473.2
4.	Dependency on reserve forest for fodder	%	60	46	5
5.	Dependency on reserve forest for fuel	%	80	70	20
6.	Average gross irrigated area	ha	16.7	34.8	69.8

**Average value of the period*

Table: 5
Regulating service indicator values during three periods of project

S.No.	Indicator	Measurement unit	PP (1974-75)	IP (1975-1986*)	PIP (1987-2013*)
1.	Rainwater conserved	%	58	72	87
2.	Runoff peak	Semi qualitative	High	Medium	Low
3.	Drinking water quality	Ranking	Poor	Good	Very good
4.	Climate resilience ratio	Rice equivalent production	NA	0.5**	0.80@
5.		Farm income	NA	0.5**	0.94@
6.	Soil loss	t ha^{-1}	11.20	2.70	<2.00
7.	Soil carbon sequestrated	t	18911.22	NA	19524.49
8.	Crop diversification	Index	0.13	0.28	0. 83

**Average value of the period; **Values estimated during 1987 drought; @Values estimated during high rainfall year 2013*

adoption of intensive SWC measures on all the land uses in the project. Dhruvanarayana *et al.* (1987); Ram Babu *et al.* (1997); Joshi *et al.* (2005); Negi (2002); NDC (2006); GoI (2010) and Khola *et al.,* (2017a) also reported a reduction in runoff and soil loss and drought-proofing potential after imposing watershed / SWC treatments. Capability of Bhaintan watershed production system to mitigate negative impact of climatic aberrations (low or high rainfall situations) is also evident from 82% and 94% stable rice equivalent production and farm income, respectively from current enterprise combination in the watershed in comparison to average normal rainfall year production and income, which can be treated as stable production or income under rain dependent agriculture production system. Dhruvanarayana *et al.* (1987) also reported similar findings from 47 Operational Research Projects (ORP) on watershed management in India. Total soil carbon sequestrated by the watershed before the project was 18911.22 t, which reached to 19524.49 t in 2007. Thus, there was an increase of 613.27 t soil carbon stock in 0-30 cm soil depth of the watershed in 2007 as compared to 1974. Soil organic carbon (SOC %) decreased under uncultivable lands in 0-15 cm soil depth, and remained unchanged in 15-30 cm soil depth. In cultivated area, good soil carbon was built in 0-15 cm soil depth, and a marginal decrease was observed in 15-30 cm soil layer. It was also observed that soil carbon build-up was more in valley than upper and middle reaches, and in the order of grassland, horticultural and forest land uses.

3.3 Cultural Services

The group is composed of indicators for services which are associated with feeling of human well being and cultural values. Estimated values of these indicators are presented in Table 6. Cash income to the watershed primary stakeholders depends on enterprises they adopt. Cultivation of cash crop and crop diversification during IP and PIP increased cash income of farmers by 82% during IP and 137 times during PIP over PP, which is a sign of economic prosperity. The value of gini concentration ratio (GCR) decreased from 0.68 (high discrepancy) during PP to 0.60 in IP and reached to lowest level of 0.20 (lower discrepancy) in PIP. It shows that economic prosperity among the farming community improved alongwith improvement in economic equity over the project period. Thus, findings amply indicate that economic prosperity among farmers of the project area improved with equity, more so during PIP. Similar results were obtained in Khootgad and upper Koshi watersheds from INWH (Dhyani *et al.,* 2006, 2009). Out migration of able-bodied male work force from watershed reduced from 26.6% in PP to 9.3% in IP and became zero in PIP. Similar findings were reported for RVP, FPR, IWDP, DPAP and National Afforestation Programme in India (Joshi *et al.,* 2005; NDC, 2006; GoI, 2010). Reduction of male out migrant population over periods developed a feeling of secured life among farm families as the out-migrated male family members started living with them. It is a symbol of feeling of well being having high intrinsic

Table: 6
Values of cultural service indicators during three periods of project

S.No.	Indicator	Measurement unit	PP (1974-75)	IP (1975-1986*)	PIP (1987-2013*)
1.	Income distribution	GCR**	0.68	0.60	0.20
2.	Net cash income at 2013 prices	INR thousand	23.67	43.28	3249.60
3.	Out migration	%	26.60	9.30	Nil
4.	Community based organization	Number	3	5	9
5.	Self help groups (SHG)	Number	Nil	2	8
6.	Informal user groups (IUG)	Number	2	4	10
7.	Role of women in decision making	%	10	25	47
8.	Women having bank account	Number	4	12	68
9.	Average asset value index at 2013 prices	INR million	5.87	7.67	32.98
10.	School enrolment ratio	%	40	70	100
11.	Visitors visited	Number/year	Nil	85	469

**Average value of the period; **GCR – Gini Concentration Ratio* value. This also helped in proper management of available natural resources in the watershed because farmers realised that management of natural resources is essential for their livelihood security. Table 6 further indicates that the number of formal or informal groups in the watershed increased from 5 in PP to 27 in PIP. This is a healthy sign of higher social cohesiveness among farming community, which results into minimal conflict and win-win conflict resolution, and also helped them to harvest fruits of economies of scale through collective actions by the groups. Farmers benefitted in many ways by collective actions e.g. marketing (large volume purchase of inputs, sale of outputs), reduction in cost of controlling crop diseases and pests owing to application of plant protection measures by all farmers collectively, and farm diversification. Participation of farm women in family as well as community decision making processes increased from merely notional (10%) in PP to as high as 47% in PIP, and number of females having their own bank account increased from 4 in PP to 68 in PIP. These are indicators of increased level of women empowerment and gender equity over the period. Improvement of asset value index at 2013 prices over time not only indicated economic prosperity but also symbolises a good life and feel well, having high intrinsic value. School enrolment ratio improved over PP in IP and PIP periods of project. It reached to maximum possible level (100%) in PIP. It means that watershed's future generation will be educated and will be capable of taking well informed decisions to improve their future. The number of visitors, representing different categories of watershed stakeholders (technical expert, policy planners, implementers from government and non-government organizations, farmers of other watersheds and students), from different parts of the world and country visited the watershed, and were highly impressed with the project outcomes, as revealed from their positive comments on project outcome with promises to replicate the model in their respective areas. It amply indicates that the watershed became a model for community driven sustainable development, in general, and for INWH, in particular.

3.4 Supporting Services

The group includes indicators for those services which do not take part directly in production process but play vital role in project outcome and its sustainability. Therefore, they may be called process indicators, but they play vital role in achieving boundary objectives of the project. Cultivated land utilization index (CLUI) value of 0.69 in PP indicates that the arable land was under active production process only during 69% period in a year (Table 7), and in rest of the period it was without a crop. The CLUI value increased to 89% in IP and reached 93% in PIP indicating intensive land use pattern during IP and highly intensive in PIP. Intensive cultivation is expected to withdraw more nutrients from soil, and thereby lower soil nutrient status. Higher availability of N (by 63.5%), P_2O_5 (by 15.7%) and K_2O (by 2.9%) in soil during 2007 compared to PP indicates an improvement in soil nutrient status after project. The results showed an improvement in soil health even under highly intensive land use in the watershed.

Land use based soil fertility status data further indicated that available nitrogen increased by about 86% in grass land followed by about 70% in all other land uses (Table 8). Orchard land showed highest (32.29%) improvement in phosphorus availability, followed by 19.91% in grass lands, 15.69% in forest and least 3.2% in agriculture. Soils of the project area are rich in potash, and showed about 4% improvement in case of all land uses other than agriculture where it was only 0.58%. Increased availability of N, P and K nutrients in cultivated land is attributed to more availability of compost (by 2.3 times) due to adoption of sedentary animal rearing method during IP and PIP than the open grazing followed during PP. Good three tier vegetation cover with least biotic interference was major contributor for soil fertility build up in non arable lands.

3.4.1 Impact on vegetation

The impact of all the efforts to improve vegetative cover in reserve forest as well as in civil-soyam, community and private waste lands are presented in Table 9. Species diversity index (H') for shrubs and herbs were higher in Bhaintan watershed (0.48 and 0.34, respectively) than untreated watershed (0.27 and 0.32, respectively), but no difference was observed in tree class index (0.63). Species richness index (H_0) values for tree and shrubs were significantly higher in Bhaintan watershed than in untreated watershed. Similarly, vegetation equity index (E_5) values for tree, shrubs and herbs were also significantly higher in Bhaintan watershed than in untreated watershed. This

Table: 7
Level of supporting services indicators during three periods of project

S.No.	Indicator	Measurement unit	PP (1974-75)	IP (1975-1986*)	PIP (1987-2013*)
1.	Cultivated land utilization index	Index	0.69	0.89	0.93
2.	Available N**	t	838.07	NA	1367.50
3.	Available P_2O_5**	t	164.60	NA	190.40
4.	Available K_2O**	t	1257.80	NA	1294.20
5.	Availability of compost	t	183.3	198.1	611.20

**Average value of the period; **Value during PIP is for 2007 only.*

Table: 8
Change in available nutrients (kg ha^{-1}) under different land uses based on before and after project approach

Land use	Nitrogen		P_2O_5		K_2O	
	1974-75	2007-08	1974-75	2007-08	1974-75	2007-08
Grass	201.0	375.0 (86.75)	43.7	52.4 (19.91)	322.3	335.8 (4.19)
Forest	235.0	398.0 (69.36)	49.7	57.5 (15.69)	353.0	372.3 (5.47)
Agriculture	263.0	329.0 (69.41)	37.5	38.7 (3.20)	345.0	347.0 (0.58)
Orchard	210.0	357.0 (70.0)	41.5	54.9 (32.29)	338.0	353.0 (4.44)

Figure in parenthesis indicate percent change over PP

Table: 9
Plant diversity indicators values based on with and without approach

S.No.	Indicator	Measurement unit	Bhaintan watershed			Untreated watershed		
			Tree	Shrubs	Herbs	Tree	Shrubs	Herbs
1.	Species diversity index	H'	0.63	0.48	0.34	0.63	0.27	0.32
2.	Species richness	H_0	5.80	4.00	2.40	5.20	2.60	2.60
3.	Vegetation equity index	E_5	0.18	0.27	0.16	0.04	0.01	0.02
4.	*Chrysopogon fulvus* density	Plants/ha		106000			8.2	
5.	*Apluda mutica* density	Plants/ha		111000			2.6	
6.	*Portulaca oleracea* density	Plants/ha		79000			0.0	
7.	*Dichanthium annulatum*	Plants/ha		18000			0.0	

Source: Modified from Government of India 2011.

clearly adduces that project interventions in Bhaintan watershed had improved forest floral condition significantly. Density of most nutritive local grass species, namely, *Chrysopogon fulvus, Apluda mutica, Dichanthium annulatum* and *Portulaca oleracea* was significantly higher in Bhaintan watershed than in the untreated one. Increased vegetation with higher density of trees in recruitment and regeneration class, and higher density of quality shrubs and herbs helped in the long run to conserve more rain water and reduce soil loss. This is evident from the fact that after 1998, runoff remained between 13% to 15%, and soil loss < 2 t ha^{-1}.

5. CONCLUSIONS AND POLICY IMPLICATIONS

Integrated watershed management Bhaintan project implemented after appropriate boundary work, alongwith proper communication, translation, and mediation resulted in simultaneous improvement in all the ES indicators during project implementation and post implementation periods over pre-project stage. Fulfilment of all three criteria (credibility, legitimacy and saliency) of boundary work and convergence with other departments, technical backstopping, and niche harvesting improved the watershed's ecosystem, and consequently the ecosystem services (ES) from it. Value of all ES indicators from the watershed showed a quantum improvement during PIP. Improvements in cultural, regulatory and supportive services were pronouncedly observed, particularly after IP. Thus, proper intensive landuse plan can lead to win-win situation rather than tradeoff among different ES. Therefore, it is imperative that regular monitoring of implemented watershed management projects be done for enumeration of ES emanating from such projects in the country. Based on this, the government may frame a policy along these lines for watershed management projects in the country. In addition to quantification of the ES, their valuation also holds the key to prioritizing investment in watershed development in the country. It is a need of the hour and the authors intend to address this aspect of ES in the following research paper.

ACKNOWLEDGMENTS

The authors are grateful for financial support provided for this research by Ford Foundation and Indian Council of Agricultural Research. The authors acknowledge the guidance provided by the Directors of ICAR-IISWC (formerly CSWCRTI), Dehradun. The contribution of all the Staff of ICAR-IISWC for implementation and monitoring of the project is duly acknowledged. The support provided by the State Departments of Government of Uttarakhand (formerly part of State of Uttar Pradesh) is also duly acknowledged. The authors are especially thankful to the farmers of the Bhaintan watershed for their cooperation in its planning, implementation, monitoring and evaluation.

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