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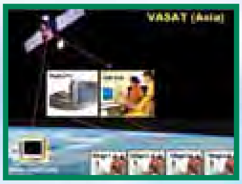

Use of High Science Tools in Integrated Watershed Management

Proceedings of the National Symposium

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Application of Econometic Methods for Assessing the Impact of Watershed Programs

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Abstract

Watershed programs in India are contributing to water resources development, agricultural production and ecological balance. Impact assessment of watershed development project includes: (i) developing a framework to identify what impacts to assess and (ii) developing a framework to look after the indicators together and assessing the overall impact of the project. The nature of watershed technologies and their impact on different sectors pose challenges to the evaluation process. More specifically, major challenges include (i) choice of methodologies, (ii) selection of indicators, (iii) choice of discount rate, (iv) quantifying benefits in upstream and downstream, (v) defining the zone of influence, and (vi) extent of natural and artificial recharge conventional methods using financial measures attempt to quantify the impacts in an isolated manner. In order to evaluate the impacts of watershed programs in a holistic manner, the Economic Surplus (ES) approach has been applied. The economic surplus incorporates both consumer surplus and producer surplus. The consumer surplus is the amount that consumers benefit by being able to purchase a product for a price that is less than they would be willing to pay. The producer surplus is the amount that producers benefit by selling at a market price mechanism that is higher than they would be willing to sell for. In the case of watershed programs, producers are mainly the farm households who produce the goods using the benefits of the watershed interventions such as soil and moisture conservation, water table increase and livestock improvement activities and consumers are mainly the other stakeholders in the region, viz. non-farm households representing the labourers, business people and people employed in non-agricultural activities. The ES method is demonstrated using the data from a cluster of 10 watersheds in the Coimbatore district of Tamil Nadu. The distributional effects of watershed programs are also captured through the ES method. The results of the conventional method had indicated that the BCR is 1.23, IRR is 14% and NPV is Rs 567912. The results of the ES method had indicated that the BCR is 1.93, the IRR is 25 % and the NPV is Rs 2271021. The conventional

evaluation method had thus underestimated the watershed impacts. Hence, possibilities of using the ES methodology in the future watershed evaluation programs could be examined.

Introduction

The overall objectives of the watershed programs, by and large, are three fold, viz. promoting economic development of the rural area, employment generation, and restoring ecological balance (Department of Land Resources 2006). The watershed development program assumes importance in India where nearly two-third of the cropped area is under rain-fed, characterized by low productivity, degraded natural resources and widespread poverty, particularly in the rural areas. Under such situation, understanding the nature and extent of impact of these watershed development programs on various domains in the rural economy is crucial for the development personnels/specialists, economists and policymakers. It would guarantee more food, fodder, fuel, and livelihood security for those who are on the bottom of the rural income scale.

A watershed is a geographical area that drains to a common point, which makes it an attractive unit for technical efforts to conserve soil and maximize utilization of surface and sub-surface water for crop production (Kerr *et al.* 2000). Different ministries like Ministry of Agriculture (MoA), Ministry of Rural Development (MoRD) and Ministry of Environment and Forest (MoEF) are involved in the implementation of watershed development programs in the country. Watershed development has been conceived basically as a strategy for protecting the livelihoods of the people inhabiting the fragile eco-systems, experiencing soil erosion and moisture stress. Different types of treatment activities are carried out in a watershed. They include soil and moisture conservation measures in agricultural lands (contour/field bunding and summer ploughing), drainage line treatment measures (loose boulder check dam, minor check dam, major check dam, and retaining walls), water resource development/management (percolation pond, farm pond, and drip and sprinkler irrigation), crop demonstration, horticulture plantation and afforestation (Palanisami and Suresh Kumar 2003). Training in watershed technologies and related skills is also given periodically to

farmers in watersheds. In addition, members are also taken to other successful watershed models and research institutes for exposure. These efforts appear to be contributing to groundwater recharge. The aim has been to ensure the availability of drinking water, fuel wood and fodder and raise income and employment for farmers and landless labourers through improvement in agricultural production and productivity (Rao 2000). Today watershed development has become the main intervention for natural resource management. Watershed development programs not only protect and conserve the environment, but also contribute to livelihood security.

As an important development program, watershed development has received much attention from central and state governments. Up to X^{th} Five Year Plan (till March 2005), an area of 17.24 million ha was treated with a total budget of Rs 9368.03 crore under Ministry of Agriculture, 27.52 million ha with an outlay of Rs 6855.66 crore under Ministry of Rural Development and an area of 0.82 million hectares with an outlay of Rs 813.73 crore under Ministry of Environment and Forest. A total of 45.58 million ha has been treated through various programs with an investment of Rs 17,037 crore. The average expenditure per annum during the X^{th} Five Year Plan comes to around Rs 2300 crore (Department of Land Resources 2006). As millions of rupees are being spent on the watershed development programs, it is essential that the programs become successful.

With programs so large and varied, it is important to understand how well they function overall and which aspects should be promoted and which to be dropped. However, despite this importance, little work has been done to assess their impacts. This paper partially fills this gap by examining both social and environmental outcomes. In particular, it tries to answer the questions: (i) What impacts the watershed development activities have on rural areas? and (ii) How do watershed development activities impact on groundwater resources, soil and moisture conservation, agricultural production and socio-economic conditions? It would help the policymakers in up-scaling and mainstreaming watershed development programs in the country.

To successfully implement the watershed development activities, the Government of India has issued various guidelines. The GoI guidelines

were first issued in 1995. In order to make more participation of people in the watershed development and management, the GoI guidelines were further revised and issued in 2001. Subsequently, to involve Panchayati Raj Institutions more meaningfully in the implementation of watershed development activities, the popular Haryali guidelines were introduced in 2003. In addition to all these guidelines, the guidelines for NWDPRA watershed development programs, CAPART, NABARD and NGO implemented watershed guidelines were released separately over the period. Though these guidelines have, by and large, been successful in the implementation of various watershed development activities, they have some lacuna particularly in the context of institutional issues, post-project maintenance and sustainability and monitoring and evaluation of watershed development activities. Recently, the GoI has issued Common Guidelines 2008 for the effective implementation of watershed development programs in the country.

In spite of the guidelines, the implementation aspects normally deviate due to local demand. Several studies have indicated that the watershed structures are not maintained after completion and benefits may decline over years (Palanisami and Sureshkumar 2006). Also, to push up the implementation of the watersheds at other locations, the evaluation of the existing watersheds has been conducted positively. But, it is always mentioned that the benefits and costs are based on several assumptions. Impact analysis of an area-based program like watershed development has inherent difficulties. Apart from the benefits accrued from different technologies, the impact of watershed development should be looked into three major dimensions, viz. scales (household level, farm level and watershed level) temporal and spatial. The dimensions of impact of watershed technologies further complicate the impact assessment.

Different studies have developed a variety of indicators for impact assessment. These indicators cover watershed development activities including soil erosion, groundwater recharge and water resources potential, agricultural production, socio-economic conditions and overall impact incorporating the extent of green cover. These indicators have been compared with before and after the watershed treatment activities with that of the control village where watershed treatment activities are not taken up. The other methodologies, such as Total

Economic Valuation (Logesh 2004) and bio-economic modelling have also been employed by the researchers. However, still the researchers face challenges in quantifying the impacts of watershed development activities.

The problem of impact assessment of watershed development project includes the following aspects: (i) developing a framework to identify what impacts to assess, where to look for these impacts and selecting appropriate indicators to assess the impacts, and (ii) developing a framework to look after the indicators together and assessing the overall impact of the project. The nature of watershed technologies and their impact on different sectors pose challenges to the project monitoring and evaluating agencies, economists, researchers and policymakers. More specifically, major challenges include (i) choice of methodologies, (ii) selection of indicators, (iii) choice of discount rate, (iv) quantifying benefits in upstream and downstream, (v) defining the zone of influence, and (vi) extent of natural and artificial recharge (Palanisami and Suresh Kumar 2006).

Since the watershed development technologies benefit not only the participating farm households, but also non-participating farm and other rural households in the watershed village, the economic surplus method has been used to study the impact of the watershed programs using data from sample watersheds in Coimbatore district of Tamil Nadu state.

Methodology

Economic Surplus Approach

The Economic Surplus (ES) approach is widely followed for evaluating the impact of technology on the economic welfare of households (Moore *et al.,* 2000; Wander et al. 2004; Maredia et al. 2000; Swinton, 2002). The economic surplus method measures the aggregated social benefits of a research project. With this method it is possible to estimate the return to investments by calculating a variation of consumer and producer surplus through a technological change originated by research. Afterwards, the economic surplus is utilized together with the research

costs to calculate the net present value (NPV), the internal rate of return (IRR), or the benefit-cost ratio (BCR) (Maredia et al. 2000). The model can be applied to the small/large open/closed economy within the target domain of production environment. The term surplus is used in economics for several related quantities. The consumer surplus is the amount that consumers benefit by being able to purchase a product for a price that is less than they would be willing to pay. The producer surplus is the amount that producers benefit by selling at a market price mechanism that is higher than they would be willing to sell for. In the case of watershed programs, producers are mainly the farm households who produce the goods using the benefits of the watershed interventions such as soil and moisture conservation, watertable increase and livestock improvement activities and consumers are mainly the other stakeholders in the region, viz. non-farm households representing labourers, business people and people employed in non-agricultural activities.

Theoretical Framework

The model is based on the Marshallian theory of economic surplus that stems from shifts over time of the supply and demand curves. In Figure 1, the rightward shift (S_1) of the original supply curve (S_0) generates economic surplus for producers and consumers. Such a shift can stem from changes in production technology, in the present case watershed development intervention. Given that the demand function remains constant, the original market equilibrium a (P_0, Q_0) is transferred by the effect of technological change to b (P_1,Q_1).

Consumers gain because they are able to consume a greater amount (Q_1) at a lower price (P_1). The area P_0abP_1 represents the consumer surplus. The watershed development intervention affects agricultural producers in two ways: (i) lower marginal costs (according to the theory, the supply curve corresponds to the curve of marginal costs as of the minimum value of the curve of average variable costs), and (ii) lower market price (P_0 reduced to P_1). Thus, the producers' surplus is defined as the Area P_1bl_1 - Area P_0al_0.

The mathematical model used was based on the scheme proposed by Pachico et al. (1987), in which supply and demand functions were

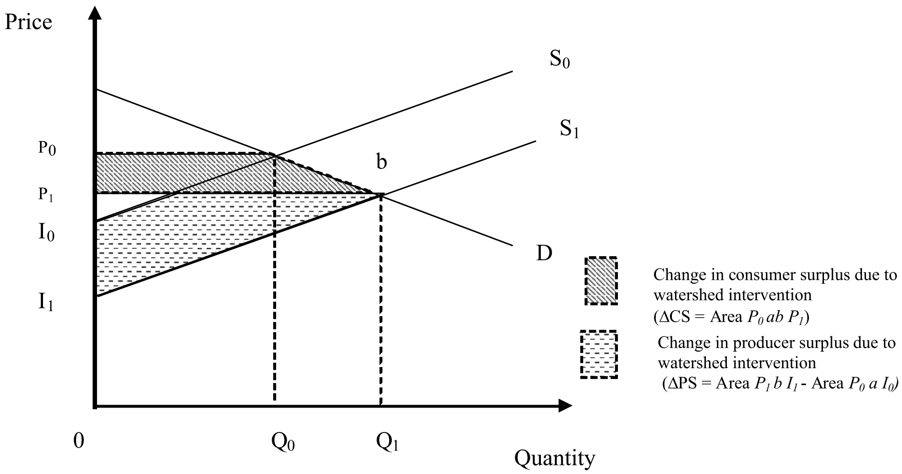

Figure 1. Graphical representation of economic surplus method.

nonlinear with constant elasticity, i.e. log-linear. The supply function for a product market was assumed that supply curves of the following functional form:

$$s_0 = c(P_0 - P_{lo})^d \qquad (1)$$

where, s_0 = Initial supply before watershed intervention,
c, d = Constants,
P_0 = Price of product, and
P_{lo} = Minimum price that producers are willing to offer.

Typically, the watershed development programs involving the entire community and natural resources influence different aspects such as agricultural production system, environment and socio-economic conditions of the watershed villages. By virtue of its nature, watershed is an area-based technology cutting across villages comprising both private and public lands. Thus, the benefits from watershed development activities not only limited to the users/beneficiaries but also to the non-participating farmers. For instance, the watershed development technologies are expected to have positive impacts on groundwater recharge, soil and water conservation, maintaining ecological balance, increased fodder availability, increased crop yield, etc. Similarly, the increased agricultural production favours the non-farming community

like labourers, rural artisans and other rural households. Thus, the watershed development brings benefits not only to the producers (farmers) but also to the consumers (farmers, labour households and other households in the watershed village). In this context, the economic surplus approach captures the total benefits accrued due to watershed development intervention in the rural areas.

The advantage of the economic surplus approach lies in the fact that the distribution of benefits to different segments of the society could be estimated. The watershed development could be treated as a 'public good' and covers both the private and public lands. Moreover, the benefits due to watershed development activities are not restricted to the producers alone. Increased supply and hence changes in price of the agricultural products will also benefit the consumers positively. In this context, the economic surplus approach captures the impact of watershed development activities in a holistic manner.

Application of Economic Surplus Method to Watershed Evaluation

Watershed programs play a dual role of safeguarding the interest of the producers as well as consumers, as in several locations, the drought-proofing aspects of the watershed programs are easily felt (Palanisami and Suresh Kumar 2007). In the case of producers, they can change the crop pattern due to increased water levels in their wells, moisture conservation in the soil, increase water use for the existing crops, increase the number of livestock and fodder production. There is also a change in the cost of production of the commodities in the watershed. Over the years, there is an increase in technology adoption due to watershed programs. In the case of consumers, the increased crop production in the watershed results in availability of produce at lower prices. Consumption levels also get increased among the consumers. Labour employment is increased due to increased land and crop production and processing activities in the watershed. Evidences show that the production levels have increased as a result of watershed interventions and the consumers have started enjoying the benefits of localized production in the regions. Hence, for the purpose of the analysis, it was assumed that, the output supply curve shifts gradually

over time when the benefits from the watershed developmental activities start benefiting the agricultural sector through water resource enhancement. The supply shift factor due to technological change, in our case, watershed intervention, is known as K. This factor varies in time depending on the dynamics of the rainfall, adoption, dissemination of soil and moisture conservation technologies and maintenance activities undertaken in the watershed. The supply shift factor (K) can be interpreted as a reduction of absolute costs for each production level, or as an increase in production for each price level (Libardo et al. 1999).

Micro economic theory defines consumer surplus (individual or aggregated) as the area under the (individual or aggregated) demand curve and above a horizontal line at the actual price (in the aggregated case: the equilibrium price). Following IEG, World Bank, 2008, the demand curve is assumed to be log-linear with constant elasticity. Thus, the demand equation for this demand function can be written as:

$$P = gQ^{\eta} \tag{2}$$

where, η is the elasticity and g is a constant. Once, the parameters η and g are estimated, then consumer surplus could be estimated by equation (3):

$$CS = \int_{Q_0}^{Q_1} gQ^{\eta} dQ - (Q_1 - Q_0)P_1 \tag{3}$$

Combined, the consumer surplus and the producer surplus make up the total surplus.

Estimation of Benefits

Following the theory of demand and supply equilibrium, economic surplus (benefits) as a result of watershed development intervention is measured by equation (4):

$$B = K * P_0 * A_0 * Y_0 * (1 + 0.5\, Z * \varepsilon_d) \tag{4}$$

where, K is the supply shift due to watershed intervention.

The supply shift due to watershed intervention can be mathematically represented by equation (5):

$$K = \forall * \rho * \psi * \Omega \quad (5)$$

where, K represents the vertical shift of supply due to intervention of watershed development technologies and is expressed as a proportion of initial price. $\forall$ is net cost change which is defined as the difference between reduction in marginal cost and reduction in unit cost. The reduction in marginal cost is defined as the ratio of relative change in yield to price elasticity of supply (ε_s). Reduction in unit cost is defined as the ratio of change in cost of inputs per hectarpe to (1+change in yield). ρ is the probability of success in watershed development implementation. Ψ represents adoption rate of technologies and Ω is the depreciation rate of technologies.

Z represents the change in price due to watershed interventions. Mathematically, Z can be defined by equation (6):

$$Z = K * \frac{\varepsilon_s}{(\varepsilon_d + \varepsilon_s)} \quad (6)$$

where, P_0, A_0, and Y_0 represent prices of output, area and yield of different crops in the watershed before implementation of watershed development program. If we use the with and without approach, then these represent area, yield and price of crops in control village.

Cost of Project

The analysis considered cost towards watershed development investment during the project period and maintenance expenditure incurred in the project. For watershed development projects with multiple technologies or crops, incremental benefits from each technology and crop were added to compile the total benefits. The worthiness of the watershed development projects was then evaluated at 10 per cent discount rate. Using above estimates of returns and costs, net present value (NPV), benefit-cost ratio (BCR), and internal rate of return (IRR) were computed.

Study Area and Data Collection

The study was conducted in Coimbatore district of Tamil Nadu, India. The predominant soil types are red soil, laterite, clay loam, sandy clay loam,

and black cotton soil. Differences in soil types have differential impact on the water resources and agricultural production and productivity. The success of the watershed development programs critically depends on rainfall in the region. The major crops grown were: sorghum, cotton, sugarcane, maize, coconut and vegetables. Of the total cropped area, the area irrigated accounted for 56.82 per cent.

The chief source of irrigation in the district was through wells. Over the years, there has been a general decline in the water level in the whole of Coimbatore district, which is attributed to indiscriminate pumping of groundwater. The groundwater resource degradation has in turn resulted in changes in crop patterns, well deepening, and an increase in well investments, pumping costs, well failure, and abandonment and

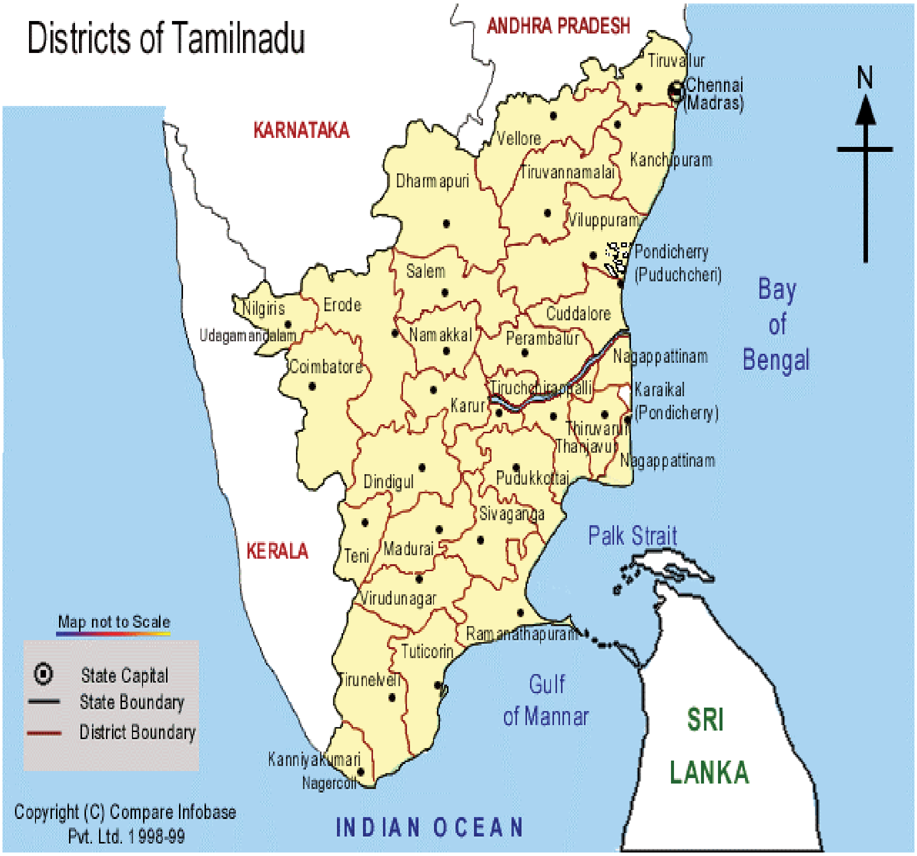

Figure 2. Map of the study area.

migration of farmers (Palansami and Suresh Kumar 2007). It is in this context that groundwater augmentation by artificial recharge through watershed development programs gained momentum.

Data

The major data were derived from the recently completed study on Comprehensive Assessment (CA) of Watersheds Programs in India implemented by the ICRISAT team (Wani *et al*. 2008). For the purpose of our study, the data were drawn from a cluster of 10 watersheds implemented in Coimbatore district of Tamil Nadu. The details of all these watersheds with area treated are given in Table.1. A variety of indicators were developed and used for the impact assessment. The indicators of impact of watershed development activities covering soil erosion, groundwater recharge and water resources potential, agricultural production, socio-economic conditions and overall impact including the extent of green cover were developed. To make a comparative study, one control village where no watershed treatment activities were carried out, was selected for each watershed. The control villages were selected so as to have similar agro-climatic conditions. The select indicators were compared with before and after the watershed treatment activities and also with that of the control village. Thus, the data pertaining to 10 watershed villages and 10 control villages were

Table 1. Details of watersheds covered for the study in Coimbatore district of Tamil Nadu.

Name of the Block	Name of watershed	Area (ha)
Annur	Kattampatty I	460.0
	Kattampatty II	467.5
	Kuppepalayam	672.5
Avinashi	Naduvenchery	767.5
	Karumapalayam	752.5
	Chinneripalayam	524.8
Sulur	Arasur I	605.0
	Arasur II	590.0
	Rasipalayam	560.0
Palladam	Kodangipalayam I	455.0

gathered. The information on price elasticity of demand and supply of various farm products was obtained from the published sources.

Results and Discussion

This section presents the key results and findings from the field experience of impact assessment of watershed programs implemented under Drought Prone Area Program (DPAP) in Coimbatore district of Tamil Nadu. The general characteristics of the sample farm households in the study watershed were analysed and have been presented in Table 2. It could be seen that the average size of the holding worked out to be 1.28 ha and 1.75 ha, respectively for watershed and control villages. It is evident from the analysis that the average number of workers was 2.5 and 2.1 out of 4.07 and 4.2 for watershed and control villages, respectively.

The labour force participation rate came out to be 61.48 per cent and 50.79 per cent. The higher labour force participation was due to better scope for agricultural production, livestock activities and other off-farm and non-farm economic activities. It is evidenced from the analysis that the labour force participation rate among farmers in watershed villages was higher, implying that the enhanced agricultural production was due to watershed treatment activities. Construction of new percolation ponds, major and minor check dams and the rejuvenation of existing ponds/tanks had enhanced the available storage capacity

Table 2. General characteristics of sample farm households.

Particulars	Watershed village	Control village
Farm size (ha)	1.28	1.75
Household size	3.31	3.34
Land value (Rs/ha)	230657	153452
No.of wells owned	1.35	1.20
Average area irrigated by wells (ha)	1.48	1.80
Value of household assets (Rs)	261564[1]	184385
No.of persons in the household	4.07	4.2
Number of workers	2.5	2.1
Labour force participation (%)	61.48	50.79

[1]indicates that value was significantly different at 10 per cent, level from the corresponding values of control village

in the watersheds to store the run-off water for surface water use and groundwater recharge. The additional surface water storage capacity created in the watersheds ranged from 9299 m^3 to 12943 m^3. This additional storage capacity further helped in improving the groundwater recharge and water availability for livestock and other non-domestic uses in the village. On the basis of the data collected from the sample farmers, it was found that the water level in the open-dug wells had risen in the range of 0.5-1.0 metre in watershed villages. The depth of the water column in the few sample wells was recorded both in watershed and control villages for comparison. The depth of the water column in the wells was found to be higher in the watershed villages than in control villages. For instance, depth of the water column in the wells in Kattampatti watershed village was 3.53 m compared to 2.16 m in the control village leading to a difference of 63.43 per cent.

Information related to duration of pumping hours before well went dry (or water level depressed to a certain level) and time it took to recuperate to the same level were collected from the sample farmers across villages. Due to watershed treatment activities, groundwater recuperation in the nearby wells had increased. The increase in recuperation rate varied from 0.1 m^3 hr^{-1} to 0.3 m^3 hr^{-1}. It was also observed that the recharge to wells decreased with their distance from the percolation ponds and check dams and the maximum distance where the recharge to the wells had occurred was observed to be 500-600 m from the percolation ponds.

The area irrigated in watershed villages registered a moderate increase after the watershed development activities in most of the watersheds, whereas in control village it declined slightly over the period. The irrigation intensity was found higher in watershed treated village than in untreated village. This shows that watershed development activities helped increase the water resource potential of a region through enhanced groundwater resources, coupled with soil and moisture conservation activities. In the case of control villages, the watertable in the wells had declined due to continuous pumping. It is one of the reasons why farmers in most of the villages demand watershed programs in their villages.

The analysis also revealed increase in net cropped area, gross cropped area and cropping intensity in both the watersheds (Table 3). For

Table 3. Cropped area, cropping intensity and crop diversification.

Particulars	Watershed villages		Control villages	
	Before	After	Before	After
Net area irrigated (ha)	1.08	1.10[1]	1.68	1.62
Gross area irrigated (ha)	1.25	1.35[2]	1.84	1.62
Irrigation intensity	115.74	122.73[2]	109.52	100.00
Net cropped area (ha)	1.15	1.28[2]	1.78	1.62
Gross cropped area (ha)	1.38	1.88[2]	2.43	2.16
Cropping intensity (%)	120.00	146.88	136.52	133.33
Crop Diversification Index (CDI)	1.0		0.97	

[1] and [2] indicate that values were significantly different at 1 and 5 per cent levels from the corresponding values of control village

Crop diversification index (CDI) was worked out by employing Composite Entropy Index (CEI) based on the proportion of different crops in the farm. The Composite Entropy Index for crop diversification was worked out as:

$$C.E.I = -\left(\sum_{i=1}^{N} P_i.\log_N P_i\right) * \{1-(1/N)\}$$

where, CEI = Composite Entropy Index,
P_i = Acreage proportion of i^{th} crop in total cropped area, and
N = Total number of crops.

example, the cropping intensity worked out to be 146.88 per cent in the watershed village, which is higher than in the control village (133.33 per cent). The composite entrophy index (CEI) was used to compare diversification across situations having different and large number of activities. The CEI has two components, viz. distribution and number of crops or diversity. The value of crop diversification index (CDI) increases with the decrease in concentration and rises with the number of crops/ activities. In general, CDI is higher in the case of watershed treated villages than control villages, confirming that watershed treatment activities help diversification in crop and farm activities.

The details regarding livestock per household and per hectare of arable land have been furnished in Table.4. The livestock income has been a reliable source of income for the livelihood of the resource-poor farmer households. Cattle, sheep and goats were maintained as important sources of manure and were the liquid capital resource. It could be seen that nearly 46.67 per cent and 93.33 per cent of the households in watershed and control villages maintained cattle. Access to grazing land and fodder had made the farm households to maintain livestock in

Particulars	Watershed village	Control village
Per cent of households	46.67	93.33
Herd size (number)	2.57	2.64
Per hectare of gross cropped area (number)	2.01	1.63

Table 4. Livestock per household and per hectare of arable land.

their farms to derive additional income. But, the analysis revealed that relatively more number of households in control villages maintained livestock. It was mainly due to the fact that inadequate grazing land and poor resource-base for stall feeding persuaded them to feed their livestock with green leaves and fodder obtained from crops and crop residues. The farm households in control villages maintained mainly milch animals to derive additional income for their livelihood.

Application of Economic Surplus Method

The impact of watershed development activities on yield of crops and hence the cost was estimated and has been presented in Table 5. The change in yield due to watershed intervention across crops varied from 31 per cent in maize to 36 per cent in cotton. It was the maximum change in yield due to watershed intervention. Reduction in marginal cost due to supply shift ranged from 32.8 per cent in vegetables to 63.6 per cent in sorghum. Net cost change varied from 32 per cent in vegetables to 59.8 per cent in sorghum.

Table 5. Impact of watershed development intervention on yield and cost.

Crops/ enterprises	Change in yield (%)	Reduction in marginal cost (%)	Reduction in unit cost (%)	Net cost change
Sorghum	33	63.6	3.76	59.8
Maize	31	39.9	2.29	37.6
Pulses	36	41.0	1.47	39.6
Vegetables	32	32.8	0.76	31.9
Milk	28	27.3	7.81	19.5

Note: The reduction in marginal cost was the ratio of relative change in yield to price elasticity of supply (ε_s). Reduction in unit cost was the ratio of change in cost of inputs per hectare to (1+change in yield). Ci was the input cost change per hectare.i.e., C_u = Ci/(1+change in yield;. The net cost change (∀ was the difference between reduction in marginal cost and reduction in unit cost, ie., ∀ Cm-Cu.

The change in total surplus due to watershed development activities was estimated and has been presented in Table 6. The change in total surplus was higher in sorghum and maize than crops like pulses and vegetables. Being the major rain-fed crops, these two crops benefited more from the watershed interventions. The change in total surplus due to watershed intervention was decomposed into change in consumer surplus and change in producers surplus. It was evident that the producers surplus was higher than the consumer surplus in all the crops. For instance, in sorghum, the producers surplus worked out to be 61.2 per cent whereas the consumers surplus was only 38.8 per cent. Watershed development activities benefited the agricultural producers more. It was interesting to note that unlike in the crop sector, the milk production had different impacts on the society. The decomposition analysis revealed that watershed development activities generated

Table 6. Impact of watershed development activities on the village economy.

	Total benefits due to watershed intervention (B)		
Crops/enterprises	Change in total surplus (ΔTS)	Change in consumer surplus (ΔCS)	Change in producer surplus (Δ PS)
Sorghum	293177.3 (100.0)	113636.3 (38.8)	179541.0 (61.2)
Maize	177774.2 (100.0)	85424.0 (48.1)	92350.2 (51.9)
Pulses	25777.5 (100.0)	12580.3 (48.8)	13197.2 (51.2)
Vegetables	29663.6 (100.0)	10627.5 (35.8)	19036.1 (64.2)
Milk	176878.5 (100.0)	105974.1 (59.9)	70904.4 (40.1)

Note : The change in total surplus in the village economy due to watershed intervention was decomposed in to change in consumer surplus and change in producer surplus. The decomposition of total surplus was as follows:

$\Delta TS = \Delta CS + \Delta PS = P0Q0K(1+0.5Z\eta)$

$\Delta CS = P_0Q_0Z(1+0.5Z\eta)$

$\Delta PS = P_0Q_0(K-Z)(1+0.5Z\eta)$

Table 7. Results of economic analysis employing economic surplus method.

Particulars	Economic surplus method	Conventional method
Benefit-cost ratio	1.93	1.23
Internal rate of return (%)	25	14
Net present value (Rs)	2271021	567912

more consumers surplus in milk production. The overall impact of different watershed treatment activities was assessed in terms of net present value (NPV), benefit-cost ratio (BCR) and internal rate of return (IRR). The NPV, BCR and IRR were worked out using the economic surplus methodology assuming 10 per cent discount rate and 15 years life period.

The BCR is worked out to be more than one, implying that the returns to public investment such as watershed development activities were feasible. Similarly, the IRR worked out to be 25 per cent, which is higher than the long-term loan interest rate by commercial banks indicating the worthiness of the government investment on watershed development. The NPV worked out to be Rs 567912 for the entire watershed. The NPV per hectare worked out to be Rs 4542 (where the total area treated was 500 ha) implying that the benefits from watershed development were higher than the cost of investment of the watershed development programs of Rs 4000 ha^{-1}.

Conclusions and Policy Recommendations

The study has concluded that the watershed impact assessment should be given due importance in the future planning and development programs. The study has demonstrated that the economic surplus method captures the impacts of watershed development activities in a holistic manner and assesses the distributional effects, and therefore it would be a fairly good methodology to assess the impacts of watershed development. The watershed development activities have been found to have significant impact on groundwater recharge, access to groundwater and hence the expansion in irrigated area. Therefore, the

policy focus must be on the development of these water-harvesting structures, particularly percolation ponds wherever feasible. In addition to these public investments, private investments through construction of farm ponds may be encouraged as these structures help in a big way to harvest the available rain water and hence groundwater recharge.

Watershed development activities have been found to alter crop pattern, increase crop yields and crop diversification and thereby could provide enhanced employment and farm income. Therefore, alternative-farming system combining agricultural crops, trees and livestock components with comparable profit should be evolved and demonstrated to the farmers.

Once the groundwater is available, high water intensive crops are introduced. Hence, appropriate water saving technologies like drip is introduced without affecting farmers' choice of crops. The creation and implementation of regulations in relation to depth of wells and spacing between wells will reduce the well failure, which could be possible through Watershed Association. The existing NABARD norms such as 150 metres spacing between two wells should be strictly followed.

People's participation, involvement of Panchayati Raj Institutions, local user groups and NGOs along side institutional support from different levels, viz. the central and state government,,district and block levels should be ensured to make the program more participatory, interactive and cost effective.

Acknowledgements

The authors thank the anonymous referee for his valuable comments. They are also grateful to Dr. Praduman Kumar, former Professor of Agricultural Economics, IARI, New Delhi, for his significant contributions in developing this paper.

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