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# A Manual on Impact Assessment of Watersheds

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# Abstract

Recognising the importance of watershed development as a strategy of rural development, both central and state governments, non-governmental organisations, International Development Agencies invest huge funds on watershed development. The watershed approach enables the planners to internalize such externalities and other linkages among agricultural and related activities. Experience shows that various watershed development programme brought significant positive impact. Impact evaluations contribute to improve the effectiveness of policies and programs. Different methodologies have been used in the evaluation literature mainly the qualitative and quantitative methods. Choosing appropriate methodology for impact assessment of natural resource management interventions is essential.

This bulletin outlines the various concepts and methods in watershed impact evaluation with examples. The use of economic surplus approach with consumer and producers' surplus is compared with the conventional approach with only producers' surplus. Also incorporation of the rainfall variability in the watershed evaluation is demonstrated. A simple computer based watershed programme incorporating the various components of the watershed development is also developed and included.

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# 1. Introduction

Governments in the developing countries actively pursue various forms of policy instruments like implementation of development programs to achieve desired economic growth. The objective of such development programs lies in transforming a set of resources into desired results or outcomes. This is particularly so for the policies designed to alleviate poverty and to foster economic growth in the agricultural sector of the developing economies. Under these circumstances, understanding the nature, objectives and scope of the development program and the responsiveness of target groups are the imperatives for developmental personnel/specialist, economists and policy makers. This is very crucial for the developmental programs like watershed development to recommend improvements that will guarantee more food, fodder, fuel, and livelihood security for those who are at the bottom of the rural income scale. This calls for a systematic feedback of information from the project areas and beneficiaries for whom the project is intended. To provide the project management with such information, it is essential to understand the results of their activities for which data should be gathered on a continuing basis and analyzed without delay.

## 1.1. An Overview of Watershed Development Programs in India

Watershed development has emerged as a new paradigm for planning, development and management of land, water and biomass resources following a participatory bottom-up approach. The Government of India has been implementing watershed development programs through different ministries viz., Ministry of Agriculture, Ministry of Rural Development, Ministry of Environment and Forests and Ministry of Planning and Programme Implementation. Some important ongoing watershed development program include, Drought Prone Area Programme (DPAP), National Watershed Development Project in Rain-fed Agriculture, Desert Development Programme (DDP), River Valley Project (RVP), international programs of DANIDA, DFID (UK), GTZ, SDC, SIDA and others, state-funded watershed development programs, etc. In addition, based on the experience, the Government of India (GOI) has recently created Watershed Development Fund (WDF) in collaboration with National Bank for Agriculture and Rural Development (NABARD). The objective of this fund is to create necessary conditions to replicate and consolidate the isolated successful initiatives under different programs in the government, semi-government and non-governmental organization (NGO) sector. In addition, several initiatives on peoples' participation in resource management have taken place. Prominent among them are- Chipko Movement, Save Narmada Movement, AVARD's Irrigation Scheme, Water Council (*pani Panchayat*), Ralegan Siddhi, etc. The Ralegan Siddhi is the one among the very successful models of peoples' participation.

## 1.2. Need for Economic Impact Assessment of Watersheds

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 the utilization of surface and subsurface water for crop production (Kerr, et al., 2000). Further, the watershed is not only the hydrological unit of land draining out into a common point but human beings and animals are also integral part of watershed and their actions have impact on the health of a watershed (Wani et al., 2002). This approach aims to optimize moisture retention and reduce soil erosion, thus maximizing productivity and minimizing land degradation. Improved moisture management increases the productivity of improved seeds and fertilizers, so conservation and productivity-enhancing measures are complementary. Excess surface runoff water is harvested in irrigation or percolation tanks while subsurface drainage recharges groundwater aquifers, so conservation measures in the upper watersheds have a positive impact on productivity in the lower watersheds. The watershed approach enables the planners to internalize such externalities and other linkages among agricultural and related activities by accounting for all types of land uses in all locations and seasons. Socio-economic relationships among people in a watershed can complicate efforts to introduce seemingly straightforward technical improvements. This is because a watershed contains multiple decision-makers which affects watershed development. In general, watershed technologies are likely to fail if they divide benefits unevenly but require universal co-operation to make them work. In this case, equity becomes a prerequisite to efficiency (Kerr and Sanghi, 1992).

Recognising the importance of watershed development as a strategy of rural development, both Central and state governments, NGOs, international development agencies have been investing huge funds in watershed development programs. Different types of watershed treatment activities are carried out. 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 production demonstration, planting of horticultural crops and afforestation (Palanisami and Suresh Kumar, 2003).

The watershed development programs influence different aspects like agricultural production system, environment and socio-economic conditions of the watershed villages (Fig.1). The watershed development programs involving the entire community and natural resources influence (i) productivity and production of crops, changes in the land use and cropping patterns, adoption of modern technologies, increase in milk production, etc., (ii) attitude of the community towards project activities and their participation in different stages of the project, (iii) socio-economic conditions of the people such as income, employment, assets, health, education and energy use, (iv) impact on environment, (v) use of land, water, human and livestock resources, (vi) development of institutions for implementation of the watershed developmental activities and (vii) ensuring sustainability of the improvement. It is thus clear that watershed development is a key to sustainable production of food, fodder, fuel wood and meaningfully addresses the social, economical and cultural issues of the rural community. By virtue of its nature, watershed is an area-based technology cutting across villages comprising both private and public lands. The benefits from watershed developmental activities are not just limited to the users/beneficiaries but also to the non-participating farmers as well.

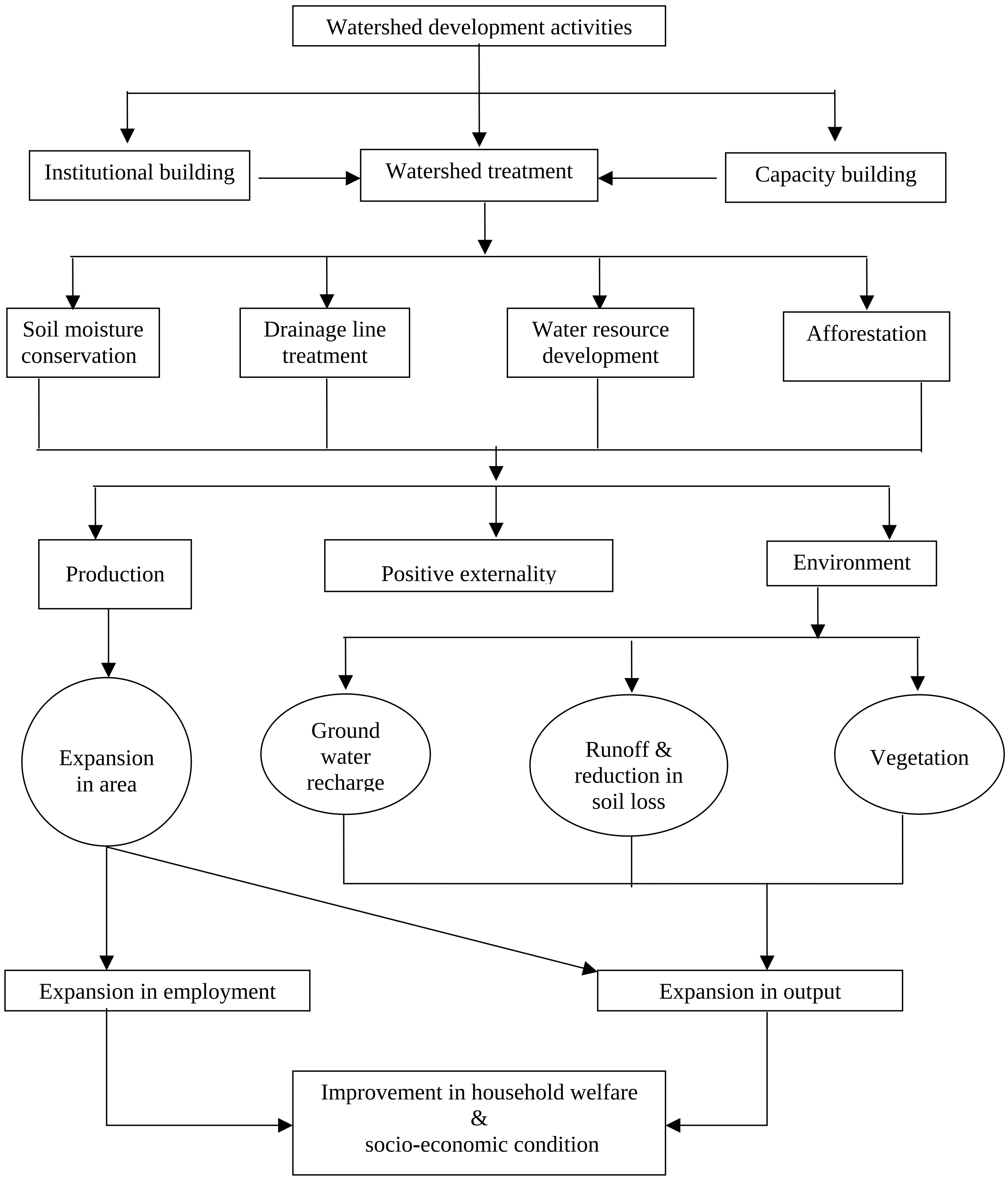


*Figure.1. Framework for Watershed Impact Assessment.*

Experience shows that various watershed development programs brought significant positive impact. There have been marked improvement in the access to drinking water due to groundwater recharge in the project area, increase in crop yields and substantial increase in cropped area, rise in employment and reduction in migration of labour. Availability of fodder has also improved leading to a rise in the yield of milk. The most important factor accounting for the positive impact of watershed developmental programs is community participation and the decentralization of program administration. Joshi et al. (2009) assessed the impacts of watershed programs in India through the meta-analysis of published results and identified the drivers of collective action in watersheds such as tangible economic benefits to small and marginal farmers, good local leadership, peoples' participation, bottom-up approach, knowledge-based entry point activity, good community-based organizations, decentralized decision-making, targeted activity for women and vulnerable groups with good capacity building and technical backstopping. The experience especially from Maharashtra shows that the encouraging performance of the watershed program can be attributed largely to the positive response from the people, especially in the tribal areas with their traditions of community participation and the political and administrative will for decentralizing the administration and strengthening the Panchayat Raj Institutions (Rao, 2000).

Watershed development and management has become of big concern in India. As the Central and State governments are making investments in watershed development, a proper assessment of the benefits accrued to the economy is essential. A programme such as watershed development, which involves a hierarchy of administration and communities at the grass roots level in highly varying agro-climatic and socio-economic conditions, invariably requires periodical assessment for achieving developmental objectives. Typically, an implementing agency would see a greater value in spending a few extra crores of rupees for undertaking works in the field rather than spending this money for monitoring and evaluation. However, according to some observers, mid-course corrections can help improve the benefits substantially, in some cases up to 100 per cent. But even if we consider the improvement to be very modest, say, 10 per cent, then a one per cent of program outlay on meaningful monitoring, evaluation would have a very high pay-off in terms of achieving the program objectives. It is of utmost importance, therefore, to put in place an institutional mechanism for research and monitoring and evaluation in the field of watershed development by involving reputed institutions in the country for upgrading the quality of evaluation.

Information generated by impact evaluations of watershed developmental projects facilitate considered decisions on whether to expand, modify, or eliminate a particular policy and can be used in prioritizing public actions. In addition, information from impact evaluations contribute to improve the effectiveness of policies and programs by addressing the questions such as: (i) Does the program achieve the intended goal?, (ii) Can the changes in outcomes be explained by the program, or are they the results of some other factors occurring simultaneously?, (iii) Do program impacts vary across different groups of intended beneficiaries (males, females, indigenous people, small and large farmers), regions, and over time?, (iv) Are there any unintended effects of the program, either positive or negative?, (v) How effective is the program in comparison with alternative interventions? and (vi) Is the program worth the resources it costs?

## 1.3. Challenges in Impact Assessment of Watershed Development

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) that are temporal and spatial. The dimensions of impact of watershed technologies further complicate the impact assessment.

The problem of impact assessment of a watershed development project lies on the following: (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 overall impact of the project. The nature of watershed technologies and its impact on different sectors pose challenges to project monitoring and evaluating agencies, economists, researchers and policy makers. More specifically, major challenges include (i) the choice of methodologies, (ii) selection of indicators, and (iii) choice of discount rate.

### (i) Choice of Methodologies

***Methods of impact assessment***

Choosing appropriate methodology for impact assessment of natural resource management interventions is essential. Different methodologies have been used in the evaluation literature, mainly the qualitative and quantitative methods (Shiferaw et al., 2004). The quantitative methods such as experimental or randomized control designs are being widely used. Some other quasi-experimental designs are widely used in the evaluation literature (Baker, 2000). The non-experimental or quasi-experimental designs such as matching methods or constructed controls, double difference, instrumental variables or statistical control methods and reflexive comparisons are being used by the evaluating agency. Qualitative techniques are also used for carrying out impact evaluation with the intent to determine impact by the reliance on something other than the counterfactual to a causal inference (Mohr 1995). The qualitative approach uses relatively open-ended methods during design, collection of data and analysis. The benefits of qualitative assessments are that they are flexible, can be specifically tailored to the needs of the evaluation using open-ended approaches, can be carried quickly using rapid techniques, and can greatly enhance the findings of an impact evaluation through providing a better understanding of stake holders' perceptions and priorities, and the conditions and processes that may have affected program impact (Baker, 2000). The qualitative methods are not exempted from limitations. Limitations like subjectivity involved in data collection, the lack of comparison group, and the lack of statistical robustness, given mainly small sample sizes, which make it difficult to generalize to a larger and representative population. Also, the validity and reliability of data from qualitative analysis are highly dependent on the methodological skill, sensitivity, and training of evaluator.

Economists have been employing total economic valuation (TEV) methodology in assessing the impact of watershed development activities. In order to assess the impact of a watershed development in a broad perspective, bio-economic modeling is widely been employed by the researchers. Bio-economic modeling is considered as a hybrid methodology in impact assessment as it incorporates both bio-physical and socio-economic features. But one major lacuna in employing bio-economic modeling is that it requires experimental data on bio-physical parameters often which limit the economists to use this methodology.

***Approaches of impact assessment***

One dominant perspective in impact assessment literature is to view natural resource development projects as constituting a set of inputs that are transformed through activities into a set of outputs and the impact of these projects on people are through the changes in output and through activities that produce these outputs (Gregerson and Contreras,1992). These impacts are of main concern in Economic Approach. The other approach, resulting from a change in the basic conception of development, sees projects more in terms of process pursuing multiple objectives: social, economic, environmental and institutional pursuing (eg. equity, efficiency, sustainability, community organizations, etc.,). Project goals and objectives, and assessment of achievements and impacts have become the central concerns of this approach. Many studies using or proposing this approach implicitly or explicitly use variants of a Logical Framework Approach as a basis. These approaches build the evaluation function within the management systems of the project cycle. The third approach is Participatory Evaluation where evaluation systems are designed and implemented in partnership mode with the people involved in the projects.

***Scale/time lags***

Being a common property resource, treatments in watersheds generate externalities. Conflicts arise between downstream and upstream farmers in sharing benefits and making investments. Also, watersheds include private and common lands, the impact of various watershed treatment activities on different scale of dimensions such as farm level, household level, watershed level form crucial in impact assessment of watershed treatment activities. The time is an extremely important element in natural resource management, particularly watershed development projects where the benefits and costs of development activities rarely occur the same time. For instance, investments on construction of rainwater harvesting structures occur in the early years, but the benefits occur during later part, resulting in a large time gap between investment and receipt of revenues. Time also complicates comparing investments with different timings and magnitude of benefits and costs.

***Samples for the study***

Another important issue faced by the evaluators is the choice of methodology for selecting sample respondents for the impact assessment. Should a researcher study samples from a watershed area itself by employing before/after approach or should they study samples both the treated and control villages employing with/without approach? Also, case studies raise a number of methodological issues in impact assessment of watershed development activities. For instance, issue arises in relation to sampling i.e. should the researcher use random sampling or purposive sampling in selecting among watersheds to assess the impacts? Each approach has its own pros and cons and no clear consensus seems to have emerged.

### (ii) Selection of Indicators

There are various indicators of impact. Changes in economic welfare are an obvious one and changes in distributional outcomes are another. It is difficult to derive appropriate indicators in assessing the program impacts. Assessing the economic value of the increased outputs in the watersheds as a result of various treatment activities is a valid measure of its impacts.

Development of indicators for impact assessment forms crucial aspects in impact assessment of watershed development programs, where the impact of different activities on different development domains is complex. Although several studies list a good number of indicators, there is little effort in developing a comprehensive framework for the identification, analysis and usage of appropriate indicators in watershed development projects. They can be obtained either by synthesis (a range of information obtained from primary or secondary data is combined to form the indicator) or selection (from primary or analysed data). It is important to identify data requirements, generate data and update the database at regular intervals. In using indicators there are many problems such as: (i) establishing causal links between indicators and the actual changes they are supposed to reflect, (ii) different indicators may give conflicting signals for the same results, (iii) establishing the relative importance of changes in different indicators (as a common denominator like price/money value is lacking) and (iv) lack of or problem of arriving at a rational method to assess the significance of quantum change. Another such problem lies in inter-comparison of projects.

As the impact of watershed development activities is multi-faceted and complex, it may not always be possible to measure the results that have been achieved because they may be intangible or it may be too costly to measure them effectively. In such cases indications that success is being achieved will make good proxies. Such indicators, however, must be chosen carefully so that they are reliable substitutes to direct measurement and are easy to measure in terms of time and effort. The choice of indicators is determined by who the end-user is. These issues pose challenges in impact assessment of watershed development.

### (iii) Choosing the Discount Rate

Enough has been discussed and debated in natural resources economics on the determination of methodology to use in discounting and selection of a discount rate. If the economy is optimal and all of society's wishes are reflected in financial markets, the determination of a discount rate would be straight forward. It would be related to some financial rate such as interest on bank deposits. However, the economy is non-optimal or second best. Further more, determining society's preferences and how these are reflected through government spending is difficult. Problems centered on whether discounting should occur at the social rate of time preference (the social discount rate) or at a marginal rate for private investment (the private discount rate). It is generally argued that society is more concerned with the future, especially with negative natural resource and environmental consequences, than the individual or private firms. Consequently, the social discount rate will be lower, however, some support the notion that private and social rates do not differ. Most economists suggest using an opportunity cost approach for evaluating government projects is the most efficient and the easiest to implement.

One big debatable issue in the field of natural resources evaluation is the choice of discount rate to be used in either economic analysis or financial analysis of project impact assessment. Impact assessment of watershed development is not an exception to this. As watershed development involves development of both common and private lands, it generates many positive externalities and led to spill over effects. Moreover, as it involves huge government spending, selection of a 'discount rate' is a crucial one*.*

## 1.4. Conclusion

Today watershed development has become the main intervention for natural resource management and growth engine for sustainable development of dryland areas (Wani et al., 2009). Watershed developmental programs not only conserve soil and water resources and maintain environmental quality, but also contribute to livelihood security. The importance of watershed development as a conservation program is being recognized, not only for rain-fed areas, but also for high rainfall areas, coastal regions, and the catchments areas of dams. With a large investment of financial resources in the watershed program, it is important that the program is successful. Hence the challenges in the watershed impact assessment should be given due importance in the future planning and development of the programs.

# 2. Indicators for Evaluation of Watershed Development Projects

## 2.1. Types of Evaluation

The problem of developing evaluation framework for any watershed development project lies in the following:

- developing a framework to identify what impacts to assess, where to look for these impacts and to selecting appropriate indicators to assess the impacts,
- developing a framework to look for the indicators for assessing the overall impact of the project.

Evaluation is a periodic assessment of the relevance, performance, efficiency and impact of the project in the context of its stated objectives.

Several types of evaluations have been used in different studies and some of the more useful typologies are reviewed here.

Based on the objectives of the project, the evaluation system may be defined as:

- validation evaluation to evaluate the assumptions used in the project formulations,
- effectiveness evaluation to evaluate the progress towards stated physical and financial goals,
- achievement evaluation to evaluate the changes in the living standards or in the hydrologic and environmental conditions brought about by the project.

Based on the stage in the project cycle at which evaluation is conducted, the evaluation systems are classified into the following.

- Baseline: Pre-project assessment to analyse the viability of the project.
- Ongoing or intermediate - to check the effectiveness of each individual activity conducted throughout the project's life cycle.
- Terminal evaluation – conducted at the end of the project to evaluate the efficiency of the project implementation.
- Post-terminal evaluation – to evaluate long-term project accomplishments, conducted several years after project completion.

In general, the evaluating agency will evaluate the project either during the project implementation phase i.e. mid-term or ongoing evaluation or after completion of the project period i.e. ex-post evaluation. Ongoing evaluation is a series of periodic 'breaks' to analyse the monitored information to probe further the signals received and assess how things are moving. The important questions raised are: Are activities being accomplished on time? Is progress towards achievement of objectives satisfactory? Throughout the ongoing evaluation of a program, the emphasis is placed on delivering information, which is modest in both scale and scope but sharply focused on the practical implications for management. The very purpose of the ongoing evaluation is to assess the continuing relevance, present and future outputs, and the effectiveness during implementation. The main focus is on assessing the validity of the project design and targets, assessment of the effects and review of cost effectiveness.

Ongoing evaluation is target-oriented. Terminal/ex-post evaluation is usually done after completion of the project mainly to assess the impact of the project i.e to assess the success or failure of the project. The purpose of the ex-post evaluation is to assess the output, effect and impact and drawing lessons for future planning and development. This type of valuation is beneficiary-oriented.

## 2.2. Approaches

The approach used for the analysis of impact can be accomplished in two ways. Firstly, 'with project' parameters compared to the 'pre-project' situation gives the incremental benefits due to the project. But these increments in the parameters intrinsically include the changes due to the state of the art technology. Thus sometimes, the benefits may be exaggerated.

Secondly, the literature on project analysis unanimously suggests the use of comparison between the 'project parameters' and the 'non-project control region'. This method automatically incorporates the correction for the impact of the technology in the absence of the project. This essentially follows with and without approach. However, some researchers employ a combination of both with and without and before and after approaches.

## 2.3. Measuring Success in Tangible Outputs

Whether a watershed development project is moving ahead towards the target can be measured and monitored at the local community level through simple methods. There have to be some indicators that show whether the objectives are being met. The output and its quality are also to be monitored. The evaluating agency must consider the following aspects.

**Land and water:** Usually, watershed development projects attempt to reduce soil erosion, conserve rainwater and improve water availability, resulting in increased food, fodder and fuel availability in the watershed development project area. Different qualitative and quantitative methods can be used to find out whether soil erosion is being reduced or not. Quantitative estimation of reduced soil erosion can be made through runoff measurement, using automatic hydrological gauging station and sediment sampling devices at the developed and under-developed or pre- and post watershed development stages of the project (Pathak et al., 2005). This would provide information on effectiveness of the program or otherwise soil conservation measures like gully plugs, bunds, loose stone check dams, etc.

**Yield of crops:** The changes in crop yields over a period of time would indicate improvement or otherwise in land productivity. To measure the crop yield, two or more dominant crops in the region can be selected. Yield data for sample farmers (small, medium and large land holders); and also yield data from farmers fields in the upper or lower slope can be collected (Wani et al., 2006).

**Drinking water availability:** Increase in the drinking water availability is one of the important expected outputs of a watershed development project. In most watershed development project areas, hand pumps are a common source of drinking water.

These hand pumps usually go dry in the summer season. However, if the water conservation mechanisms are effective, there would be an increase in the water table depth, and hand pumps might yield water for a longer period.

**Water available in ponds:** The period for which water is available in the village ponds is a good indicator of the effectiveness of water harvesting mechanisms undertaken in a watershed developmental project.

*Water table in wells:* Increase in the water table depth in a watershed development area can be measured by taking a record of the water table in open and bore wells in the area. Total discharge of water from wells in a particular month would be a good indicator of the increased availability of water in the area. The recharge time can also be measured to determine the availability of water.

*Fodder availability:* Pasture land protection and development: Increased availability of fodder in the region is important objective of a project. The common lands (pasture lands or revenue waste lands) are developed as pasture lands by planting trees or grasses and protecting the area. Increased fodder availability due to increased area under pasture or fodder cultivation and increased fodder productivity per unit of land area can be measured through cutting experiments in an area.

**The pasture land area starts producing grasses within two years:** Mostly grasses are cut and carried home by villagers during the initial period. The number of head loads can be counted and the average weight of a head load is multiplied with the number of head loads to arrive the grass output.

**Area planted with trees, number of trees planted and their survival percentage:** Tree plantation on common land and private lands is one of the main objectives in a watershed development project. Tree plantation is done mainly to increase the availability of fuel wood, tree fodder, minor tree produce, etc. The number of trees planted and percentage of surviving seedlings should be reported. Natural regeneration of rootstock should be included in the data.

**Numbers and kinds of animals and their productivity:** Census of animals should be taken up in a watershed development project at the start, after two years and at the end of project. The animals considered could be cows, buffaloes, goats, sheep, etc. The changes in the number and composition of the livestock should be noted along with their productivity with parameters, milk yield, draught power, wool, manure, etc.

**Village institutions:** One of the important objectives of a watershed developmental project is to build and strengthen the village level institutions. The growth and development of local bodies, farmers' organizations, self-help groups and their effective functioning can be taken into account for this purpose.

**Migration:** A watershed developmental project, if successfully implemented, leads to an increased availability of water, fodder and employment. These factors would help in reducing the migration of people and animals, especially those who migrate for want of employment, water and fodder.

**Employment generated:** Various activities taken up in a watershed developmental project generate employment for villagers. Employment is the immediate benefit that villagers get out of a project. Watershed projects can increase employment in agricultural, animal husbandry and non-farm activities. The level of employment can be taken as a measure of success of a project.

## 2.4. Indicators for the Evaluation of Watershed Development Projects

There is no single indicator of successful watershed development project development, so the most feasible approach is to compare the performance of a variety of indicators. The various performance indicators also reflect the diversity of the project objectives. These include raising rain-fed agricultural productivity, recharging groundwater for drinking and irrigation, raising productivity of non-arable lands, creating employment, improving livelihoods, increasing incomes, promoting collective action and building or strengthening the social institutions.

### (i) Bio-physical Indicators

*Forest/vegetation:* Frequency, density, height, girth, canopy percentage and biomass. Survival and growth percentage, changes in forest area, etc.

*Channel Morphology:* Periodic survey of channels for deposition of silt behind structures.

*Arable Lands:* Area under different crops, irrigated and un-irrigated area, purchased inputs used, crop yields, fruit yields.

*Land Use:* Changes in the land use pattern and cropping patterns.

### (ii) Socio-Economic Indicators

Human population, family income from different sources, revenue generated from Common Property Resources, cattle population, milk, meat production, changes in housing facilities, disposal of family income on different heads like food, education, health, etc., source of fuel and or energy for domestic uses, farm and house hold assets acquired, literacy level, infrastructural development, growth and functioning of social institutions and organisations. The list of various indicators for monitoring and evaluation of watershed development projects are given in the Table 1.

### (iii) Evaluation Measures

*Bio-physical Measures:* Selected measures of productivity, protection or conservation, reclamation and ecological benefits determined before and after the implementation of the works can be used:

*Hydrological Indices*: (a) Changes in runoff, depth or water yield, (b) Peak runoff before and after, (c) Changes in duration of flow in the stream

*Water Availability Indices:* (a) Changes in surface water storages e.g., ponds, tanks capacities, etc. (b) Changes in groundwater table (i.e. water table rise) and well yield. Groundwater levels as observed from open wells and bore wells can be used for

**Table 1. Performance indicators can be used for evaluation**

| Performance criteria | Indicators | Measures |
|---|---|---|
| Groundwater recharge and water resource potential | Measurement of groundwater levels, climate variation and pumping volume | Duration of water availability in wells<br>Water table in wells<br>Surface water storage capacity<br>Hydrological Index<br>Index of water conservation practices<br>Difference in number of wells<br>Number of wells recharged /defunct<br>Difference in irrigated area<br>Difference in no.of seasons irrigated<br>Difference in village level drinking water adequacy<br>Difference in Irrigation intensity |
| Environment quality | Carbon sequestration, potential, air and water quality and recreation facilities, increased biodiversity | Water and air quality parameters such as $CO_2$, $N_2O$, concentration and load of suspended particles in air |
| Water quality | Concentration of $NO_3$-N and $PO_4$, in water samples<br>Traces of pesticides and higher concentrations of $NO_3$-N, $PO_4$, fluorides, turbidity | Total dissolved solids (TDS, pH, EC) in water samples; $NO_3$-N, $PO_4$, fluorides and pesticide residues in water samples.<br>Concentration of pesticide residues in water samples |
| Agricultural productivity/ profits | Agricultural productivity and net returns at plot level | Agrl.productivity Index (API)<br>Crop Yield Index (CYI)<br>Crop Diversification Index (CDI)<br>Cropping System Index (CSI)<br>Index of agroforestry Practices (IAP)<br>Difference in cropping pattern<br>Difference in Cropping Intensity<br>Difference in Yield of crops<br>Farm profit |
| Household welfare | Household income and wealth | Difference in per capita income<br>Difference in employment<br>Difference in household income<br>Difference in persons migrated |
| | Nutritional status | Food Security Index (FSI)<br>Child nutrition and health |
| Socio-economic and institutional indicators | Development of CBOs and infrastructure | Infrastructure Development Index (IDI) |
| | Impact on women (decision making, health, life style and awareness) | Women's Participation Index (WPI)<br>Peoples' Participation Index |
| | People's Participation Index | Index of Social Affiliation (ISA)<br>Differences in number of CBOs and quality of their functioning |
| | Institutions | Difference in number of institutions |
| | Ownership rights | Difference in no.of agrl.labourers<br>Difference in no.of landless labourers<br>Difference in farm households by size groups |
| Over all impact | Economic returns to investment | NPV, BCR and IRR |
| | Extent of green cover | Forest Eco Index |

determining changes by comparing water tables with that of outside the watershed development project or before implementation of works. (c) Some indirect measures include increase on number of wells, increase in irrigated area, duration of pumping before well goes dry and time it takes to recuperate.

Soil Erosion and Sedimentation Indices: (a) Changes in the soil loss. (b) Changes in the sediment yield to pond or tank. (c) Silt deposition in the channel bed behind the structures. (d) Nutrient and organic carbon losses.

*Agricultural Crops Indices:*

Crop Yield Index: A measure of the comparison of the yield of all the crops in a given farm or watershed development project with the average yield of these crops in a locality, *taluk,* district, state or county. The relationship is expressed in per cent.

$$\text{Crop Yield Index (CYI)} = \frac{\text{Average yield in the watershed village } (t\ h^{-1})}{\text{Average yield in the area } (t\ h^{-1})} \text{X100}$$

Apart from annual crops, yield of fruits, fodder and fuelwood may also be measured similarly.

### (iv) Socio-economic Measures

There are many direct and indirect outcomes of the project that can be associated with the impact of watershed developmental project. As a result, education, purchasing power of the households, assets position, and infrastructural development are likely to be improved. Some of the important socio-economic measures (possession of assets, consumer durables, per capita availability of watershed development project produce, improvement in housing pattern, literacy) can be used for impact assessment. Apart from the above social-economic measures, a number of indices can be used to measure the levels of community participation, rate of adoption of a technology, employment generation, the change in borrowing pattern, performance of the self-help-groups, etc. These indices can also be used to monitor and evaluate the impact on social capital and network development. The performance of community-based organization (CBO) activities in the watershed developmental project can be monitored through the functioning and the effectiveness of CBOs such as SHGs, UGs (user groups), watershed committees, etc.

### (v) Economic Measures

Measures such as (a) net present value (NPV), (b) benefit-cost ratio (BCR) and (c) internal rate of return (IRR) are used for assessing the impact of watershed development project.

***Net Present Value (NPV)***

The most straight forward discounted cash flow measures of development project worth is the NPV. This is simply the present worth of the incremental net benefit or incremental cash flow stream. It may also be computed by finding the difference between the present worth of the benefit stream and the present worth of the cost stream.

$$NPV = \sum_{i=1}^{n} \frac{B_n}{(1+i)^n} - \sum_{i=1}^{n} \frac{C_n}{(1+i)^n}$$

Where,

$B_n$ = Benefits in the period 'n'

$C_n$ = Cost in the period 'n'

$i$ = Discount rate

$n$ = Number of years

NPV may be interpreted as the present worth of the income stream generated by an investment on a project. The criterion is the NPV must be positive. Suppose the NPV worked out to be negative. Then we would have a case in which, at the discount rate assumed, the present worth of the benefit stream is less than the present worth of the cost stream i.e. insufficient to recover investment. NPV is also the preferred selection criterion to choose among mutually exclusive projects.

***Benefit-Cost Ratio (BCR)***

This is the ratio obtained when the present worth of the benefit stream is divided by the present worth of the cost stream.

$$BCR = \sum_{i=1}^{n} \frac{B_n /(1+i)^n}{C_n /(1+i)^n}$$

The BCR implies that returns per rupee of investments. The criterion is BCR should be greater than one.

***Internal Rate of Return (IRR)***

This is the rate that makes the net present worth of the incremental net benefit stream or incremental cash flow equal zero. It is the maximum interest that a project could pay for the resources used if the project is to recover its investments and operating costs and still break-even.

$$IRR = LDR + (HDR - LDR)\left[\frac{\text{NPV at LDR}}{\text{Sum of NPV at HDR and LDR, signs ignored}}\right]$$

LDR and HDR are the lower and higher discount rates, respectively. The criterion is to select the project with IRR greater than the opportunity cost of the capital. The above measures can be used to assess the individual components of watershed developmental projects (Daves, 1974). While evaluating the watershed development projects care must be taken in distinguishing between financial and economic analysis of the watershed development projects. Both the financial and economic analyses are not different and both types of analyses are required for the project screening and selection (Palanisami, 1997). However, there is difference in the approach and since financial analysis deals with the cost and benefit flows from the point of view of a farm, as opposed to the economic analysis, which deals with the cost and benefits.

The methods nevertheless differ in several important ways. A farm is interested in financial profit and the stability of the profit, while society or government is concerned with much wider objectives such as food self-sufficiency, rural employment, poverty alleviation and resulting net benefits to society as a whole. The two analyses also differ on account of the basis used for valuing inputs and outputs from a given project. The resulting cost and benefits are not necessarily the same under the two types of analysis. Financial analysis considers costs as all payments that reduce the monetary resources of the project, and considers as benefits (or revenues) all receipts that increase the project's financial resources. Economic analysis treats costs as only those payments that reduce the nation's real resources, and benefits as only those receipts which increase the nation's real resources. Therefore, the objectives of the two analyses are different.

### 2.5. Cost and Benefit estimation in Watershed Development Project Evaluation

The watershed development activities are largely financed by the Central, State governments, international development agencies and NGOs. Therefore, the applicable view point for project evaluation is that of the society as whole. The primary criterion for project evaluation is whether the resources expended are allocated so that the resources will yield as high a return in social benefits as they would in alternative uses. The general objective is maximization of social welfare. Operationally, this requires that the sum of all project benefits, wherever they accrue, be equal to or greater than all project costs wherever they fall.

**(i) Procedure for cost estimation:** The cost of implementing various soil and water conservation measures in a watershed development project are classified as installation, operation and maintenance and induced costs.

- *Installation costs/establishment costs:* Project installation costs include costs of construction of various engineering structures, establishment of tree plantations, etc. Planning costs are almost borne by the project implementing agency and are not included in the cost of individual projects.
- *Operation and maintenance costs:* The basic assumption underlying estimation of operation and maintenance costs is that works of improvement must be operated and maintained so that they will deliver full benefits throughout the life of the project for which they were designed. These costs involve largely maintenance, including annual and periodic repairs and replacement of any project components expected to have a lifetime shorter than the project. Typically, the operation costs include the costs of maintaining soil and water conservation and rainwater harvesting structures, CPRs and productivity enhancement trials and costs for regulating water levels or flows using manually-operated gates, and administration and servicing.
- *Induced costs:* It is defined as all uncompensated adverse effects in goods and services caused by the construction or operations of a project. Examples of such costs include production losses in excess of estimated damages to lands used by the project, detrimental downstream effects, and damages to wildlife resources.
- In addition to the project costs, the associated costs – classified as non-project costs – can be included in the evaluation of watershed development projects.

The associated costs are costs over and above project costs necessary to attain the benefits attributed to watershed development projects. There are two types of associated costs, generally considered are costs of changing land use pattern (eg.land clearing) and increased on-farm production costs necessary to achieve increased output.

- *Total costs:* Not all costs estimated for a watershed development project are included when total costs are arrived. Though the associated costs are included in project benefit-cost analyses, they are not included with other costs on the cost side. Rather, they are treated as 'negative benefits' and are subtracted from gross project benefits. Before annual total project costs can be determined, installation/ establishment costs must be converted to an annual basis. This is done by amortising capital expenditure over the project life period.

**(ii) Procedure for benefit estimation:** In evaluating the watershed development project enough care must be taken into account in estimating the benefits of the project. The benefits include both direct and indirect benefits. The direct benefits include increased production, reduction in the cost of inputs used, increased income through enhanced employment level, increased availability of fuelwood, fodder, etc. The indirect benefits include drought-mitigation benefits, increased water availability for drinking and agriculture, change in water quality, improvement in soil fertility, reduction in water loss, increased carbon sequestration, reduced siltation of water bodies, increased recreational benefits, etc. The total benefits of the projects can then be arrived to assess the economic feasibility of the watershed development project.

## 2.6. Computer Based Model for Watershed Evaluation

A computer-based prototype model for watershed impact evaluation has been developed at Water Technology Centre, Tamil Nadu Agricultural University, Coimbatore, India. The model is named WADIAM (Watershed Development Impact Assessment Model). The model was developed in Microsoft Visual Basic with MS Access. WADIAM can be used for evaluation of watershed development activities using either with or without/ before and after approaches. The model permits the assessment of various indicators on three major aspects of impact viz, agricultural production, socio-economic and various watershed treatment activities. The details of the model are furnished in Appendix-I.

## 2.7. Conclusions

Realising the potential and importance of watershed development and their likely impact on the economy, enough efforts have been taken to identify and develop indicators for proper monitoring and evaluation of watershed development projects. This will be useful for the researchers, government agencies and other agencies involved in monitoring and evaluation of watershed development projects.

## 3. 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 NPV, the IRR, or 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 econimics 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, 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.

### 3.1. 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 2, 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 $P_1bI_1$ - Area $P_0aI_0$.

The mathematical model used was based on the scheme proposed by Pachico et al. (1987), in which supply and demand functions were non-linear with constant elasticity, i.e. log-linear. The supply function for a product market assumed to be supply curves of the following functional form:

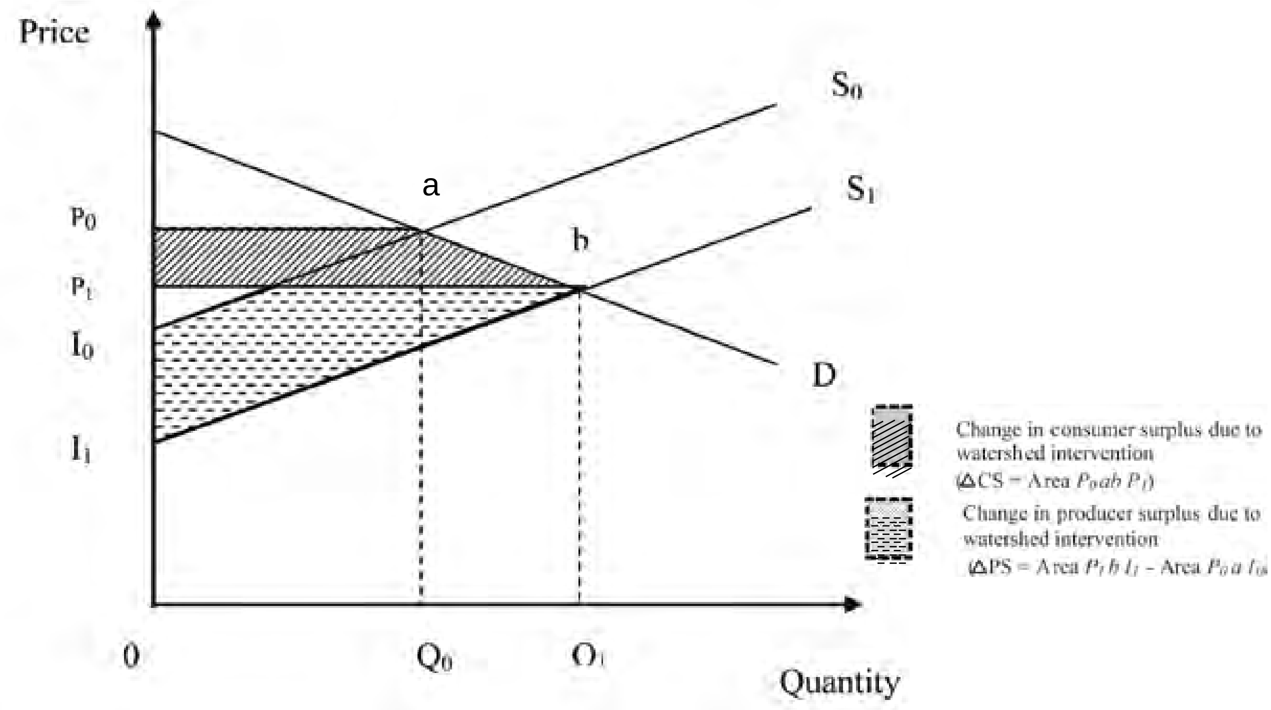


*Figure. 2. Graphical representation of economic surplus method.*

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

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, 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 are not limited only to the users/beneficiaries but extended 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 biodiversity 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 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.

### 3.2. 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:

$$P = gQ^{\eta} \quad (2)$$

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

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

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

### 3.3. 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):

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

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 ($\varepsilon_s$). Reduction in unit cost is defined as the ratio of change in cost of inputs per hectare (1+change in yield). $\rho$ is the probability of success in watershed development implementation. $\psi$ represents adoption rate of technologies and $\Omega$ 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.

### 3.4. Cost of Project

The cost involves the 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.

## 4. Empirical Studies

### 4.1. Indicators for Evaluation

This section presents the key indicators from the field experience of impact assessment of watershed programs implemented under Drought Prone Area Programme (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.

**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* | 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 |

* indicates that value was significantly different at 10 per cent level from the corresponding values of control village

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 evident 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 in the watersheds to store the runoff 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 for 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 ground water 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 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 entropy 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.

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:

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

where,

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

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 livestock.

| 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*** | 1.68 | 1.62 |
| Gross area irrigated (ha) | 1.25 | 1.35** | 1.84 | 1.62 |
| Irrigation intensity (%) | 115.74 | 122.73** | 109.52 | 100.00 |
| Net cropped area (ha) | 1.15 | 1.28** | 1.78 | 1.62 |
| Gross cropped area (ha) | 1.38 | 1.88** | 2.43 | 2.16 |
| Cropping intensity (%) | 120.00 | 146.88 | 136.52 | 133.33 |
| Crop diversification index (CDI) | 1.0 | | 0.97 | |

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

| Table 4. Livestock per household and per hectare of arable land | | |
|---|---|---|
| Particulars | Watershed village | Control village |
| Per cent of households having cattle | 46.67 | 93.33 |
| Herd size (number per household) | 2.57 | 2.64 |
| Cattle number per hectare of gross cropped area | 2.01 | 1.63 |

Access to grazing land and fodder had made the farm households to maintain livestock in 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 farmers 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.

### (i) Financial analysis

To assess the overall impact of different watershed treatment activities conventional financial indicators like BCR and IRR can be worked out. The BCR and IRR were worked out for the Kodangipalayam watershed in Coimbatore district using conventional methodology assuming 10 per cent discount rate with a life period of 15 years (Table 5). For illustration purposes, the cost and benefit streams are assumed to be constant during the project period.

While working out the cost, all the costs including the costs on watershed treatment activities, entry point activities, training, administration costs were included. In working out benefits, only the benefits accrued from farm activities viz., crop activities and savings due to reduction in well deepening and new well drilling costs were accounted. The difference in farm income between before and after watershed treatment was taken into account for the purpose. The benefits are valued at the prices of reference year.

| Table 5. Benefit and cost stream in Kodangipalayam watershed | | | | | | |
|---|---|---|---|---|---|---|
| Year | Costs (Rs) | Benefits (Rs) | Cash flow (Rs) | Discount factor (@10%) | Discounted benefits (Rs) | Discounted costs (Rs) |
| 1 | 392506 | 0 | -392506 | 0.9091 | 0 | 356824 |
| 2 | 392506 | 0 | -392506 | 0.8264 | 0 | 324385 |
| 3 | 392506 | 0 | -392506 | 0.7513 | 0 | 294896 |
| 4 | 392506 | 0 | -392506 | 0.6830 | 0 | 268087 |
| 5 | 392506 | 0 | -392506 | 0.6209 | 0 | 243715 |
| 6 | 0 | 700557 | 700557 | 0.5645 | 395446 | 0 |
| 7 | 0 | 700557 | 700557 | 0.5132 | 359497 | 0 |
| 8 | 0 | 700557 | 700557 | 0.4665 | 326815 | 0 |
| 9 | 0 | 700557 | 700557 | 0.4241 | 297105 | 0 |
| 10 | 0 | 700557 | 700557 | 0.3855 | 270095 | 0 |
| 11 | 0 | 700557 | 700557 | 0.3505 | 245541 | 0 |
| 12 | 0 | 700557 | 700557 | 0.3186 | 223219 | 0 |
| 13 | 0 | 700557 | 700557 | 0.2897 | 202926 | 0 |
| 14 | 0 | 700557 | 700557 | 0.2633 | 184479 | 0 |
| 15 | 0 | 700557 | 700557 | 0.2394 | 167708 | 0 |

| Table 6. Financial analysis on watershed development activities, Kodangipalayam watershed | |
|---|---|
| Particulars | Values |
| Net present value (NPV)(Rs) | 1184923 |
| Benefit cost ratio (BCR) | 1.79 |
| Internal rate of return (IRR) (%) | 20 |

The results from Table 6 indicate that in general the BCR is 1.79, implying that the returns to public investment such as watershed development activities are feasible. Similarly, the IRR is worked out to be 20 per cent, which is higher than the long-term loan interest rate by commercial banks (10 per cent), indicating the worthiness of the government investment on watershed development. The net present value is Rs 11.85 lakh.

### 4.2. 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 7. 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.

The change in total surplus due to watershed development activities was estimated and has been presented in Table 8. 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.

**Table 7. 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 (Cm) was the ratio of relative change in yield to price elasticity of supply ($\varepsilon_s$ ). Reduction in unit cost ($C_u$) 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 intervention was decomposed into change in consumer surplus and change in producer surplus. It was evident that the producer surplus was higher than the consumers surplus in all the crops. For instance, in sorghum, the producer 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 more consumer surplus in milk production.

**Table 8. Impact of watershed development activities on the village economy**

| Crops/ Enterprises | Total benefits due to watershed intervention (Rs) | | |
|---|---|---|---|
| | Change in total surplus (ΔTS) | Change in consumer surplus (ΔCS) | Change in producer surplus (ΔPS) |
| Sorghum | 293177.3 | 113636.3 | 179541.0 |
| | (100.00) | (38.8) | (61.2) |
| Maize | 177774.2 | 85424.0 | 92350.2 |
| | (100.00) | (48.1) | (51.9) |
| Pulses | 25777.5 | 12580.3 | 13197.2 |
| | (100..00) | (48.8) | (51.2) |
| Vegetables | 29663.6 | 10627.5 | 19036.1 |
| | (100.00) | (35.8) | (64.2) |
| Milk | 176878.5 | 105974.1 | 70904.4 |
| | (100.00) | (59.9) | (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:

$\Delta_{TS} = \Delta CS + \Delta PS = P_0 Q_0 K(1 + 0.5Z\eta)$; $\Delta CS = P_0 Q_0 Z(1 + 0.5Z\eta)$; $\Delta PS = P_0 Q_0 (K - Z)(1 + 0.5Z\eta)$.

| Table 9. Results of economic analysis employing economic surplus method | | |
|---|---|---|
| **Particulars** | **Economic surplus method** | **Conventional method** |
| Net present value (NPV) (Rs) | 2271021 | 1184923 |
| Benefit-cost ratio (BCR) | 1.93 | 1.79 |
| Internal rate of return (IRR) (%) | 25 | 20 |

The overall impact of different watershed treatment activities was assessed in terms of NPV, BCR and 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 22,71,021 for the entire watershed. The NPV per hectare worked out to be Rs 4542 (where the total area treated was 500 ha) implied that the benefits from watershed development were higher than the cost of investment of the watershed development programs of Rs 4000 ha[1].

## 4.3. Conclusions

The watershed impact assessment should be given due importance in the future planning and developmental programs. The study has demonstrated that the economic surplus method captures the impacts of watershed developmental 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 in 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 ground water is available, high water-intensive crops are introduced. Hence, appropriate water saving technologies like drip is introduced without affecting farmers'

[1] However, recently the watersheds in India have been allotted a budget of approximately Rs 6000 per ha. Thus, a watershed with a total area of 500 hectares receives Rs 30 lakhs for a five-year period. The bulk of this money (80 per cent) is meant for development/treatment and construction activities. According to the new Common Guidelines 2008, the budgetary allocation is of Rs 12000 per ha.

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 PRIs, local user groups and NGOs along side institutional support from different levels, viz. the Central and State governments, district and block levels should be ensured to make the programme more participatory, interactive and cost effective.

## 5. Meta Analysis

Meta-analysis has become popular among economists to assess the impacts at macro level. The purpose is to collate research findings from previous studies, and distil them for broad conclusions. The approach is popularly known as analysis of the analyses. Meta analysis can be helpful for policy makers, who may be confronted by numerous conflicting conclusions (Joshi et al., 2005, 2009).

This section is mainly drawn from the recent study made by the ICRISAT-led consortium team (Wani et al., 2008).

### 5.1 Integrated Watershed Management: An example from Indian Micro-Watershed Management

A holistic approach to water productivity improvements can be seen in the extensive integrated watershed management strategy for developing vast dryland areas adopted by the Government of India. By essentially managing rainfall and inflows of water in a given watershed more efficiently and beneficially for local populations, a range of locally important natural and social features have improved (Wani et al., 2008). An ICRISAT-led consortium carried out a meta-analysis of 636 Indian micro-watersheds. The evidence clearly revealed that watershed programs are providing multiple benefits through the improved management of landscape water resources benefiting both livelihoods and the environment.  It showed augmented rural incomes, generating rural employment (150 person days $ha^{-1}$), increased crop yields, increased cropping intensity (35.5%), reduced runoff (45%) and soil loss (1.1 t $ha^{-1}$), augmented ground water, building social capital and reducing poverty. In terms of economic efficiency watersheds generated an average BCR of 2 and 0.6 per cent of watersheds failed to give a return to the investment (benefit cost ratio less than one). As shown in Figure 3 (Joshi et al., 2008), the IRR from the watersheds investment was 27.4 per cent. Thirty two percent of watersheds showed a mean BCR of greater than two and 27 per cent of watersheds yielded an IRR of more than 30 per cent, which showed immense potential to upgrade watershed programs in the country (Table 10).  Thus, water productivity gains, as in using water more efficiently improving both human and environmental well-being, and in challenging poverty-affected tropical drylands.

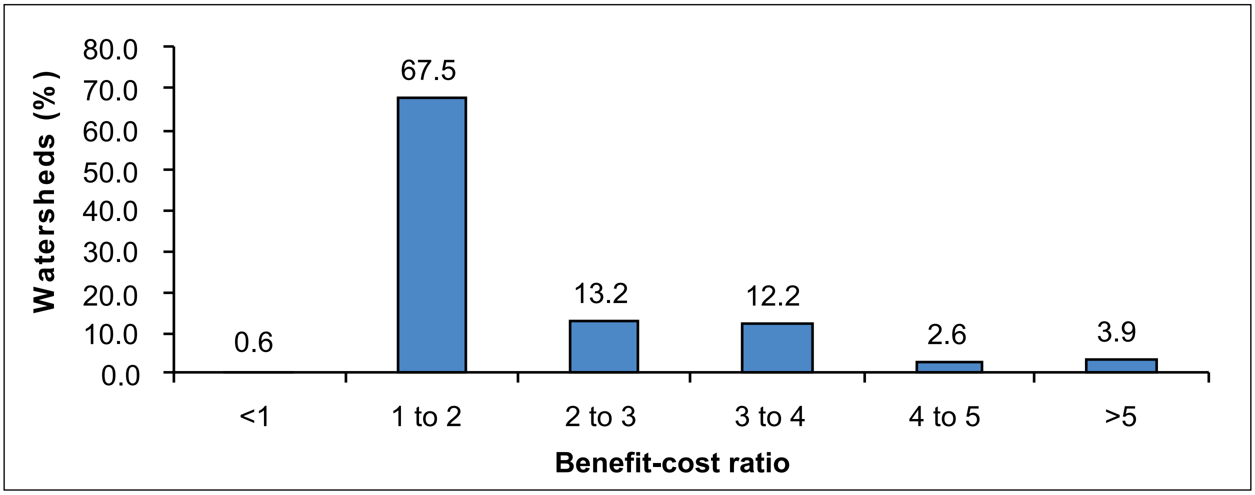


*Figure 3. Distribution (%) of watersheds according to BCR.*

**Table 10. Summary of benefits from the sample watersheds**

| | Particulars | Unit | No. of studies | Mean | Mode | Median | Minimum | Maximum | t-value |
|---|---|---|---|---|---|---|---|---|---|
| Efficiency | BCR | Ratio | 311 | 2.0 | 1.7 | 1.7 | 0.8 | 7.3 | 35.09 |
| | IRR | Per cent | 162 | 27.40 | 25.9 | 25.0 | 2.0 | 102.7 | 21.75 |
| Equity | Employment | Person days $ha^{-1}$ $year^{-1}$ | 99 | 154.50 | 286.7 | 56.5 | 5.00 | 900.0 | 8.13 |
| Sustainability | Increase in irrigated area | Per cent | 93 | 51.5 | 34.0 | 32.4 | 1.23 | 204 | 10.94 |
| | Increase in cropping intensity | Per cent | 339 | 35.5 | 5.0 | 21.0 | 3.0 | 283.0 | 14.96 |
| | Runoff reduced | Per cent | 83 | 45.7 | 43.3 | 42.5 | 0.34 | 96.0 | 9.36 |
| | Soil loss saved | Tons $ha^{-1}$ $year^{-1}$ | 72 | 1.1 | 0.9 | 1.0 | 0.1 | 2.0 | 47.21 |

Reddy (2000) reviewed 22 impact assessment studies conducted across the country from 1967 to 1997. It is evident from his review that the impact of watershed development projects over the years shows positive impacts on crop yields, cropping intensity and cropping pattern changes. Also, there are significant variations in the magnitude of the impact across regions and crops. The magnitude of the impact is also dependent on the nature of activities undertaken in the watershed. It is found that all the studies have shown that net incomes have increased significantly have favourable BCR. These studies reveal that the BCR is stable at 1.75, implying positive impacts produced by the watershed development programmes in the country.

Many other studies were employed before and after approaches to assess the impact of watershed development activities (Palanisami and Suresh Kumar, 2006).

These studies focused the impact of various watershed treatment activities on various impact domains like soil and moisture conservation, water resources development, impact of cropping pattern and yield, and over all economic impacts. These studies found that there is significant impact on soil and water erosion control, soil moisture conservation, water resources development, cropping pattern, and increase in yield. The watershed development has also produced desired results in terms of improvement in socio-economic conditions, and the environment.

Experiences of most of the impact assessment studies report that watershed development interventions have produced desired positive impacts. But the magnitude of these impacts found to vary across regions, impact domains, etc.

The impacts of various watershed development activities are discussed under different domains with various indicators. The watershed development activities are expected to influence various bio-physical aspects such as soil fertility, expansion in cropped area, cropping intensity and productivity of crops; socio-economic aspects like employment, food security, income of the households, migration, and peoples participation; economic aspects such as over all impacts on the rural economy; environmental aspects like water table in the wells, irrigated area, soil loss, runoff and water pollution, etc; expansion in production of high-value agricultural commodities; and non-farm ancillary activities. These impacts on different domains are discussed hereunder.

## 5.2. Bio-physical Impacts

The watershed development activities have significant positive impacts on various bio-physical aspects such as investment on soil and water conservation measures, soil fertility status, soil and water erosion, expansion in cropped area, changes in cropping pattern, cropping intensity, production and productivity of crops.

As one expects the watershed treatment activities have produced significant changes in the bio-physical aspects of the watershed. These include improved conservation of soil and moisture, improvement and maintenance of fertility status of the soil (Sikka et al., 2000; Sastry et al., 2002; Ramasamy and Palanisami, 2002; Palanisami and Suresh Kumar, 2002; AFC, 2001), reduced soil and water erosion. The organic carbon increased by 37 per cent due to watershed intervention (Sikka et al., 2000) and most studies revealed that there is significant reduction in soil and water erosion. Significant reduction in soil and water erosion (77.78 per cent reduction) is observed by Wakjira (2003).

Impact and evaluation study of soil conservation scheme under DPAP indicates that only marginal impacts were realised in terms of land use pattern, crop pattern, yield rate, etc., (Evaluation and Applied Research Department, 1981). Evidences show that soil conservation appears to have had positive impact on retention of moisture, reduced soil erosion, change in land use pattern and crop yield. Soil loss reduced from 18758 kg $ha^{-1}$ to 6764 kg $ha^{-1}$ from 1988 to 1989. Between 1985-86 and 1989-90 the yield rate of all the crops had increased an annual compound growth rate (CGR) of 3.94% to 16.40% (Evaluation and Applied Research Department, 1991).

Improvement in soil fertility coupled with increased water resources in the watershed area led to expansion in cropped area, cropping intensity, increase in production and productivity of crops. Most of the studies found that there is significant increase in cropped area and it ranged from 6.84 per cent (Sreedharan, 2002) to 52 per cent (Sastry et al., 2002). The increase in cropped area further helped in increase in production and productivity. The productivity enhancement due to watershed development is a common phenomenon in most of the watersheds. The increase in yield of crops ranged from 5 per cent (Shobarani, 2001) in Karnataka to 91.11 per cent (Wakjira, 2003).

The cropping pattern changes have taken place both in additional area brought under well irrigation from the fallow lands and in area under rain-fed cultivation. The area under high water-consuming crops increased by 25.3% in first crop, and 29.4% in second crop period (Evaluation and Applied Research Department. 1990). Similarly,

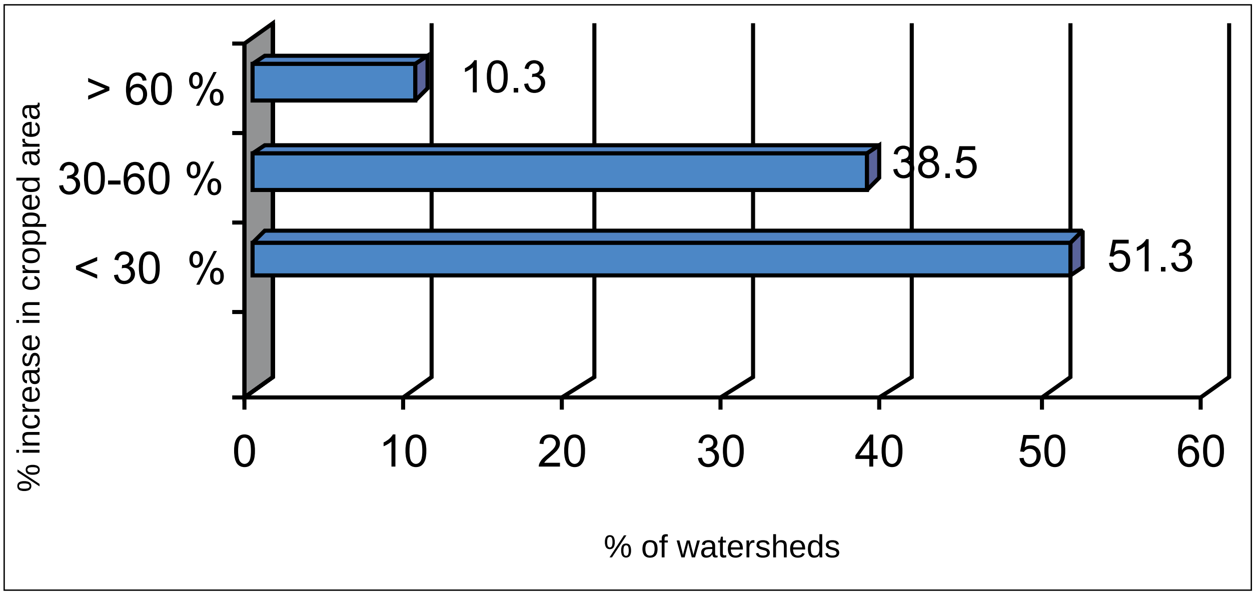


*Fig.4. Percentage of watersheds by increase in cropped area.*

the evidence shows that the cropping intensity is increased from 120 per cent to 146.88 per cent in Kattampatti watershed and 102.14 per cent to 112.08 per cent in Kodangipalayam watershed (Palanisami and Suresh Kumar, 2004). Increase in Crop Productivity Index, Fertilizer Application Index, and Crop Diversification Index was also observed (Sikka et al., 2000 and 2001).

It is lucid from the analysis that though there are differences in impacts, the watershed development activities have made significant positive impacts on the bio-physical aspects, leading to increased soil fertility, cropping pattern changes, corp production and productivity.

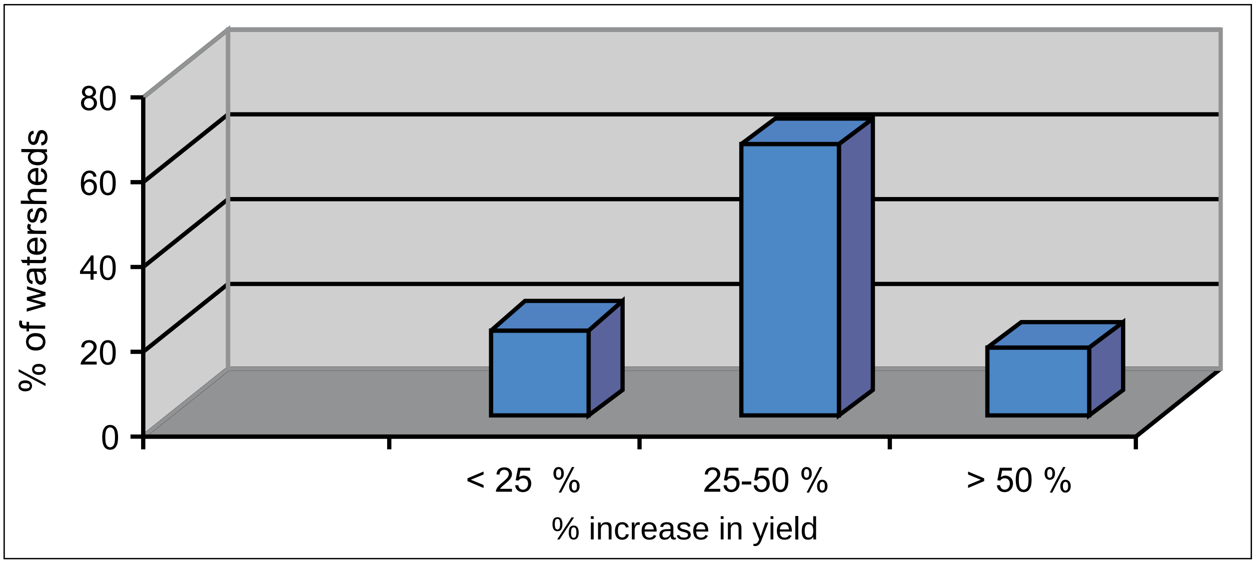


*Fig. 5. Percentage of watersheds by increase in yield.*

## 5.3. Socio-economic Impacts

The watershed development technologies aimed not only to conserve the natural resources but also improving the socio-economic conditions of the rural people who depend upon for their livelihood. The impacts of various watershed treatments are however varying. The changes in various bio-physical, environmental aspects will have significant impacts on the socio-economic conditions of the people. Watershed development programs are designed to influence the bio-physical aspects, the environmental aspects and thereby bringing changes in socio-economic conditions (Deshpande and Rajasekaran, 1997).

The socio-economic indicators like changes in household income, changes in per capita income, consumption expenditure, differences in employment, changes in persons migrated, people's participation, changes in household assets and changes in wage rate at village level were considered for the impact assessment.

The watershed intervention helped the rural farm and non-farm households to enhance their income level. Evidences show that the rural labour households in the treated villages derived Rs. 28732 when compared to Rs. 22320 in control village, which is 28.73 per cent higher in Kattampatti watershed. Similarly, the per capita income was also relatively higher among households of watershed treated villages. The percentage difference among households across villages worked out to 13.17 per cent in Kattampatti and 70.44 per cent in Kodangipalayam watershed (Palanisami and Suresh Kumar, 2004).

Increase in per capita income and household income helps the rural households to enhance their asset position. The asset position of the households increased significantly and it varied from 13 per cent (Agricultural Finance Corporation, 2001) to 50 per cent. The increased income helps the households to ensure quality foods and achieve nutritional security in many cases.

Any development program is expected to generate adequate employment to the local people. Casual employment was created during the implementation of works such as bunding, leveling, construction of check dams, percolation ponds, summer ploughing, crop demonstration, retaining wall, plantation, etc. Also the watershed development programs have significant bearing on reduction in out migration. As sufficient employment opportunities are created due to watershed intervention by expansion in cropped area and so on, the landless rural labour households and other marginal and small farmers get adequate employment for their livelihood.

This in turn helps reduction in out migration. Evidences show that the out migration has been reduced by 20-50 per cent in many watersheds (Sastry et al., 2002). In some watersheds the reduction is noticed upto a higher level of 43 per cent (Ramakrishna, et.al., 2006).

Like all other development programs, watershed development program is banking heavily on participatory approach. Though, watershed development program envisages an integrated and comprehensive plan of action for the rural areas, people's participation at all levels of its implementation is very important. This is so because the watershed management approach requires that every piece of land located in watershed be treated with appropriate soil and water conservation measures and used according to its physical capability. For this to happen, it is necessary that every farmer having land in the watershed accepts and implements the recommended watershed development plan. As the issue of sustainable natural resource management becomes more and more crucial, it has also become clear that sustainability is closely linked to the participation of the communities who are living in close association with these natural resources. This requires sustained effort in two important areas: (i) to inform and educate the rural community, demonstrate to them the benefits of watershed development and that the project can be planned and implemented by the rural community with expert help from government and non-government sources and (ii) to critically analyse the various institutional and policy aspects of watershed development programs in relation to participatory watershed management.

Experiences from evaluation study of 15 Drought Prone Area Programme (DPAP) watersheds conducted in Coimbatore district of Tamil Nadu, India, show that the overall community participation was found to be as 42 per cent. The participation was found to be 55, 44 and 27 per cent, respectively at planning, implementation and maintenance stages. This suggests community participation in watershed development program yet to reach more.  Similarly, overall contribution for works on private land was found to be 14.71 per cent. It varied from a low of 7 per cent for fodder plots to a maximum of 22 per cent for horticulture and farm pond. However, contribution in terms of cash/or kind towards development of structures at common lands such as percolation ponds, check dams, etc., was found to be nil. Level of adoption of various soil and moisture conservation measures and their maintenance indicate that there is a wide variation in level of adoption, with a low of 2.4 per cent in farm pond, 30.40 per cent in summer ploughing, 36.80 per cent in land leveling, 44 per cent in contour bunding. Follow up by farmers is also found to be poor in most of the technologies and it accounts for 5.23 per cent in farm ponds, 21.58 per cent for contour bunding, etc., (Sikka et al., 2000).

The Water Technology Centre, Tamil Nadu Agricultural University, carried out mid-term evaluation of 18 watersheds under Integrated Wasteland Development Programme (IWDP) in Pongalur block of Coimbatore district, Tamil Nadu. The results reveal that peoples' participation index at planning stage was 52.69 per cent, followed by implementation stage (39.28 per cent). This shows low peoples' participation at both the stages of the project (Palanisami et al., 2002). In several watersheds, the structures are not maintained due to lack of funds as well as lack of co-ordination among beneficiaries. Also because of the local (*panchayat*) elections, many of the presidents of the watershed associations have not been re-elected, resulting in lack of co-ordination particularly during the post-project management. There is a decline in interest in watershed structures during the post-implementation phase and this can be attributed to (i) failure or collapse of the new institutions set up to manage watersheds; and (ii) lack of clear norms on how to operate Watershed Development Funds (Suresh Kumar 2007).

Thus ensuring peoples' participation in different stage of watershed implementation and management is crucial, which would help achieving the objectives of watershed development in a sustained manner.

## 5.4. Environmental Impacts

The watershed development activities generate significant positive externalities, which have bearing on the improving agricultural production, productivity, socio-economic status of the people who are directly or indirectly depending upon the watershed for their livelihood. The environmental indicators include water level in the wells, changes in irrigated area, duration of water availability, water table of wells, surface water storage capacity, differences in number of wells, number of wells recharged /defunct, differences in irrigation intensity and watershed eco index (WEI).

The impact assessment studies conducted by different agencies and scientists across regions over a period of time imply that watershed development activities generated significant positive impacts in the environment. One of the important objectives of watershed development is in-situ water and soil conservation and water resources development in the watershed village, the treatment activities helped in conservation and enhancement of water resources. Most of the studies report that water levels in the wells increased, leading to expansion in irrigated area in the watershed. Though many studies have not measured the actual water level increase in the wells a few studies made an attempt to measure the increase in water levels in the wells. The increase in water levels in the wells is varied from 0.1 meter to 3.5 meters and this varied across seasons. Similarly, the expansion in irrigated area due to watershed development activities is varied from 5.6 per cent to 68 per cent across regions and seasons. Experiences show that the increase in water level in the wells is observed to be less than 2 meters (57.22 per cent of watersheds). About 30.48 per cent of watersheds witnessed an increase of 2-5 meters and only 12.3 per cent of watersheds have an increase of more than 5 meters in water level in the wells.

Watershed development activities produced significant positive impact on water table, perenniality of water in the wells and pumping hours that resulted in an increased irrigated area and crop diversification (Sikka et al., 2000 and 2001). Madhu et al., 2004 found that the conservation and water harvesting measures in the watershed

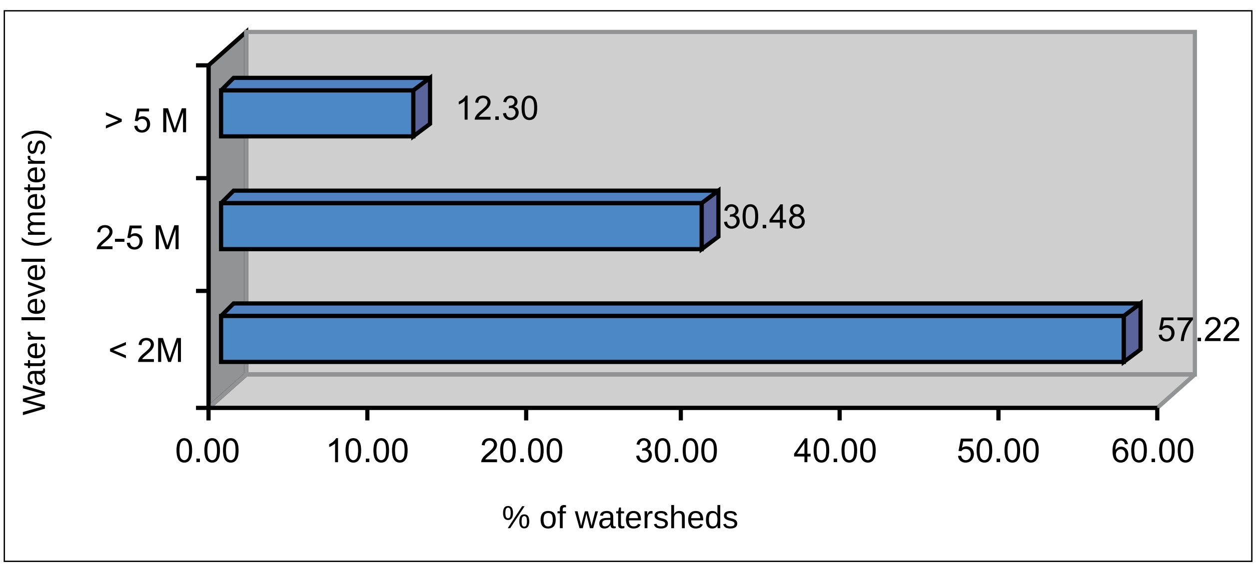


*Fig. 6. Percentage of watersheds by water levels in the wells.*

helped in improving the groundwater recharge, water availability for cattle and other domestic uses, increased perenniality of water in the streams, rise in water table in the wells, sediment trapping behind the conservation measures/structures and stabilization of gully bed. The productivity of crops increased from 6.65% to 16.59% in the watershed village.

Planting trees in private farm lands and common lands is being undertaken as part of the watershed development. This created additional green cover and thus improving the environment. The watershed eco index, which reflects the addition green cover created, varied from 1.8 per cent to 43 per cent (Sikka et al., 2000 and 2001; Palanisami and Suresh Kumar, 2004; Palanisami and Suresh Kumar, 2002; Ramaswamy and Palanisami, 2002; Ramakrishna et al., 2006).

Thus it is lucid from the analysis that watershed development activities generates sufficient positive externalities and have significant impacts on the environment.

## 5.5. Overall Economic Impacts

Experiences show that watershed development activities have over all positive impacts on the village economy. Thus, it is essential to assess the impact of these watershed development activities using key indicators such as NPV, BCR and IRR. Though these indicators show the over all impact of watershed development activities, only very few studies have quantified the benefits and arrived at the NPV, BCR and IRR. The reason for this is attributed to many: (i) most of the evaluating agencies are not familiar with these techniques, (ii) inadequate data availability for quantifying benefits and costs, and (iii) non-familiarity with computer softwares. The overall impact of watershed development activities in terms of NPV, BCR and IRR are reviewed and discussed hereunder.

A few studies (Palanisami and Suresh Kumar, 2004; Palanisami, et al., 2002; Ramaswamy and K. Palanisami, 2002; Palanisami, et.al, 2006; Palanisami and Suresh Kumar, 2006; Lokesh, et.al, 2006; Logesh, 2004; Milkesha Wakjira, 2003) made an attempt to assess the over all impact of watershed development activities through BCR and NPV. The benefit cost ratio, which shows the return per rupee of investment, is ranged from 1.27 to 3.7. The size of BCR also depends on the magnitude of benefits accrued due to the watershed development activities which in turn critically depend up on the rainfall. The watersheds in the region that have an annual rainfall of 700–900 mm of rainfall have high BCR. Similarly, the watersheds that receive rainfall less than 700 mm and

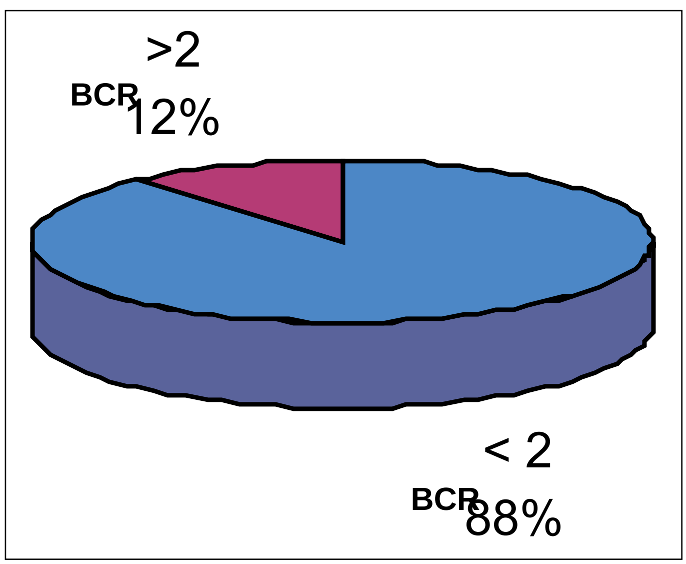


*Fig.7. Distribution (%) of watersheds by BCR category.*

700-900 mm have relatively higher IRR. The analysis also revealed that the BCR is worked out to more than 2 in around 12 per cent of watersheds. About 88 per cent of watersheds have BCR less than 2. Similarly, about 41.67 per cent of watersheds exhibit 41.67 per cent of IRR, 54.17 per cent of watersheds have IRR between 15 and 30 per cent and only 4.17 per cent of watersheds have IRR more than 30 per cent.

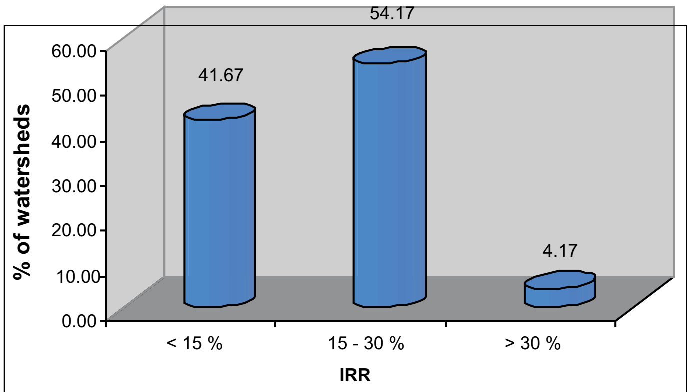

Fig. 8. Distribution (%) of watersheds by IRR category.

It is evident that the BCR varies across regions and depends upon the agro-climatic conditions such as rainfall and other topographic features. The financial analysis of impact of watershed development indicates that the BCR varied from 1.43 to 1.51, implying that the returns to public investment such as watershed development activities are feasible. Similarly, the IRR is worked out to 26 per cent and 24 per cent, respectively for Kattampatti and Kodangipalayam watersheds, which is higher than the long-term loan interest rate by commercial banks, indicating the worthiness of the government investment on watershed development (Palanisami and Suresh Kumar, 2004). The studies proved that the watershed development activities have high benefit-cost ratio of 3.5 (Lokesh, et.al, 2006) and fairly a high internal rate of return of 38 % (Ramaswamy and Palanisami, 2002).

The other indicators viz., net returns per rupee of irrigation cost is also a viable indicator, show the over all impact of watershed development activities. The net returns per rupee of irrigation cost are worked out to 1.4 to 16.32. This also varies across type of watersheds and seasons. The watershed development activities have increased the net returns per rupee of irrigation cost. The net returns have increased from 6.52 to 16.32 after the implementation of watershed development activities. Similarly, the watershed development has differential impacts and varied across size groups. It is also found that the net return per acre inch of groundwater increased by 3% and 30%, respectively for small and large farmers after WDP implementation. Water use and net returns per acre of gross irrigated area for farmers in the upstream increased by 68% and 66%, respectively and in down stream by 48% and 110%, respectively (Mengesha, 2000).

The NPV indicates that the watershed development activities produced desired results as evident from positive NPV. The net present value of the benefits derived from various watershed treatment activities is worked out to Rs.12.36 lakh (Milkesha Wakjira, 2003). As these indicators — NPV (positive), BCR (greater than one) and IRR — are greater than the opportunity cost of capital, one can conclude that the watershed development activities are financially feasible and economically viable.

## 6. Incorporation of Rainfall Risk in Watershed Impact Evaluation

Rainfall pattern is one of the important factors that influence the benefits due to watershed interventions. Normally, the water bodies such as check dams and percolation ponds get the inflows due to intensity of rainfall in the upstream regions or the catchments. The level of water storage in the structures influences the water level in the wells, which in turn influence the area irrigated in the farms. Since intra and inter year variation in rainfall is common, it is important to incorporate the impact of rainfall variability in the estimation of benefits due to watershed programs.

In what follows is the estimation of rainfall distribution using Gamma distribution using the rainfall data for Coimbatore district. Using the estimated co-efficients, the probability of occurrence of different rainfall amount will be estimated.

### 6.1. Rainfall Analysis by Gamma Distribution

The probability distribution of rainfall during south-west monsoon (SWM) covering June-September months, north-east monsoon (NEM) covering October-December months and summer periods covering January – May months and for the entire year was analysed using the gamma distribution:

$$f(x)=\frac{\lambda^k x^{k-1} e^{-\lambda x}}{\Gamma(k)}, \lambda, k>0$$

where *k* and λ are the parameters of the distribution that are estimated from the observed rainfall data from 1970-71 to 2000-01 using MATLAB, $\Gamma(k)$ is the gamma function. The mean rainfall and its standard deviation are estimated by the formula

$$\text{mean}=\frac{k}{\lambda}$$

$$\text{Standard Deviation}=\sqrt{\frac{k}{\lambda^2}}$$

The quantity of rainfall, say $x_á$ for which $Pr\{\text{Rainfall} \geq x_á\}= á$ is obtained from the equation

$$\int_0^{x_á} f(x)dx = 1-á$$

The values of $x_á$ for various values of $á$ are obtained using the MATLAB. The estimated quantities are given in Table 11 which gives the estimated parameters of the gamma distribution. The co-efficient of variation in rainfall (CV) indicates a higher variability in north-east monsoon season followed by south-west monsoon. The annual rainfall variability is about 26%.

**Table 11. Parameters of the Gamma distribution, mean rainfall (mm) and standard deviation**

| Season | λ | k | Mean | Standard deviation | CV (%) |
|---|---|---|---|---|---|
| SWM | 0.0336 | 6.3859 | 189.97 | 75.17 | 39.57 |
| NEM | 0.0154 | 5.0287 | 325.80 | 145.29 | 44.59 |
| Summer | 0.0589 | 8.7104 | 147.92 | 50.12 | 33.88 |
| Year | 0.0226 | 14.963 | 663.69 | 171.55 | 25.85 |

SWM=south-west monsoon from June –September months; NEM=north-east monsoon period from October – December months; Summer = January-May months. CV= co-efficient of variation.
λ and *k* are the parameters of the gamma distribution

The variability in rainfall is one of the main reasons for abandonment of the rain-fed agriculture by the farmers, which ultimately resulted in the intensification garden land agriculture where wells are the primary source of irrigation. Using the field experience in terms of rainfall amount and the storages in the water bodies (Palanisami, et al., 2006), the annual rainfall amount and the classification of the year are defined as below:

>901 mm Year of surplus rainfall
601-900 mm Year of normal rainfall
401-600 mm Year of below normal rainfall
201-400 mm Year of deficit rainfall
< 200 mm Year of failure rainfall

Using the λ and k, the probability distribution of the different rainfall amounts was worked out.

Px} X < 200 = 0
Px} 201 < X < 400 = 0.0437
Px} 401 < X < 600 = 0.3431
Px} 601 < X < 900 =0.5224
Px} X > 901 =0.0908

## 6.2. Results of the Analysis

Using simulation in excel, random numbers were generated for 15 years to estimate the watershed benefits. Then the classification of the 15 years based on the above classification was done. The watershed costs were then worked out using the watershed records and the benefits were calculated based on the crop area benefited. The gross income was calculated taking into account the yield, price of the produce and the cultivation costs from the watershed activities (both irrigated and rain-fed situation) in different rainfall years. Also the zone of influence of the recharge structures to benefit the wells in different locations of the watershed was considered using the results of the recharge studies done in the region (Palanisami et al., 2006). The worked out BC ratio when rainfall variability is incorporated is 1.36 and IRR is 15% (Table 12).

| Table 12. Financial evaluation of watershed investments with rainfall pattern over years | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Year** | **Rainfall year** | **Costs (Rs)** | **Benefits (Rs)** | **Cash flows (Rs)** | **Discount factor (@10%)** | **Discounted benefits (Rs)** | **Discounted costs (Rs)** |
| 1 | N | 392506 | 0 | -392506 | 0.9091 | 0 | 356824 |
| 2 | N | 392506 | 0 | -392506 | 0.8264 | 0 | 324385 |
| 3 | N | 392506 | 0 | -392506 | 0.7513 | 0 | 294896 |
| 4 | N | 392506 | 0 | -392506 | 0.6830 | 0 | 268087 |
| 5 | BN | 392506 | 0 | -392506 | 0.6209 | 0 | 243715 |
| 6 | BN | 0 | 234550 | 234550 | 0.5645 | 132397 | 0 |
| 7 | N | 0 | 700557 | 700557 | 0.5132 | 359497 | 0 |
| 8 | N | 0 | 700557 | 700557 | 0.4665 | 326815 | 0 |
| 9 | BN | 0 | 234550 | 234550 | 0.4241 | 99472 | 0 |
| 10 | BN | 0 | 234550 | 234550 | 0.3855 | 90429 | 0 |
| 11 | N | 0 | 700557 | 700557 | 0.3505 | 245541 | 0 |
| 12 | N | 0 | 700557 | 700557 | 0.3186 | 223219 | 0 |
| 13 | N | 0 | 700557 | 700557 | 0.2897 | 202926 | 0 |
| 14 | N | 0 | 700557 | 700557 | 0.2633 | 184479 | 0 |
| 15 | N | 0 | 700557 | 700557 | 0.2394 | 167708 | 0 |

N=normal rainfall year; BN=below normal rainfall year.

The results indicate that the financial measures (BCR and IRR) are less when the rainfall variation is incorporated in the watershed impact evaluation compared to the situation when rainfall variation is not incorporated (Table 13).

| Table 13. Comparison of financial measures with and without rainfall variation | | | |
|---|---|---|---|
| **Details** | **NPV (Rs )** | **BCR** | **IRR (%)** |
| Without rainfall variation | 1184923 | 1.79 | 20 |
| With rainfall variation | 544576 | 1.36 | 15 |

## References

**Agricultural Finance Corporation Ltd**. 2001. (KKE Namboodiri, CP Srikumar and GB Pillai). Report on Evaluation study of the Scheme of Soil Conservation in the Catchment of River Valley Projects and Flood Prone Rivers, Kundah Catchment, Kerala.

**Baker Judy L**. 2000. Evaluating the Impacts of Development Projects on Poverty. The World Bank, Washington, DC, USA

**Daves Thomas E**. 1974. Economics of Small Watershed Planning in Minnesota. Technical Bulletin 295, Agricultural Experiment Station, University of Minnesota.

**Department of Land Resources**. 2006. *Report of the Technical Committee on Watershed Programmes in India, From Hariyali to Neeranchal,* Department of Land Resources. Ministry of Rural Development, Government of India.

**Deshpande RS** and **Rajasekaran N**. 1997. Impact of Watershed Development Programme: Experiences and Issues, Artha Vijnana 34 (3):374-390.

**Evaluation** and **Applied Research Department**. 1981. An Evaluation report on Soil Conservation Scheme under the DPAP in Ramanathapuram district, Tamil Nadu.

**Evaluation** and **Applied Research Department**. 1991. Report on the Evaluation of Soil Conservation works executed in Sholur Micro Watersheds in Niligris district under HADP, Evaluation and Applied Research Department, Chennai.

**Hans Gregerson** and **Arnoldo Contreras**. 1992. Economic Assessment of Forestry Project Impacts. Rome: FAO Forestry Paper No.106.

**Hanumantha Rao CH**. 2000. Watershed Development in India:Recent Experiences and Emerging Issues, Economic and Political Weekly, 35 (45):3943-3947.

**Independent Evaluation Group**. 2008. The Welfare Impact of Rural Electrification: A Reassessment of the Costs and Benefits, An IEG Impact Evaluation, The World Bank, Washington, D.C.

**Joshi PK, Jha AK, Wani SP, Joshi Laxmi** and **Shiyani RL**. 2005. Meta-analysis to assess impact of watershed program and people's participation. Comprehensive Assessment Research Report 8. Colombo, Sri Lanka: Comprehensive Assessment Secretariat.

**Joshi PK, Jha AK, Wani SP, Sreedevi TK** and **Shaheen FA**. 2008. Impact of Watershed Program and Conditions for Success: A Meta-Analysis Approach. Global Theme on Agroecosystems Report no. 46, Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 24 pp.

**Joshi PK, Jha AK, Wani SP** and **Sreedevi TK**. 2009. Scaling-out Community Watershed Management for Multiple Benefits in Rainfed Areas. *In*: Rain-fed agriculture: Unlocking the Potential. (SP Wani, John Rockstrom and Theib Oweis, eds.). Comprehensive Assessment of Water Management in Agriculture Series, CAB International, Wallingford, UK. PP. 258-275.

**Kerr John** and **Sanghi NK**. 1992. Indigenous Soil and Water Conservation in India's Semi-Arid Tropics, Sustainable Agriculture Programme, Gate Keeper Series Paper No.34, London: Intenational Institute for Environment and Development.

**Kerr John, Pangare Ganesh, Pangare VL** and **George PJ**. 2000. An Evaluation of Dryland Watershed Development Projects in India, EPTD Discussion Paper No.68, International Food Policy Research Institute, Washington, DC.

**Libardo Rivas R, García James A Seré, Carlos Lovell S Jarvis, Sanint Luis R** and **Pachico Douglas**. 1999. Manual on Economic Surplus Analysis Model (MODEXC). International Centre for Tropical Agriculture, Colombia.

**Logesh GB**. 2004. Economic impact assessment of watershed development programmes: A study of Kallambella watershed, Karnataka. *Ph.D. Thesis,* Unpublished, University of Agricultural Sciences, Bangalore.

**Lokesh GB, Chandrakanth MG** and **Chinnappa Reddy BV**. 2006. Total Economic Valuation of Watershed Development Programme. *In*: K. Palanisami and D. Suresh Kumar. (Ed.), Impact Assessment of Watershed Development – Issues, Methods and Experiences. Associated Publishing Company, New Delhi. PP. 251-267.

**Madhu M Subhash Chand, Sundarambal P** and **Sikka AK**. 2004. Report on Impact Evaluation of DPAP Watersheds in Coimbatore district (IV Batch), Central Soil and Water Conservation Research and Training Institute, Research Centre, Uthagamandalam, Tamil Nadu.

**Maredia, Mywish, Byerlee, Derek, Anderson,** and **Jock**. 2000. Ex-post evaluation of economic impacts of agricultural research programs: A tour of good practice. Paper presented at the Workshop on *The Future of Impact Assessment in CGIAR: Needs, Constraints and Options*, Standing Panel on Impact Assessment (SPIA) of the Technical Advisory Committee, Rome, 3-5, May.

**Mengesha BA**. 2000. Access to water resource for irrigation: Economics of Watershed Development in a drought prone Area of Karnataka. *M. Sc. (Agri.) thesis*, Unpublished, University of Agricultural Sciences, Bangalore.

**Milkesha Wakjira**. 2003. Economic analysis of watershed Development Study of Rajanakunte Micro-watershed. Karnataka. *Ph.D. thesis,* Unpublished, University of Agricultural Sciences, Bangalore.

**Mohr, Lawrence B**. 2000. Impact Analysis for Programme Evaluation 2nd Edition Thousand Oaks Calif: Sage Publications cited in Baker Judy L, Evaluating the Impacts of Development Projects on Poverty, The World Bank, Washington, DC, USA.

**Mohr Lawrence B**. 2000. Impact Analysis for Programme Evaluation 2nd Edition Thousand Oaks Calif: Sage Publications cited in Baker Judy L, Evaluating the Impacts of Development Projects on Poverty, The World Bank, Washington, DC.

**Moore, Michael R, Gollehon Noel R** and **Hellerstein Daniel M**. 2000. Estimating producer's surplus with the censored regression model: An application to producers affected by Columbia River Basin Salmon Recovery, *Journal of Agricultural and Resource Economics,* 25(2):325-346.

**Pachico D, Lynam JK** and **Jones PG**. 1987. The distribution of benefits from technical change among classes of consumers and producers: An ex-ante analysis of beans in Brazil. Research Policy, 16:279-285.

**Palanisami K.** 1997. Financial Analysis in Agricultural Project Planning, In National Short-term Training on Irrigation in Agriculture: Planning and Budgeting (K Palanisami, C Paulraj and A Mohamed Ali, eds.) 16-17, July, Tamil Nadu Agricultural University, Coimbatore.

**Palanisami K. Suresh Kumar D** and **Chandrasekaran B**. 2002. Watershed Management:Issues and Policies for 21st Century, Associated Publishing Company Ltd., New Delhi.

**Palanisami K** and **Suresh Kumar D**. 2002. Participatory Watershed Development Programs: Institutional and Policy Issues, Paper presented in the Workshop on Rain-fed Agriculture in Asia: Targeting Research for Development, 2-4, December 2002, ICRISAT, Patancheru, India

**Palanisami K, Devarajan S, Chellamuthu M** and **Suresh Kumar D**. 2002. Mid-term evaluation of IWDP Watersheds in Coimbatore district of Tamil Nadu, Tamil Nadu Agricultural University, Coimbatore.

**Palanisami K, Suresh Kumar D** and **Gnanamurthy P**. 2003. Watershed Development: Outreach Research Activities, Tamil Nadu Agricultural University, Coimbatore.

**Palanisami K, Suresh Kumar D** and **Balaji P**. 2003. Evaluation of Watershed Development Projects:Approaches and Experiences, Tamil Nadu Agricultural University, Coimbatore.

**Palanisami K** and **Suresh Kumar D**. 2006, Challenges in impact assessment of watershed development. *In*:*Impact Assessment of Watershed Development: Methodological Issues and Experiences* (K Palanisami and D Suresh Kumar, eds.) Associated Publishing Company Ltd., New Delhi.

**Palanisami K** and **Suresh Kumar D**. 2004. Participatory Watershed Development: Institutional and Policy Issues, Indian Journal of Agricultural Economics, 59(3):376.

**Palanisami K, Ravi Raj, Ian Gale S, Thirumurthi D, Macdonald, Gurunathan S, Calow RC, Dhanalakshmi G, Shanthi R** and **Newmann I**. 2006. Augmenting Groundwater Resources by Artificial Recharge – A case study of Kodangipalayam village in Coimbatore district, Tamil Nadu, TNAU - BGS, UK Project Report, Tamil Nadu Agricultural University, Coimbatore.

**Palanisami K** and **Suresh Kumar D**. 2007. Watershed development and augmentation of groundwater resources: Evidence from Southern India, Paper presented at *Third International Groundwater Conference*, February 7-10, Tamil Nadu Agricultural University, Coimbatore, India.

**Pathak P, Sahrawat KL, Rego TJ,** and **Wani SP**. 2005. Measurable biophysical indicators for impact assessment: changes in soil quality. *In*: Shiferaw, B., Freeman, H.A., Swinton, S., (eds.), Natural Resource Management in Agriculture: Methods for Assessing Economic and Environmental Impacts. CABI Publishing, Wallingford, Oxfordshire, UK. PP. 53-74.

**Rao CH**. 2000. Watershed development in India: Recent experiences and emerging issues, *Economic and Political Weekly*, 35 (45):3943-3947.

**Ramakishna YS, Reddy YVR and Reddy BMK**. 2006. Impact Assessment of Watershed Development Programme in India. *In*: Impact Assessment of Watershed Development – Issues, Methods and Experiences (Palanisami K and Suresh Kumar D, eds.), Associated Publishing Company, New Delhi. pp. 223-238.

**Ramaswamy K** and **Palanisami K**. 2002. Some Impact Indicators and Experiences of Watershed Development in Drought Prone Areas of Tamil Nadu. *In*: K. Palanisami et.al., (ed.), Watershed Management – Issues and Policies for 21$^{st}$ Century, Associated Publishing Company, New Delhi. pp. 182-191.

**Ratna Reddy V**. 2000. Sustainable Watershed Development : Institutional Approach, Economic and Political Weekly. pp. 3435-3444.

**Ravindra A**. 2000. Evaluation Framework for Community Based Natural Resource Management.

**Sastry G, Reddy YVR** and **Singh HP**. 2002. Appropriate Policy and Institutional Arrangements for Efficient Management of Rain-fed Watersheds in 21$^{st}$ Century. In K. Palanisami et.al., (ed.), Watershed Management – Issues and Policies for 21$^{st}$ Century. Associated Publishing Company, New Delhi, pp. 228-234.

**Shiferaw, Freeman HA** and **Swinton S** (eds.). 2004. Natural Resource Management in Agriculture: Methods for Assessing Economic and Environmental Impacts. CABI Publishing

**Shiklomanov, I**. 2000. Appraisal and assessment of world water resources. *Water International* 25(1):11-32.

**Shobha Rani S**. 2001, Economics of Groundwater Recharge in Huthur watershed in Southern Dry zone of Karnataka, *M.Sc. thesis,* Unpublished, University of Agricultural Sciences, Bangalore

**Sikka AK, Narayanasamy N, Pandian BJ, Selvi V, Subhash Chand** and **Ayyapalam**. 2001. Report on Participatory Impact Evaluation of Comprehensive Watershed Development Project, Tirunelveli, Central Soil and Water Conservation Research and Training Institute, Research Centre, Uthagamandalam, Tamil Nadu.

**Sikka AK, Subhash Chand, Madhu M** and **Samra JS**. 2000. Report on Evaluation Study of DPAP Watersheds in Coimbatore district, Tamil Nadu.

**Sikka AK, Subhash Chand** and **Samra JS.** 1999. Need and Measures for Monitoring and Evaluating Impacts of Watershed Programmes, Workshop on Watershed Development under IWDP Proceedings, (S Vijyakumar, AK Sikka and K Subbian, eds.) District Rural Development Agency, Coimbatore. pp.119-124.

**Sreedharan CK**. 2002. Joint Forest Management and Watershed Development Programme in Tamil Nadu: An Experience in TAP. *In:* (K Palanisami et.al., eds.), Watershed Management – Issues and Policies for 21st Century, India: Associated Publishing Company, New Delhi. pp. 265-274.

**Suresh Kumar D**. 2007. Can Participatory Watershed Management be Sustained? Evidence from Southern India, SANDEE Working Paper No 22-07, (Nepal : South Asian Network for Development and Environmental Economics).

**Swinton SM**. 2002. Integrating sustainability indicators into the economic surplus approach for NRM impact assessment. *In:* Methods for Assessing the Impacts of Natural Resources Management Research. A summary of the proceedings of the ICRISAT-NCAP/ICAR International Workshop, (B Shiferaw, HA Freeman, eds.), ICRISAT, Patancheru, India, 6-7 December.

**Wander, Alcido Elenor, Magalhaes, Marilia Castelo. Vedovoto, Graciela Luzia.** and **Martins, Espedito Cezario**. 2004. Using the economic surplus method to assess economic impacts of new technologies — Case studies of EMBRAPA, *Rural Poverty Reduction through Research for Development* Conference on International Agricultural Research for Development, Deutscher Tropentag, 5-7,October, Berlin.

**Wani SP, Pathak P, Tam HM, Ramakrishna A, Singh P** and **Sreeedevi TK**. 2002. Integrated Watershed Management for Minimizing Land Degradation and Sustaining Productivity in Asia. *In:* Integrated Land Management in Dry Areas. Proceedings of a Joint UNU-CAS International Workshop (Zafar Adeel, ed.), 8-13 September 2001, Beijing, China. pp. 207-230.

**Wani SP, Sreedevi TK, Ramakrishna YS, Piara Singh** and **Pathak P**. 2006. Improved Livelihoods in Watersheds through Consortium Approach: Reflections and Learnings. Presentation appeared in Proceedings of National Workshop on development: Future Challenges held on 10 February 2006 at New Delhi. pp. 33-66

**Wani SP, Joshi PK, Raju KV, Sreedevi TK, Wilson JM, Shah Amita, Diwakar PG, Palanisami K, Marimuthu S, Jha AK, Ramakrishna YS, Meenakshi Sundaram SS** and **D'Souza Marcella**. 2008. *Community watershed as a growth engine for development of dryland areas. A Comprehensive assessment of watershed programs in India*. Global Theme on Agroecosystems Report no. 47, International Crops Research Institute for the Semi-Arid Tropics, Patancheru, 36 pp.

**Wani SP, John Rockstrom** and **Theib Oweis** (Eds). 2009. Rain-fed agriculture: Unlocking the Potential. Comprehensive Assessment of Water Management in Agriculture Series, CAB International, Wallingford, UK. pp. 1-325.

**Wiggins** and **Shield.** 1995. Clarifying the Logical Framework as a Tool for Planning and Managing Development Projects. Project Appraisal, 10 (1).

# APPENDIX-I

## Computer Based Model for Watershed Evaluation

A computer-based model called “WADIAM” was developed for watershed impact evaluation and used for the analysis of impact assessment of watershed development activities. A brief description of the model is presented.

**About the model**

A computer based model called WADIAM (Watershed Development Impact Assessment Model) which can be used for evaluation of watershed development activities using either with or with out/before and after approaches.

WADIAM, is a interactive model designed and developed for watershed impact assessment. The model permits the assessment of various indicators on three major aspects of impact viz, agricultural production, socio-economic and over all impact of various watershed treatment activities. The impact on agricultural production includes the impacts such as groundwater development, expansion in area irrigated, cropping pattern, agricultural productivity. The socio-economic aspects consists of impact on income, migration, etc. Over all impact captures the impact on environment through watershed eco-index and financial/economic analysis like net present value (NPV), benefit-cost ratio (BCR) and internal rate of return (IRR). Enough provision has been made for reporting the results.

**Features of the model**

The model runs with menus. The important menus and their components are listed here:

**FILE**

EXIT

**INDICATORS**

- AGRICULTURAL PRODUCTION
    - WATER RESOURCES DEVELOPMENT
    - SOIL AND MOISTURE CONSERVATION
    - CROPPING PATTERN
    - CROPPING INTENSITY
- SOICO-ECONOMIC INDICATORS
    - INCOME
- OVER ALL IMPACT
    - ECO-INDEX
    - ECONOMIC INDICATORS

**REPORTING**

**HELP**

ABOUT WADIAM

FOR ASSISTANCE

For running the model see the manual on “WADIAM : Users Guide”.


*Figure. 1. About the WADIAM.*

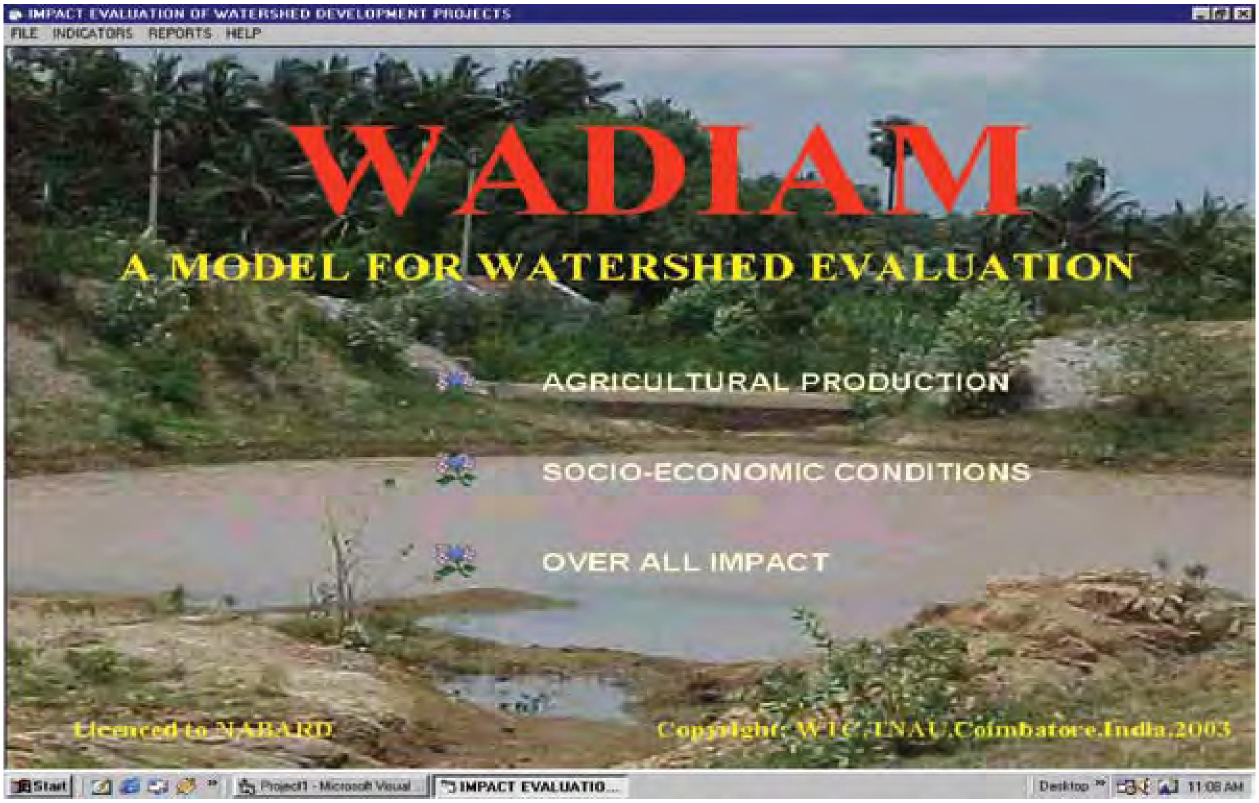


Figure. 2. Main menu.

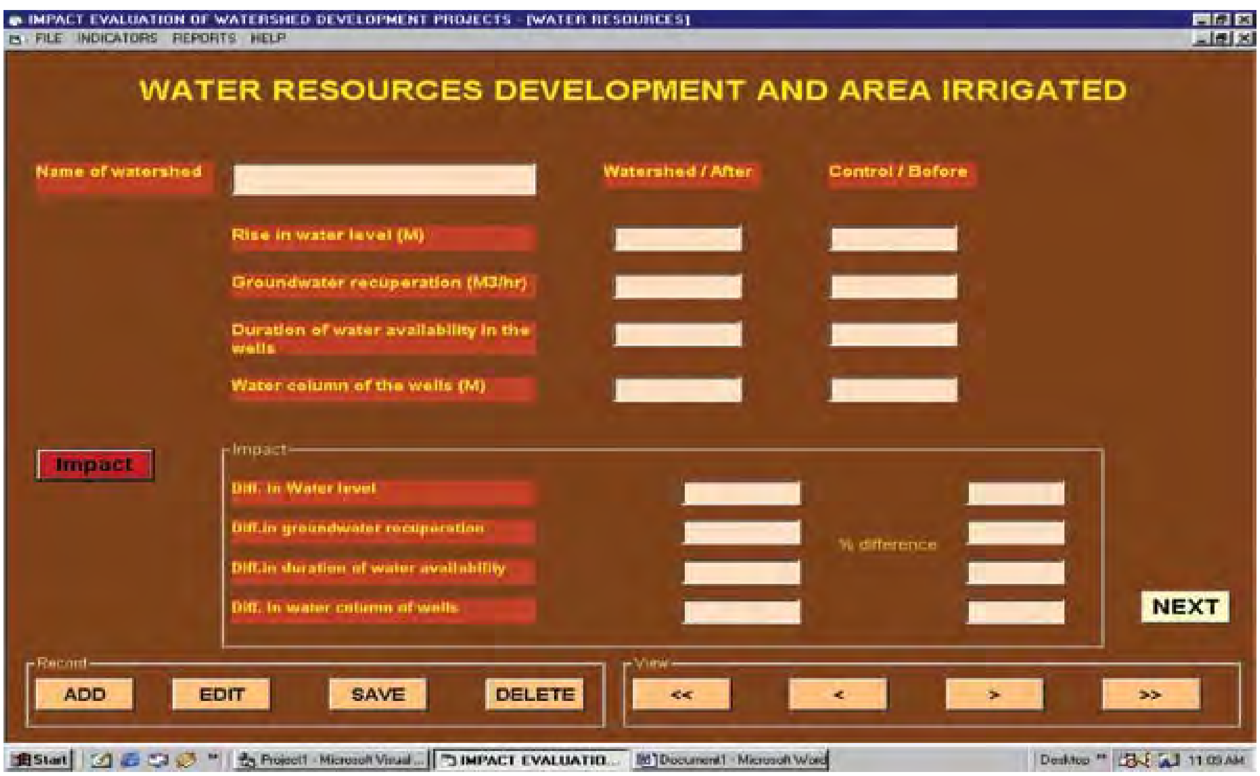


Figure. 3. Water resources development and area irrigated.

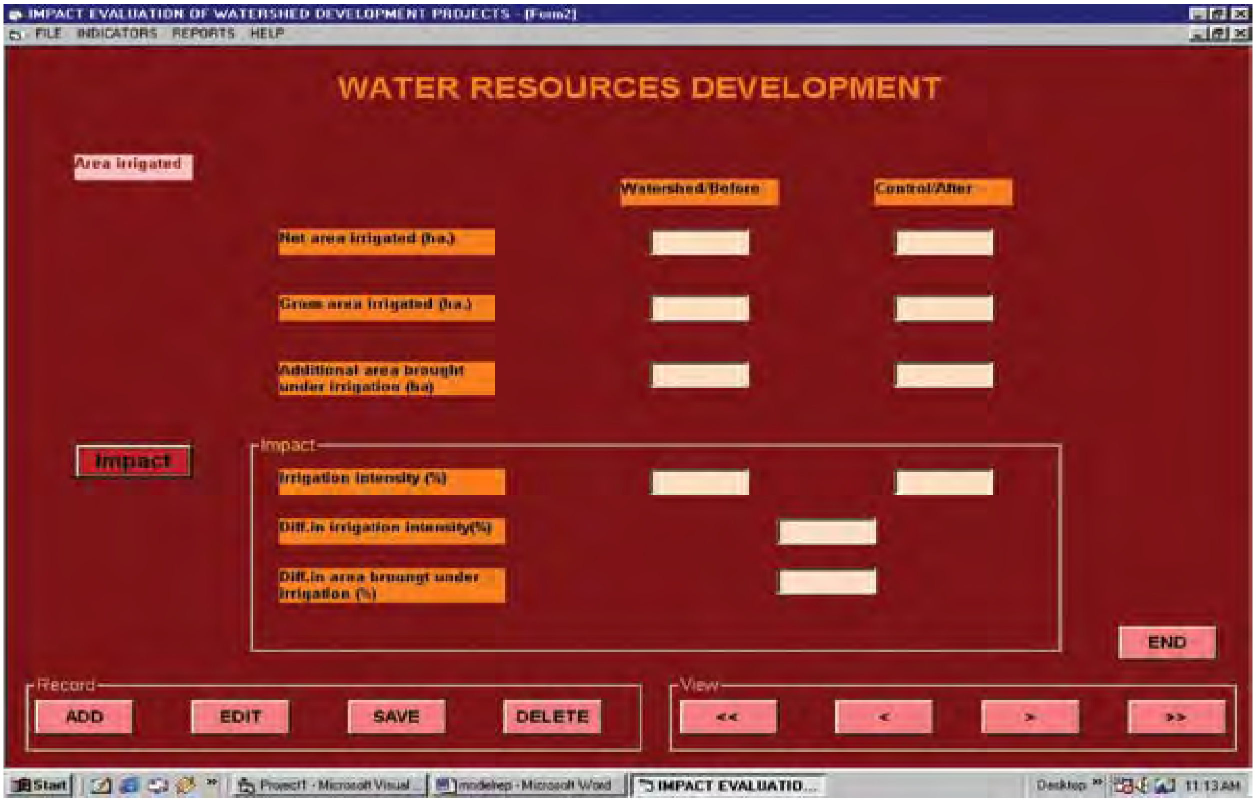


Figure. 4. Water resources development.

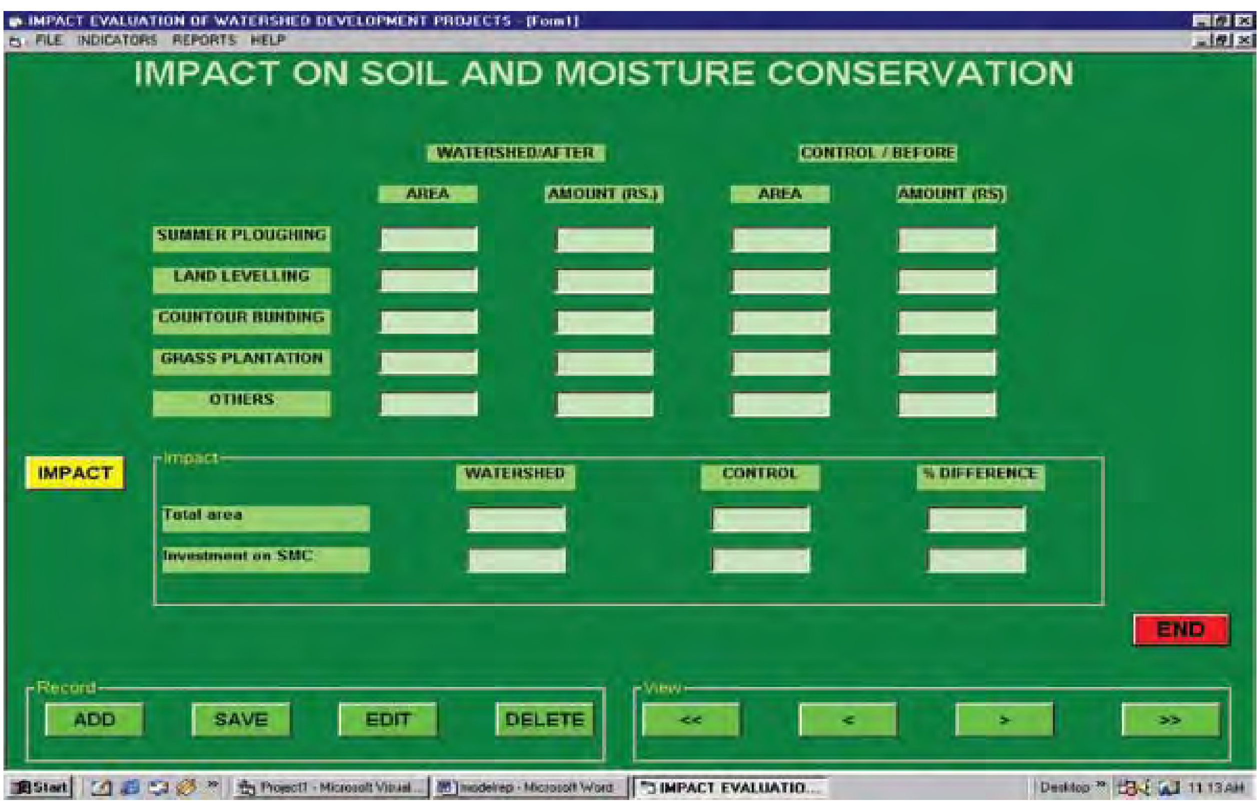


Figure. 5. Impact on soil and moisture coservation.

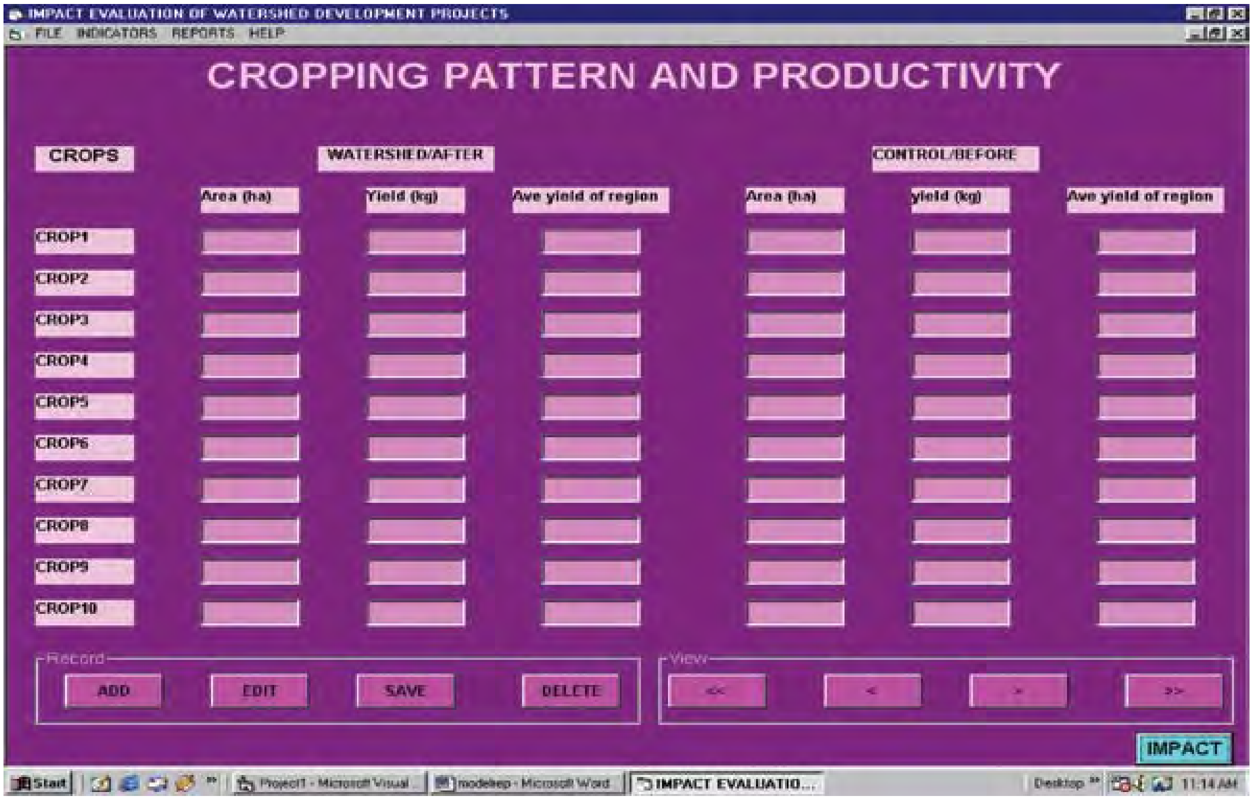


Figure. 6. Impact on cropping pattern and productivity.

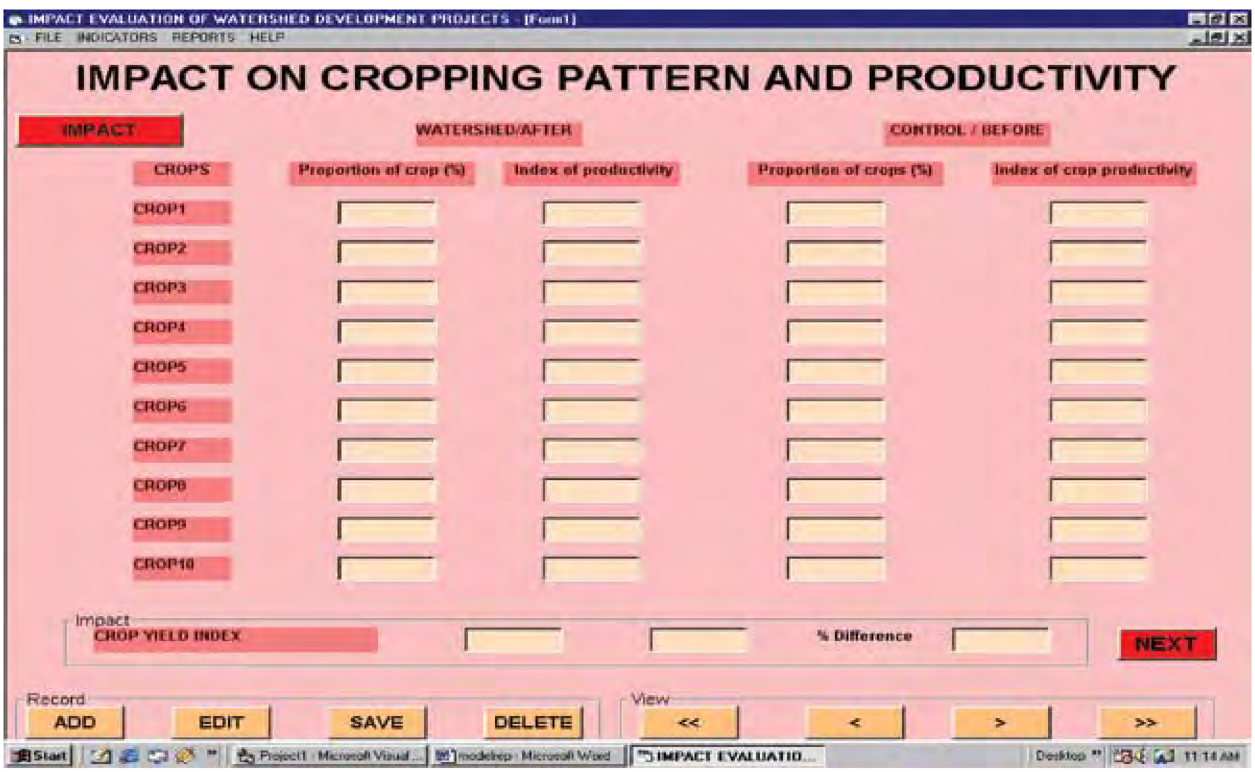


Figure. 7. Impact on cropping pattern and productivity.

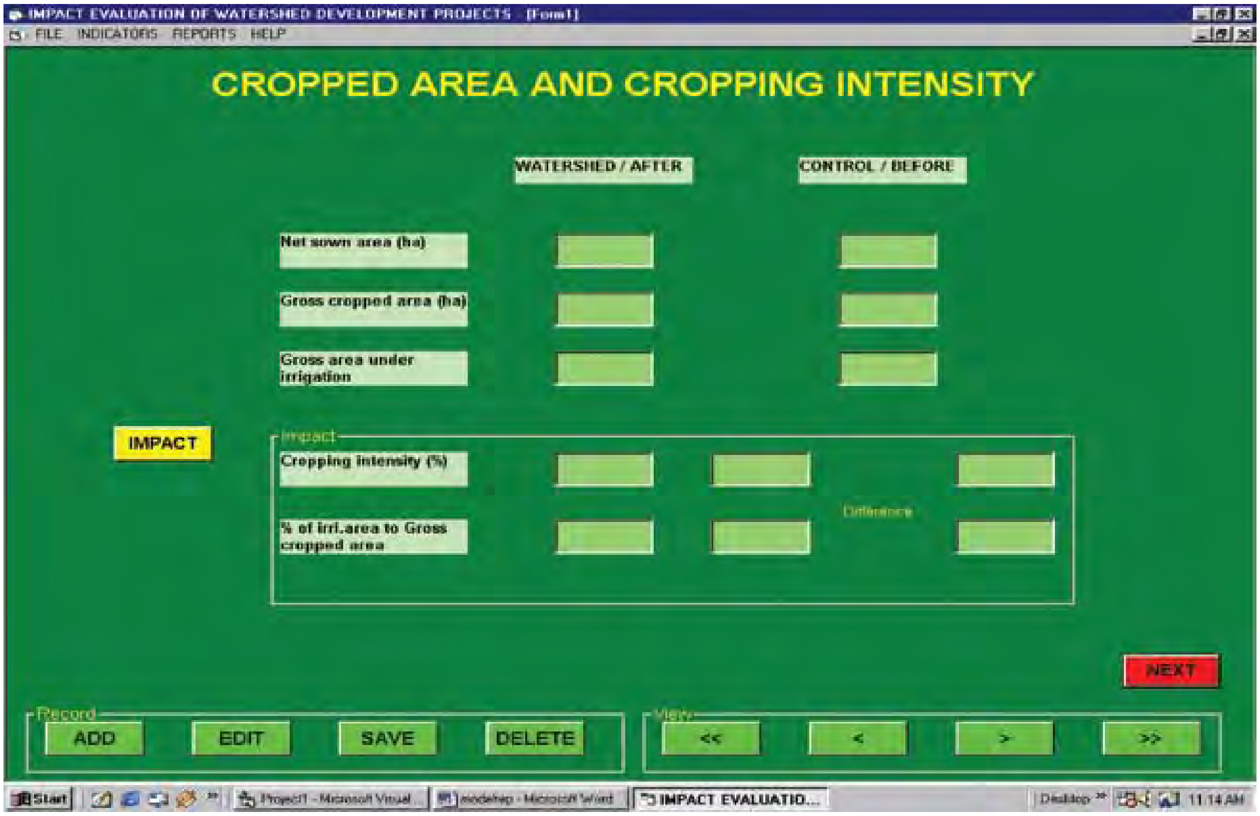


*Figure. 8. Impact on cropped area and cropping intensity.*

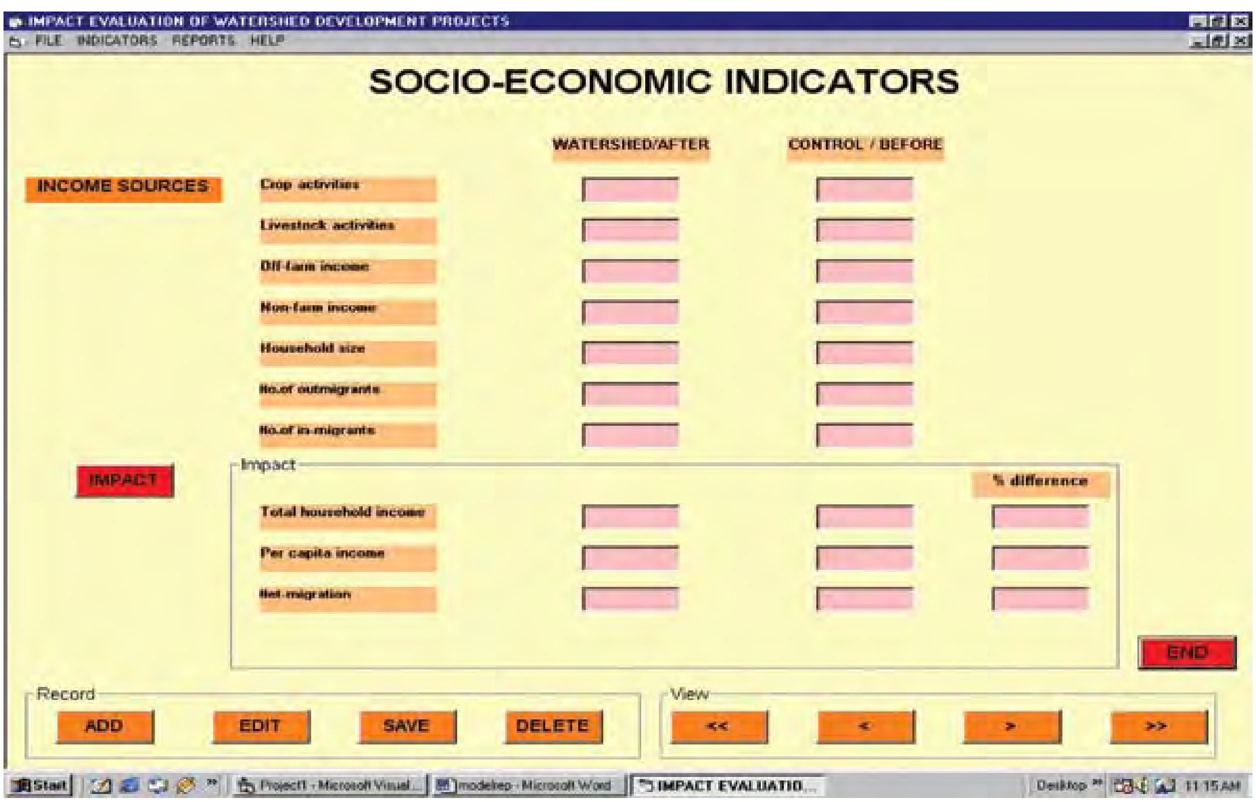


*Figure. 9. Impact on socio-economic conditions.*

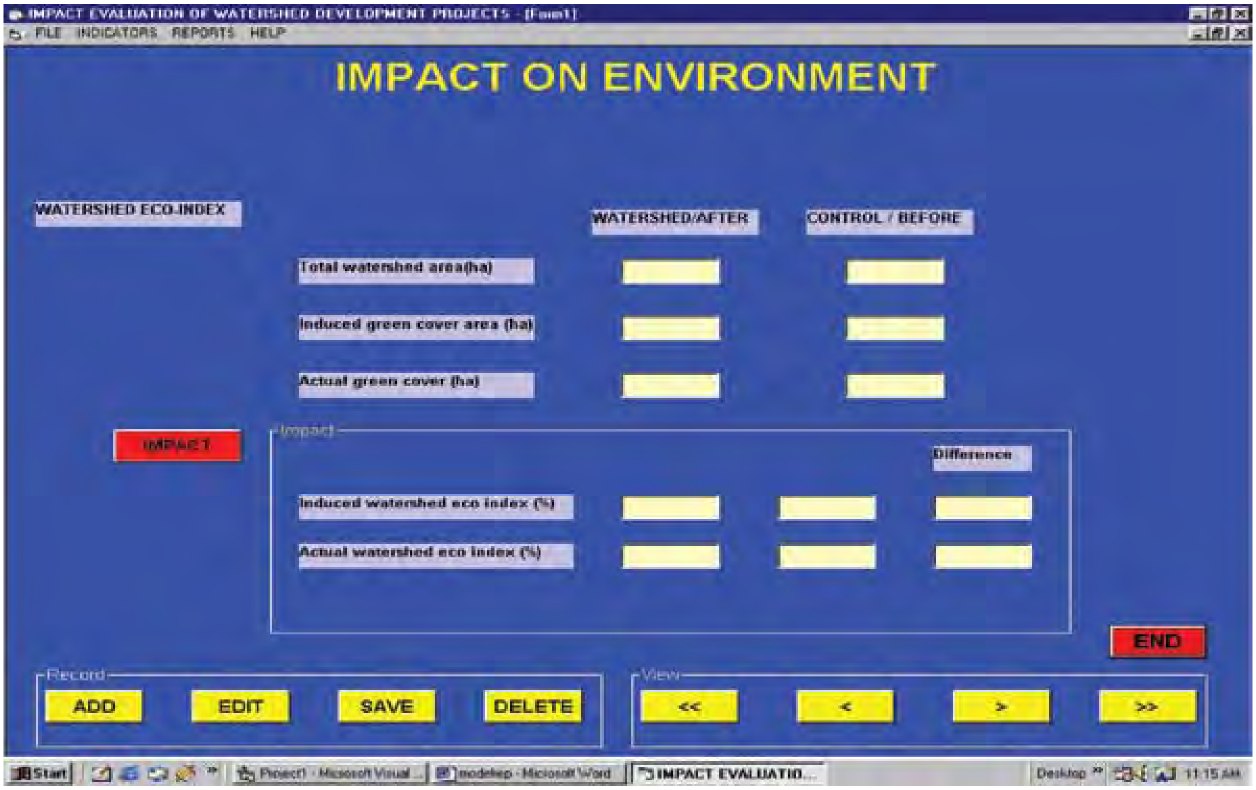


*Figure. 10. Impact on environment.*

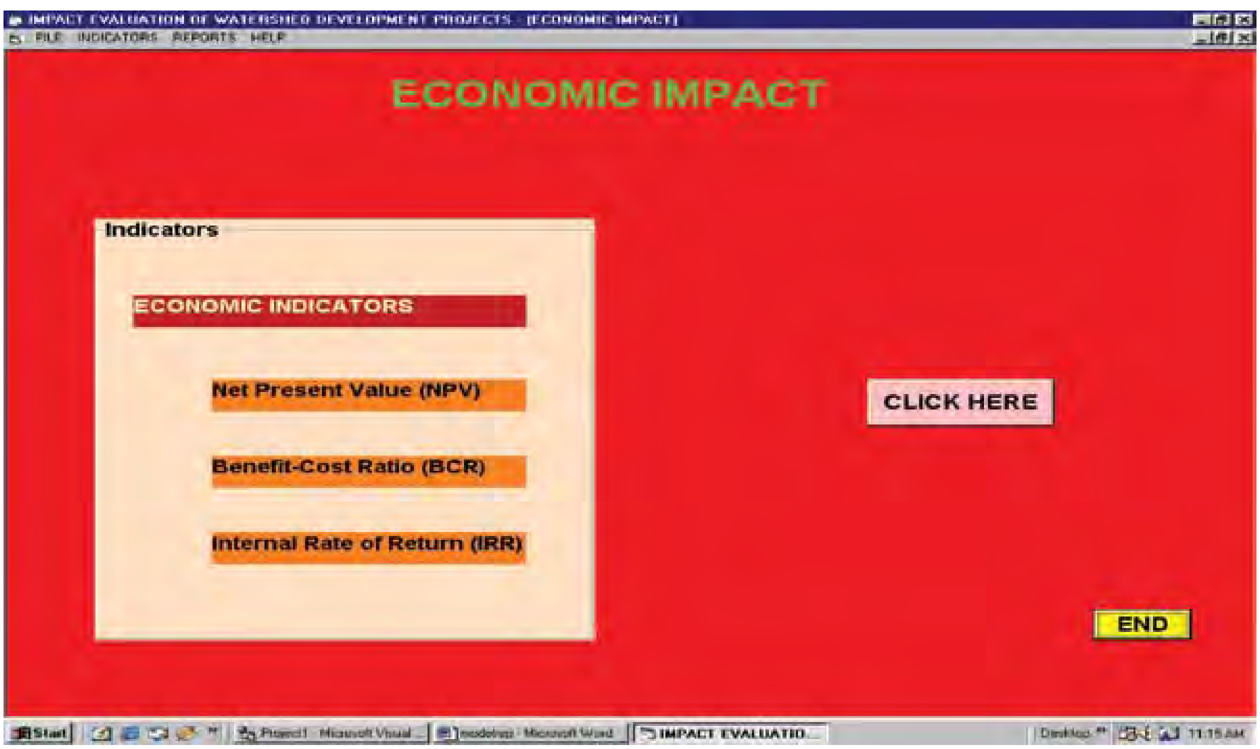


*Figure. 11. Economic impacts.*

# About ICRISAT

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is a non-profit, non-political organization that does innovative agricultural research and capacity building for sustainable development with a wide array of partners across the globe. ICRISAT's mission is to help empower 600 million poor people to overcome hunger, poverty and a degraded environment in the dry tropics through better agriculture. ICRISAT is supported by the Consultative Group on International Agricultural Research (CGIAR).

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