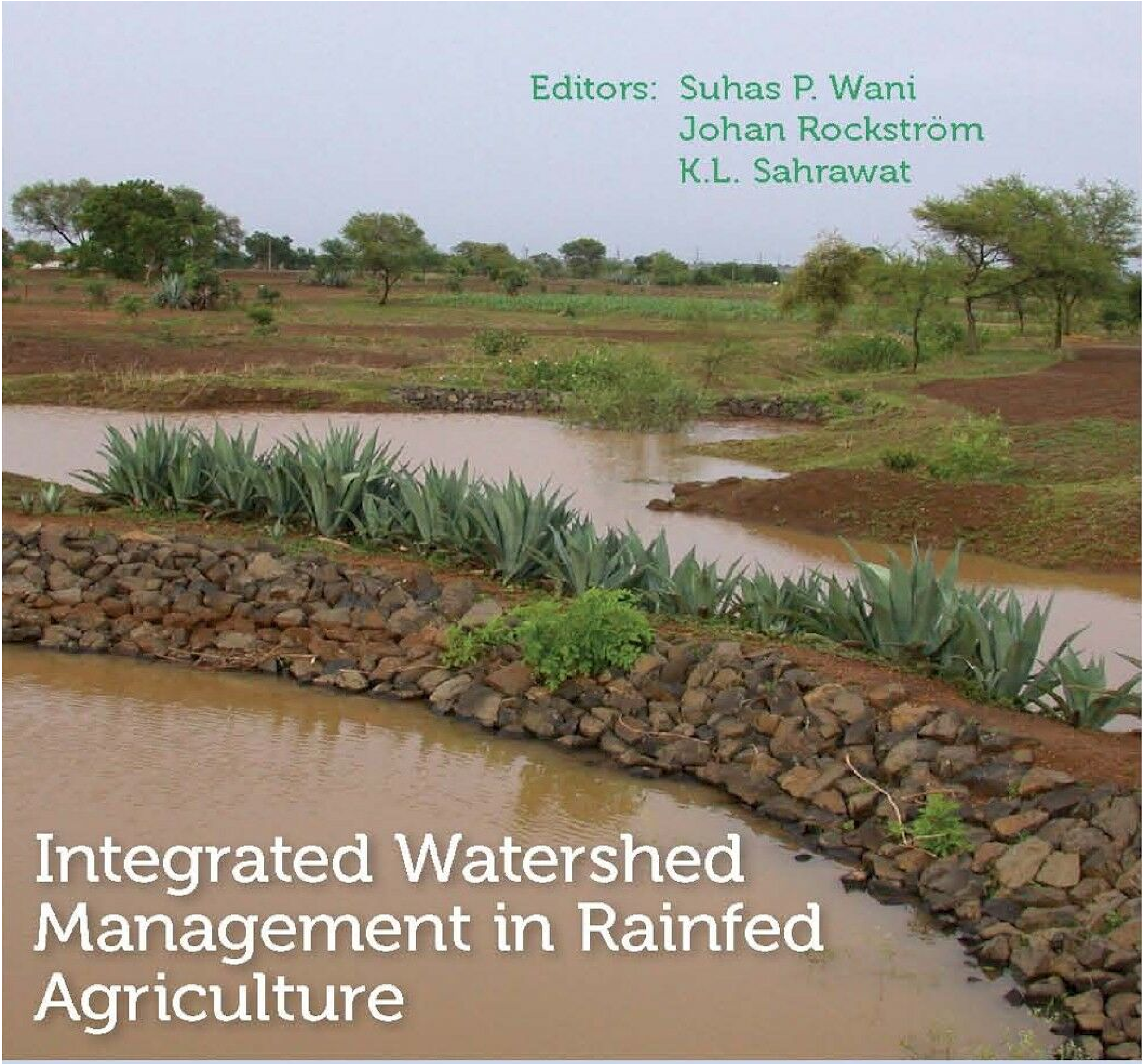
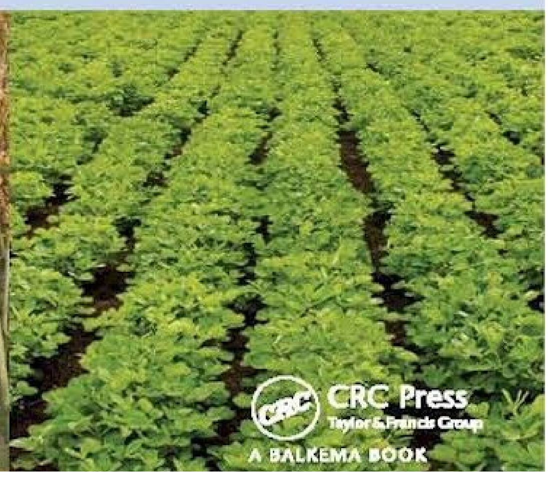
Editors: Suhas P. Wani
Johan Rockström
K.L. Sahrawat



Integrated Watershed Management in Rainfed Agriculture





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Chapter 11

Impact of watershed projects in India: Application of various approaches and methods

K. Palanisami, Bekele Shiferaw, P.K. Joshi, S. Nedumaran, and Suhas P. Wani

11.1 INTRODUCTION

Governments in developing countries like India actively pursue various forms of policy instruments like the implementation of development programs to achieve desired economic growth. The objective of such development programs is to transform a set of resources into desired results for upscaling. This is particularly so for the policies designed to alleviate rural poverty and foster economic growth in the agricultural sector of developing economies. For achieving these goals, understanding the nature, objectives, and scope of the development program and the responsiveness of target groups is imperative for all those engaged in developmental work including staff and policy makers. This applies to watershed program staff engaged in the development and implementation of technologies for enhancing food, fodder, and fuel productivity and ensure livelihood security for those below the poverty line. Thus, a systematic feedback from the project areas and beneficiaries is of crucial importance. Evaluation and monitoring studies provide the needed information for upscaling the interventions by implementing agencies. The objective of this chapter is to discuss in detail various methodologies employed in evaluating the performances of the watershed development programs in India. Given the significance of the watershed programs in meeting the challenges especially in rainfed agriculture, it is important to see how the issues facing the watershed evaluation could be addressed through the review of the different evaluation criteria and methods that have been field tested already. This chapter aims to derive the messages from the past studies focusing on the measurement methodologies in watershed evaluation. The chapter is organized into four sections. Section 1 deals with the introduction and an overview of the watershed development programs in India, section 2 outlines the various approaches used in watershed evaluation, section 3 applies the various methodologies with examples from the fields, and section 4 gives the conclusions and policy recommendations.

11.1.1 An overview of watershed development programs in India

The concept and history of watershed development in India started way back in 1880 with the Famine Commission and then in the Royal Commission of Agriculture in 1928. Both Commissions laid the foundation for organized research in a watershed framework. Small-scale watershed development programs to conserve soil and water and prevent land degradation began during the early twentieth century, e.g., Lingajat

Peetadhipathi, near Bijapur in Karnataka. The activities included construction of bunds in the then Bombay Provinces for rural employment during drought relief operations. In this sequence, Bombay Land Development Act, 1943, provided a model for other states enlightening watershed development. Realizing the importance of the watershed programs for land reclamation, a multidisciplinary Soil Conservation Department was set up at Hazaribagh under the Damodar Valley Corporation. Then the Government of India supported program started in the mid-1950s and the focus on watershed programs was sharpened with the establishment of the Soil Conservation Research, Demonstration and Training Center at eight locations, namely Dehradun, Chandigarh, Agra, Valsad, Kota, Hyderabad, Bellary, and Ootacamund, which in turn established as Central Soil and Water Conservation Research and Training Institute (CSWCRTI) by linking all the eight centers in 1956. The center started watershed activities in 42 locations mainly at a small scale to understand the technical processes of soil degradation and options for soil conservation (for review see Joshi *et al.*, 2004).

The first large-scale government supported watershed program was launched in 1962–63 to monitor the siltation of the multipurpose reservoirs as "Soil Conservation Works in the Catchments of River Valley Projects (RVP)". This was followed by another mega-project, the Drought Prone Area Programme (DPAP) in 1972–73, which aimed at mitigating the impact of drought in vulnerable areas. On similar lines, the Desert Development Programme (DDP) was added for the development of desert areas and for drought management in the fragile, marginal, and rainfed areas. These schemes were implemented in 45 catchments spread over 20 states covering about 96.1 million ha area (Government of India 2001a).

Several programs were launched under the Operational Research Program (ORP) of CSWCRTI and Central Research Institute for Dryland Agriculture (CRIDA) and 41 model watersheds under the framework of the Integrated Watershed Development Program, which includes a system combining erosion and runoff, and improved land management (i.e., through vegetative cover, bunds, check-dams, and small percolation tanks) with irrigation wells for lifting groundwater on a sustainable basis so that the amount of water withdrawn is less than or equal to the annual recharge of groundwater. The system was an extension of the idea of water harvesting by which runoff water is collected in small ponds directly through gravity flows (Rajagopalan 1991). The program was organized as multidisciplinary and multi-agency and functionally participatory with the active involvement of farmers of the watershed. The key for the success of the integrated watershed development program was participatory planning and implementation by government agencies and non-government organizations (NGOs). The impact was documented in terms of increased crop productivity, increased employment, better crops and cropping systems, which ensure higher and regular cash flow, additional area under sustained irrigation and cropping, and reduced production risks (Joshi *et al.*, 2004).

The severe drought during 1987 forced the Government of India to give more thrust to agriculture in the rainfed areas. Hence, a committee was constituted to examine the effectiveness of watershed-based programs in the rainfed areas. The committee recommended that the watershed development programs in the rainfed areas should optimize the production of rainfed crops (like pulses, oilseeds, coarse cereals, cotton, etc.), which improve the livelihood of the poor farmers along with soil and water conservation. The recommendations of the committee led to the formation of National

Watershed Development Project for Rainfed Areas (NWDPRA) in 1990–91. Then the Ministry of Agriculture terminated all the earlier watershed programs during the VII Five Year Plan and started new programs to cover both arable and non-arable areas and give more thrust for area-based approach for watershed development under NWDPRA. During the VIII Five Year Plan, an area of 4.23 million ha covering 2554 watersheds in 350 districts located over 25 states and two union territories were treated and developed with an expenditure of ₹9679 million. In the IX Five Year Plan, an outlay was raised to ₹10200 million to treat 2.25 million ha, which was slightly more than half of the area treated in the VIII Five Year Plan (Joshi *et al.*, 2004).

All the government-sanctioned programs in the 1980s paid more focus on soil and water conservation and attention to poverty alleviation as they operated in relatively poor and degraded areas. Economic improvement in these agricultural-dependent areas required making the land more productive, so poverty alleviation benefits were implicit. The programs also employed very poor people to carry out watershed work. They all adopted the technological approaches used in the model watersheds and none of them incorporated lessons learnt regarding institutional arrangements (World Bank 1990; Government of India 1994a). In earlier programs, the benefits and costs of watershed were unevenly distributed among all the stakeholders and programs made little or no effort to organize communities in the watersheds to solve the problems collectively. In the earlier watershed programs where village-level participation was attempted, it typically involved one or two key persons, such as the village *sarpanch* (leader) in the ICAR (Indian Council of Agricultural Research) watersheds or a trained technician in the NWDPRA (Government of India 1990).

The impact of these watershed programs showed disappointing results associated with the top-down implementation and management, inflexible or lack of site specific technology, and lack of attention to institutional arrangements (Shah 2000). Some of these programs showed good technical and economic performance in the early years, especially while project staff were still in place and the work was heavily subsidized (IJAE 1991). The benefits were not sustained for long beyond the project period in many cases (World Bank 1990; Government of India 1994a; Farrington *et al.*, 1999; Reddy 2000).

In the late 1980s, many NGOs introduced watershed development activities along with their other activities, and were better able to target the poorest people's needs. MYRADA in Karnataka, the Aga Khan Rural Support Programme (AKRSP) in Gujarat, and Social Centre in Maharashtra, all provided excellent examples of such approaches (Farrington and Lobo 1997; Hinchcliffe *et al.*, 1999). These organizations devoted much attention to organizing politically and economically weaker groups to initiate self-help activities such as thrift and credit associations and build their organizational skills, which give confidence to demand better services from the government agencies. This approach was used in the NGO-implemented watersheds to encourage people participation and sharing net benefits from watershed development (Fernandez 1994).

In the 1990s several European bilateral agencies established major watershed initiatives. Generally, these projects aimed to promote collaboration between government and NGO projects to draw on the strengths of each and to make government agencies more sensitive to the institutional issues. Some of the projects, including Indo-German in Maharashtra and Indo-British in Karnataka, drew on some NGOs' approaches to promote benefit sharing, and they tried to implement on large scale the associated institutional approaches (Farrington and Lobo 1997; Nanan 1998). Nanan (1998), however, found that despite a common focus on poverty alleviation in projects sponsored by the European Union, Danida, and the German Development Bank, benefits tended to favor landowners, whereas the landless benefited only marginally.

All these programs had their own guidelines, norms, funding patterns, and technical components based on their respective and specific aims (Government of India 1994b). In 1994 the Ministry of Rural Development introduced new comprehensive guidelines for all its projects that bypassed the state-level bureaucracy, giving unprecedented autonomy to village-level organizations to choose their own watershed technology and obtain assistance from NGOs rather than government line departments (Government of India 1994a, 1994b). These guidelines were used by the centrally sponsored schemes for watershed development under the Ministry of Rural Development and the Ministry of Agriculture.

The 1994 guidelines were in operation for five years. The guidelines were revolutionary in the extent to which they devolved power, promoted indigenous technology, and created a role for NGOs. This period has seen many successes as well as some failures in watershed development. Shah (2001) reviewed the performance of projects under the new guidelines in Gujarat state and found that benefits were heavily skewed towards wealthier households. Hence greater flexibility of the guidelines was essential to enhance the robustness of the response to the regionally differentiated demands that characterize rural India. Since different ministries were involved in the watershed development, it was decided to develop common guidelines. The Ministries of Agriculture and Rural Development jointly developed the 'Common Approach/Principles of Watershed Development' in 2000 (Government of India 2000). The Ministry of Agriculture brought out the new guidelines based on the 'Common Approach' in 2000 for NWDPRA as Watershed Areas for Rainfed Agriculture System Approach (WARASA) or *Jan Sahbhagita*. The approach allows decentralization of procedures, flexibility in choice of technology, and provisions for active involvement of the watershed community in planning, execution, and evaluation of the program.

In 2001 the Ministry of Rural Development prepared a document of revised guidelines (Guidelines for Watershed Development) based on the common principles (Government of India 2001b). The new guidelines give more flexibility that was needed at village/watershed level. These guidelines, inter alia, envisage the convergence of different programs of the Ministry of Rural Development, Ministry of Agriculture, and other Ministries and Departments. Following the 73rd and 74th Amendments to the Constitutions of India in the early 1990s, the Panchayat Raj Institutions (PRIs) have been mandated with enlarged role in the implementation of developmental programs at the grassroots level, and accordingly their role has been more clearly brought out. The 1994 guidelines were made more flexible, and workable with greater participation of the community. The new guidelines lay greater emphasis on local capacity building through various training activities and empowering community organization.

To further simplify the procedures and involve the PRIs more meaningfully in the planning, implementation, and management of economic development activities in rural areas, the new guidelines called Guidelines for Hariyali were documented in 2003 by the Ministry of Rural Development (Government of India 2003). All the new projects under the area development programs have been implemented in accordance with the Guidelines for Hariyali with effect from 1 April 2003. This committee should oversee the implementation of watershed activities concerning drinking water security.

The Watershed Development Fund (WDF) was established by the National Bank for Agriculture and Rural Development (NABARD) during 1990–91, to integrate all the watershed programs in 100 priority districts in different states of the country. A total of ₹2000 million, which includes ₹1000 million by NABARD and a matching fund by the Ministry of Agriculture, was made available under the fund. The WDF was set up on the lines of the Rural Infrastructure Development Fund (RIDF) to help the state governments augment their watershed development programs (Sharma 2001). The main purpose of the fund was to create the framework conditions to replicate and consolidate the isolated successful initiatives under the different watershed development programs.

11.1.2 Synthesis of past experience of watershed development in India

To provide useful insights on the performance of numerous watershed development programs and to examine conditions for the success of the watershed programs across different geographical regions of India, a study was carried out by Joshi *et al.* (2005). The purpose of the study was to provide insights into the importance of economic, policy, and institutional issues and constraints and suggest options for the watershed management and also identify the areas of future research.

The study concluded that even though there are some visible gains from the various watershed development programs, the sustainability of the investments undertaken by the different agencies has not been ensured mainly because of insufficient participation of the local communities. The first generation watershed programs suffered from a top-down approach and technical focus on soil and water conservation without sufficient emphasis on livelihood benefits to the rural poor. Along with several socioeconomic studies, which documented the weaknesses of various watershed management approaches, experience has shown the difficulties of the top-down approach to natural resource management (NRM). This has led to the development of new policies and guidelines for a common approach to watershed management across the different implementing agencies in the country. These policies combine the technical strengths of the older programs along with the lessons learned about the role of community participation. Even after the new policies have been issued, the watershed development program suffers from second and third generation problems. The review of literature on the policy and institutional issues for watershed management and major lessons from the case studies examined in this study indicate the few critical areas that continue to affect the success of participatory community watershed management in the country. These are mainly related to profitability of the interventions, problems of collective action and active participation by the community, cost-sharing between individual farmers and the community/state, distribution of the gains from watershed management (equity), and negative externalities (e.g., upstream-downstream tradeoffs).

These challenges are made more complex by the lack of supportive policies and legislations that encourage cost-sharing and private and collective action in watershed programs. The landless households and marginalized groups are especially vulnerable to exclusion from accessing the benefits of the programs. The high subsidies provided for the program, including soil and water conservation investments on private lands, make it difficult to effectively assess the real farmer and community demand for the programs.

Further, it is essential to overcome the conflicting objectives and share benefits and cost evenly in the heterogeneous rural setting. Given the diversity of the rural social structure, different groups and individual farmers have different and often conflicting interests. The conflicting objectives are to be minimized by evolving appropriate policies and institutional arrangements. The case studies assessed in the synthesis study have clearly shown that the success in attaining the stated objectives is associated with an integrated approach where availability of profitable technologies for resource conservation and access to local markets encourage people's participation in the watershed programs. Depending on the focus given to this combination of technical support, social organization, and market access, the review of diverse development experiences indicates that most of the government-managed watershed programs performed poorly, while those managed by research institutions and some NGOs were quite successful. Lack of capacity in these important aspects is the principal reason for poor performance and failure of many watershed development programs. Careful integration of these components in the future policies and programs would help transform subsistence agriculture in rainfed areas while also protecting the vital resource base. Periodic monitoring and evaluation of the effectiveness and efficiency of the interventions and approaches as well as assessment of the multi-faceted impacts of the new generation of watershed programs implemented under the new guidelines would be useful to generate needed data and lessons for scaling-up successful approaches.

11.1.3 Need for economic impact assessment of watershed

The watershed development programs involve the entire community and natural resources and influence: (i) productivity and production of crops, changes in land use and cropping pattern, 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) socioeconomic conditions of the people such as income, employment, assets, health, education, and energy use; (iv) environment; (v) use of land, water, human, and livestock resources; (vi) development of institutions for implementation of watershed development activities; and (vii) sustainability of improvement. It is thus clear that watershed development is a key to sustainable production of food, fodder, fuel wood, and for meaningfully addressing the social, economical, and cultural conditions 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 development activities are not only limited to the users/beneficiaries, but also the non-participating farmers.

Experience shows that various watershed development programs brought significant positive impact. There has been a marked improvement in the access to drinking water due to groundwater recharges in the project area (Kerr *et al.*, 2000; Reddy *et al.*, 2001; Kakade *et al.*, 2001), increase in crop yields and substantial increase in the cropped area (Erappa 1998; Wani *et al.*, 2002), rise in employment and reduction in migration of labor (Deshpande and Ratna Reddy 1991; Kerr *et al.*, 2000).

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 development programs is community participation and decentralization of program administration. Experience from Maharashtra shows that the encouraging performance is attributable largely to the positive response from the people, especially in the tribal areas, owing to their traditions of community participation and to political and administrative will for decentralizing administration and strengthening of the PRIs (Hanumantha Rao 2000).

A program such as watershed development, which involves a hierarchy of administration and communities at the grassroots level in highly varying agroclimatic and socioeconomic conditions, invariably requires periodical assessment for achieving developmental objectives. Typically, an implementing agency would see a greater value in spending an extra few 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 improve the program benefits substantially, in some cases up to 100%. But even if we consider the improvement to be very modest, say, 10%, then a one per cent of program outlay on meaningful monitoring and evaluation would have a very high payoff in terms of achieving the program objectives. It is of utmost importance therefore, to put in place 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 development informs decisions on whether to expand, modify, or eliminate a particular policy, and can also be used in prioritizing public actions. In addition, impact evaluation contributes to improve the effectiveness of the policies and programs by addressing the questions such as:

- Does the program achieve the intended goal?
- Can the changes in outcomes be explained by the program, or are they the result of some other factors occurring simultaneously?
- Do program impacts vary across different groups of intended beneficiaries (males, females, and indigenous people), regions, and over time?
- Are there any unintended effects of the program, either positive or negative?
- How effective is the program in comparison with alternative interventions?
- Is the program worth the resources it costs?

11.1.4 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), temporal, and spatial. The dimensions of impact of watershed technologies further complicate the impact assessment.

The problem of impact assessment of watershed development project lies in 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 the 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.

11.1.4.1 Methods of impact assessment

Choosing appropriate methodology for impact assessment is essential. Different methodologies have been used in the evaluation literature, mainly qualitative and quantitative methods. The quantitative methods such as experimental or randomized control designs are being widely used. Some other quasi-experimental designs are also widely used (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 2000). 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 stakeholders' 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, all of which make it difficult to generalize to a larger, representative population. Also, the validity and reliability of data from qualitative analysis are highly dependent on the methodological skill, sensitivity, and training of the evaluator.

11.1.4.2 Approaches of impact assessment

One dominant perspective in impact assessment literature is to view natural resources 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 approaches. 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 (e.g., 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.

11.1.4.3 Scale or 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. As watersheds include private and common lands, the impact of various watershed treatment activities on different scale of dimensions such as farm level, household level, and watershed level is crucial in impact assessment. Time is an extremely important element in NRM 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.

11.1.4.4 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 the researcher study the samples from the watershed area itself employing before/after approach or should he/she study samples both in 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.

11.1.4.5 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 analyzed data). It is important to identify data requirements, generate data, and update the database at regular intervals. In using the 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 the 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 of change. Another such problem lies in the inter-comparison of projects.

As the impact of the watershed developmental activities is multifaceted 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 or activities therein.

11.1.4.6 Choosing the discount rate

There has been much discussion and debate on 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. Furthermore, 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 as it is the most efficient and easiest to implement.

One big debateable 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 leads to spill over effects. Moreover, as it involves huge government spending, the selection of a '*discount rate*' is a crucial one.

11.1.5 Indicators for evaluation of watershed development projects

The problem of developing an 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 selecting appropriate indicators to assess the impacts.
- Developing a framework to look after the indicators together and 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 evaluation were used in different studies. Some 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 progress towards stated physical and financial goals.
- Achievement evaluation to evaluate changes in living standards or in hydrologic and environmental conditions brought about by the project.

Based on the stage in the project cycle at which evaluation is conducted, evaluation systems are classified as:

- Baseline: Pre-project assessment to analyze 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 project implementation.
- Post-terminal evaluation – to evaluate the long-term project accomplishments conducted several years after the 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 the project period is over, i.e., ex-post evaluation. Ongoing evaluation is a series of periodic 'breaks' to analyze the monitored information to probe further the signals received and assess how things are moving. Some important questions are raised: Are activities being accomplished on time? Is progress towards achievement of objectives satisfactory? Throughout the ongoing evaluation of a program 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 ongoing evaluation is to assess continuing relevance, present and future outputs, and effectiveness during implementation. The main focus is on assessing the validity of the project design and targets, assessment of 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., assess success/failure of the project. The purpose of ex-post evaluation is to assess output, effect, and impact and drawing lessons for future planning and development. This type of valuation is beneficiary oriented. The performance indicators used for the watershed impact studies are given Table 11.1.

11.2 APPROACHES

11.2.1 Before and after

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 state-of-the-art of technology. This approach would be viable when the benchmark information is available. But in reality, most of the watershed development

Table 11.1 Performance indicators used for watershed impact evaluation

Performance criteria	*Indicators*	*Measures*
Groundwater recharge and water resource potential	Measurement of groundwater levels, climate variation, and pumping volume	• Duration of water availability • Water table of wells • Surface water storage capacity • Hydrological Index • Index of water conservation practices • Difference in number of wells • Number of wells recharged/defunct • Difference in irrigated area • Difference in number of seasons irrigated • Difference in village-level drinking water adequacy • Difference in irrigation intensity
Agricultural productivity/profits	Agricultural productivity and net returns at plot level	• Agricultural Productivity Index (API) • Crop Yield Index (CYI) • Crop Diversification Index (CDI) • Cropping System Index (CSI) • Index of Agroforestry Practices (IAP) • Difference in cropping pattern • Difference in cropping intensity • Difference in yield of crops • Farm profit
Household welfare	Household income and wealth	• Difference in per capita income • Difference in employment • Difference in household income • Difference in persons migrated
	Nutritional status	• Food security index (FSI) • Child nutrition and health
Socioeconomic indicators	Development of infrastructure	• Infrastructure Development Index (IDI)
	Impact on women (decision-making, health, life style and awareness)	• Women's Participation Index (WPI)
	People's participation	• Index of Social Affiliation (ISA)
	Institutions	• Difference in number of institutions
	Ownership rights	• Difference in number of agricultural laborers • Difference in number of landless laborers • Difference in farm households by size groups
Overall impact	Economic returns to investment	• Net present value, benefit-cost ratio, and internal rate of return
	Extent of green cover	• Forest Eco Index

[a]Source: Palanisami *et al.* (2002a).

programs are implemented without collecting full set of benchmark information. Thus sometimes, the benefits may be exaggerated.

11.2.2 With and without

A comparison between the 'project parameters' with the 'non-project control region' is used for evaluation. This method automatically incorporates the correction for the impact of technology in the absence of the project. But this approach also has limitations. Though the watershed treated and control regions fall within the same agroclimatic conditions, the differences in hydro-geological profile vary within a village/even across plots in the farm. Thus, this approach can be only used to compare the villages having homogeneous conditions.

11.2.3 Combination of with and without using double difference method

When the time span is too long, economists adopt *a combination of both with and without and before and after approaches,* where they compare pre- and post-project period and with the control village as well so as to get a holistic picture on impact of watershed development activities. The double difference method explained below can be applied.

Data may be collected for both watershed treated villages and control villages before and after watershed development intervention. This enables the use of the double difference method to study the impacts due to watershed development intervention. The framework was adopted from the program evaluation literature (see Figure 11.1) (Maluccio and Flores 2005).

11.3 METHODOLOGIES: APPLICATION OF WATERSHED EVALUATION METHODS

11.3.1 Conventional benefit-cost analysis

The conventional analysis primarily includes:

- Net present value (NPV)
- Benefit-cost ratio (BCR)
- Internal rate of return (IRR)

The limitations and complexities associated with measuring, monitoring, and valuing social costs and benefits associated with NRM interventions require more innovative assessment methods. An important factor that needs to be considered in the selection of appropriate methods is the capacity for simultaneous integration of both economic and biophysical factors and ability to account for non-monetary impacts that NRM interventions generate in terms of changes in the flow of resource and environmental services that affect economic welfare, sustainability, and ecosystem health. Hence a mix of qualitative and quantitative methods is the optimal approach for capturing on-site and off-site economic welfare and sustainability impacts (Freeman *et al.*, 2005).

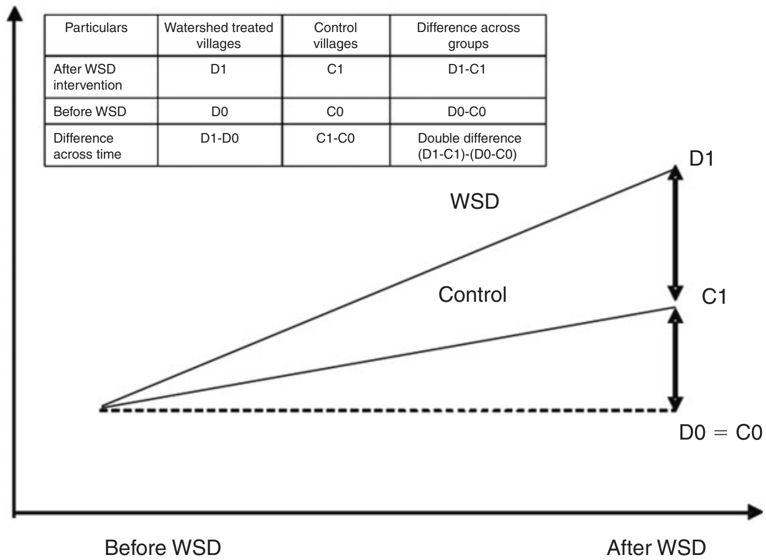

Figure 11.1 Illustration of impact of watershed development (WSD) intervention by double difference method (Source: Maluccio and Flores 2005)

The approaches that have been developed recently for evaluating the impacts of agricultural and NRM interventions are presented.

11.3.2 Econometric methods (Economic surplus approach)

The economic surplus approach to impact assessment is rooted in the microeconomics of supply and demand (Bantilan *et al.*, 2005). The basic idea is simple and is illustrated in Figure 11.2. Consumer demand can be described by downward sloping demand curve illustrating that some consumers are willing to pay more than others for a given commodity. At a market-clearing equilibrium price, P*, those consumers who were willing to pay more than P* realize benefits by getting the product for less money than they were willing to pay. Across all consumers, the area beneath the demand curve, D, and above the equilibrium price, P*, measures the total value of consumer surplus.

Producer supply can be described by an upward sloping curve that illustrates that some producers can supply a product for a lower price than others. At a market-clearing equilibrium price, P*, those producers who could supply the products at a lower price obtain extra benefits. The aggregate benefits described by the area above the supply curve, S, and below the equilibrium price, P*, measure the total producer surplus. Economic surplus is the sum of consumer surplus and producer surplus.

This is the most commonly used method for assessing the impact of agricultural research investment, particularly those related to crop improvement. This approach estimates the benefits of research in terms of change in consumer surplus and producer surplus, resulting from a shift in the supply curve by introduction of new technology. Thus, the economic surplus (sum of producer surplus and consumer surplus) is

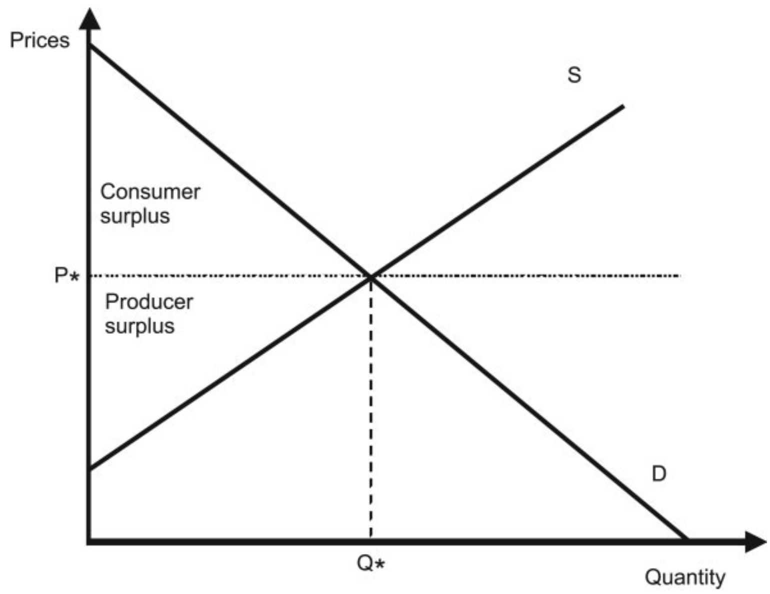

Figure 11.2 Economic surplus divided between consumer and producer surplus (Note: P* = equilibrium price; Q* = equilibrium quantity; S = supply curve; D = demand curve) (Source: Bantilan *et al.*, 2005)

taken as a measure of the gross benefit from research investment in a given year. The major challenge is to make a plausible link between changes in NRM practices and the supply of economic goods and services. The presence of non-marketed externalities further complicates the approach, although in theory, the social marginal cost of production could be used to internalize the externalities. New methods (e.g., benefit transfer function) are developed to extend the economic surplus approach for assessment of non-marketed social gains from improved NRM technologies. Bantilan *et al.* (2005) used the economic surplus approach to estimate empirically the economic and environmental impact of groundnut production technology in Maharashtra.

The econometric approach is also used to link measures of output, costs, and profits directly to past watershed development investments. The econometric approach uses regression models [like probit, logit, tobit, and two stage least squares (2SLS) regressions] to explain variations in agroecosystem services through changes in NRM pattern. This approach uses the changes in biophysical, economic, and environmental indicators as proximate indicators of the impact of the NRM technologies. The indicators include changes in land productivity; total factor productivity; reduction in costs (e.g., reduced use of fertilizers and pesticides); reduced risk and vulnerability to drought and flooding; and improved net farm income and change in poverty levels (e.g., head count ratio). However, there are some limitations in this approach related to data availability and measurement errors, and problem in internalizing externalities and inter-temporal effects. For example, the time-varying nature of the impacts of NRM practices require time-series data, ideally panel data with repeated observations from the same households and plots over a period of many years so that the dynamics of these impacts and their feedback effected on household endowments and subsequent NRM decisions are adequately assessed (Pender 2005).

Unfortunately, household and plot-level panel data sets with information on both NRM practices and causal factors and outcomes are quite rare. In the absence of such data, inferences about NRM impacts will remain limited to those possible based on the available short-term experimental data and cross-sectional econometric studies. These can provide information on near-term impacts, for example, on current production, income, and current rates of resource degradation or improvement, but do not reveal feedback effects such as how the changes in income or resource conditions may lead to changes in future adoption, adaptation, or non-adoption of NRM practices (Barrett *et al.*, 2002; Pender 2005).

Assessing the multiple and complex mechanisms by which NRM (and other factors) may affect outcomes is an important issue, and one that is more difficult to address when limited dependent variable models (such as the probit, ordered probit, and tobit models) or other non-linear models are estimated. In linear system of structural equations, the total impacts of any variable on the outcomes can be determined by total differentiation of the system and by adding up the partial effects (Fan *et al.*, 1999). But with limited dependent variable models or other non-linear models, this approach does not work. There will be no simple general relationship between the estimated coefficients of the structural model and the total impact; these relationships all depend on the level of each variable in non-linear models.

Pender (2005) applied an alternative approach to estimate total effects in non-linear models by using predictions from the estimated model to simulate both indirect and direct impacts of changes in the explanatory variables. Even though econometric models are useful in assessing the NRM impacts, they are not without problems and limitations. The most important problems are those of endogeneity of NRM practices and omitted variable bias, which can be addressed through careful data collection and use of instrumental variables estimators.

Kerr and Chung (2005) also applied the econometric approach to assess the impact of the watershed program in the semi-arid tropical India. In this study they used instrumental variables approach for evaluation because of inadequate data on baseline conditions and lack of hydrological data (such as groundwater level, runoff, soil erosion, etc.). The study found that the projects involving greater degree of participation were more successful in protecting upper catchments to promote water harvesting. On the other hand, often protection of upper catchments came at the expense of landless people whose livelihood relied heavily on them.

11.3.2.1 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, enhance moisture conservation in the soil, increase water use for the existing crops, and 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 the watershed programs. In the case of consumers, the increased crop production in the watershed results in the availability of produce at lower prices. Consumption levels also get increased among the consumers. Labor employment is increased due to increased land and crop production and processing activities in the watershed. Evidence shows that the production levels have increased as a result of watershed interventions and the consumers have started enjoying the benefits of the 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 the repair 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). The demand curve is assumed to be log-linear with constant elasticity. Thus, the equation for this demand function can be written as:

$$P = gQ^{\eta} \tag{1}$$

where, η is the elasticity and g is a constant. Once, the parameters η and g are estimated, then consumer surplus could be estimated by equation 2:

$$CS = \int_{Q_0}^{Q_1} gQ^{\eta} dQ - (Q_1 - Q_0)P_1 \tag{2}$$

Combined, the consumer surplus and the producer surplus make up the total surplus. The estimation of benefits is given in Box 1.

11.3.2.2 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.

11.3.2.3 Results of the economic surplus method

This section presents the key indicators from the field experience on impact assessment of watershed programs implemented under DPAP in Coimbatore district of Tamil Nadu. The general characteristics of the sample farm households in the study watershed were analyzed (Table 11.2). The average size of the holding was 1.28 ha and 1.75 ha, respectively for the watershed and control villages. It is evident from the analysis that

Box 1. 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 (3):

$$B = K^*P_0{}^*A_0{}^*Y_0{}^*(1 + 0.5Z^*\varepsilon_d) \quad (3)$$

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

The supply shift due to watershed intervention can be mathematically represented by equation (4):

$$K = \forall^*\rho^*\psi^*\Omega \quad (4)$$

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 defined as the difference between reduction in marginal cost and reduction in unit cost. The reduction in marginal cost is defined as the ratio of relative change in yield to price elasticity of supply (ε_s). Reduction in unit cost is defined as the ratio of change in cost of inputs per hectare to (1 + change in yield). ρ is the probability of success in watershed development implementation. ψ represents adoption rate of technologies and Ω is the depreciation rate of technologies.

Z represents the change in price due to watershed interventions. Mathematically, Z can be defined by equation (5):

$$Z = K^*\frac{\varepsilon_s}{(\varepsilon_d + \varepsilon_s)} \quad (5)$$

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

Table 11.2 General characteristics of sample farm households[a]

Particulars	*Watershed village*	*Control village*
Farm size (ha)	1.28	1.75
Household size	3.31	3.34
Land value (₹ ha^{-1})	230657	153452
No. of wells owned	1.35	1.20
Average area irrigated by wells (ha)	1.48	1.80
Value of household assets (₹)	261564*	184385
No. of persons in the household	4.07	4.2
No. of workers	2.5	2.1
Labor-force participation (%)	61.48	50.79

[a,*] indicates that value was significantly different at 10% level from the corresponding values of control village.
Source: Palanisami and Suresh Kumar (2006).

the average number of workers was 2.5 and 2.1 out of 4.07 and 4.2 for the watershed and control villages.

The labor force participation rate was 61.48% and 50.79%. The higher labor force participation was due to better scope for agricultural production, livestock activities, and other off-farm and non-farm economic activities. Results from the analysis showed that the labor 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 m 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%.

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 to 0.3 $m^3\ h^{-1}$. 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 the watershed village registered a moderate increase after the watershed development activities in most of the watersheds, whereas in the control village it declined slightly over the period. The irrigation intensity was found higher in watershed treated village than in the untreated village. The watershed developmental activities helped increase the water resource potential of a region through enhanced groundwater resources coupled with soil and moisture conservation activities. In the case of control village, the water table in the wells had declined due to continuous pumping. It is one of the reasons why most farmers demand watershed program in their villages. The analysis also revealed increase in net cropped area, gross cropped area, and cropping intensity in both the watersheds (Table 11.3). For example, the cropping intensity worked was 146.88% in the watershed village, which is higher than in the control village (133.33%). The composite entrophy index (CEI) was used to compare diversification across situations having different and large number of activities. The CEI has two components, viz., distribution and number of crops or diversity. The value of crop diversification index (CDI) increases with the decrease in concentration and rises with the number of crops/activities. In general, CDI is higher in the case of watershed treated villages than control villages, confirming that watershed treatment activities help diversification in crop and farm activities.

Table 11.3 Impact of watershed activities on cropped area, cropping intensity, and crop diversification[a]

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	

[a],** and *** indicate that values were significantly different at 1 and 5% levels from the corresponding values of control village.
Source: Palanisami and Suresh Kumar (2006).

Table 11.4 Livestock maintained in watershed and control villages[a]

Particulars	*Watershed village*	*Control village*
% of households maintained livestock	46.67	93.33
Livestock (number per household)	2.57	2.64
Livestock (number per hectare of gross cropped area)	2.01	1.63

[a]Source: Palanisami and Suresh Kumar (2006).

Based on the proportion of different crops in the farm, *CEI* for crop diversification was estimated as:

$$CEI = -\left(\sum_{i=1}^{N} P_i \cdot \log_N P_i\right)^* \{1 - (1/N)\} \tag{6}$$

where,
P_i = Acreage proportion of ith crop in total cropped area, and
N = Total number of crops.

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. Nearly 46.67% and 93.33% of the households in watershed and control villages respectively maintained cattle (Table 11.4).

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

Table 11.5 Impact of watershed development intervention on crop yield and cost[a]

Crop/Commodity	*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

[a]The reduction in marginal cost (C_m) was the ratio of relative change in yield to price elasticity of supply (ε_s). Reduction in unit cost (C_u) was the ratio of change in cost of inputs per hectare to (1 + change in yield). C_i was the input cost change per hectare, i.e., $C_u = C_i/(1 + \text{Change in yield})$. The net cost change ($\forall$) was the difference between reduction in marginal cost and reduction in unit cost, i.e., $\forall = C_m - C_u$.
Source: Palanisami *et al.* (2009).

Table 11.6 Impact of watershed development activities on the village economy

	Total benefits due to watershed intervention[a]		
Crop/Commodity	*Change in total surplus (ΔTS)*	*Change in consumer surplus (ΔCS)*	*Change in producer surplus (ΔPS)*
Sorghum	293177.3	113636.3	179541.0
	(100.0)[b]	(38.8)	(61.2)
Maize	177774.2	85424.0	92350.2
	(100.0)	(48.1)	(51.9)
Pulses	25777.5	12580.3	13197.2
	(100.0)	(48.8)	(51.2)
Vegetables	29663.6	10627.5	19036.1
	(100.0)	(35.8)	(64.2)
Milk	176878.5	105974.1	70904.4
	(100.0)	(59.9)	(40.1)

[a]The change in total surplus in the village economy due to watershed intervention was decomposed into change in consumer surplus and change in producer surplus. The decomposition of total surplus was as follows:
$\Delta TS = \Delta CS + \Delta PS = P_0 Q_0 K(1 + 0.5Z\eta)$
$\Delta CS = P_0 Q_0 Z(1 + 0.5Z\eta)$
$\Delta PS = P_0 Q_0 (K - Z)(1 + 0.5Z\eta)$
[b]Percentage values are given in parentheses.

The impact of watershed development activities on yield of crops and hence the cost was estimated (Table 11.5). The change in yield due to watershed intervention across crops varied from 31% in maize to 36% in pulses. The change in yield was maximum due to watershed intervention. Reduction in marginal cost due to supply shift ranged from 32.8% in vegetables to 63.6% in sorghum. Net cost change varied from 32% in vegetables to 59.8% in sorghum. The change in total surplus was higher in sorghum and maize than crops like pulses and vegetables (Table 11.6). Being the major rainfed crops, these two crops benefited more from the watershed interventions.

Table 11.7 Results of economic analysis employing economic surplus method[a]

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

[a]Conventional method refers to the crop production related costs and benefits.
Source: Palanisami *et al.* (2009).

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 consumer surplus in all the crops. For instance, in sorghum, the producer surplus was 61.2%, whereas the consumer surplus was only 38.8%. Watershed development activities benefited the agricultural producers more. It was interesting to note that unlike in the crop sector, milk production had different impacts on the society. The decomposition analysis revealed that watershed development activities generated more consumer surplus in milk production.

The overall impact of different watershed treatment activities was assessed in terms of BCR, and IRR using the economic surplus methodology assuming 10% discount rate and 15 years life period. The BCR was more than one, implying that the returns to public investment such as watershed development activities were feasible. Similarly, the IRR was 25%, which is higher than the long-term loan interest rate by commercial banks indicating the worthiness of the government investment on watershed development (Table 11.7). The NPV per hectare was ₹4542 (where the total area treated was 500 ha), which implied that the benefits from watershed development were higher than the cost of investment of the watershed development programs of ₹4000 per ha. However, recently the watersheds in India have been allotted a budget of approximately ₹6000 per ha. Thus, a watershed with a total area of 500 hectares receives ₹3 million for a five-year period. The bulk of this money (80%) is meant for development/treatment and construction activities. According to the new Common Guidelines 2008, the budgetary allocation is of ₹12000 per ha.

11.3.3 Bioeconomic modeling approach

Even though the economic surplus method could incorporate both the consumer and producer benefits, improvements could be made while accounting for the watershed related impacts. Further, the individual impacts of various technologies are known but there is little information on their combined impact or on the role of policy and institutional arrangements in conditioning their outcomes (Okumu *et al.*, 2000). In addition, past research seldom included the biophysical factors (like soil erosion, nutrient depletion, water conservation, etc.) in their studies, which have a direct effect in the productivity of the numerous enterprises (like crop production, livestock production, forestry, pasture development). In the recent past, the methodologies that are capable of simultaneously addressing the various dimensions of agriculture and NRM technology changes and the resulting tradeoffs among economic, sustainability, and environmental objectives have been developed (e.g., Barbier 1998; Barbier and Bergerson 2001; Holden and Shiferaw 2004; Holden *et al.*, 2004). The main innovation in the development of such methodologies is the integration of biophysical and economic information into a single integrated bioeconomic model. Bioeconomic models link economic behavioral models with biophysical data to evaluate potential effects of new technologies, policies, and market incentives on human welfare and the sustainability of the environment or natural resources (Shiferaw and Freeman 2003). So it helps the researchers in the selection of technologies that may improve the farmers' economic efficiency and welfare as well as the condition of the natural resource base over time. The models can also be used to account for externalities if the generation of externalities can be linked with NRM and economic factors. Bioeconomic models have been applied at the level of the household (e.g., Holden and Shiferaw 2004; Holden *et al.*, 2004; Holden 2005), village and watershed levels (e.g., Barbier 1998; Barbier and Bergerson 2001; Sankhayan and Hofstad 2001; Okumu *et al.*, 2002) and for agricultural sector (e.g., Schipper 1996).

11.3.3.1 Advantages of bioeconomic modeling in impact assessment studies

Bioeconomic models are used to incorporate changes in the biophysical conditions of the natural resource use within the economic behavioral models with the purpose of exploring or understanding the two way interaction (i.e., how changes in biophysical conditions affect welfare and vice versa). Such models are useful to evaluate the potential effects of new agricultural and NRM technologies, policies and market incentives on human welfare as well as the quality of the resource base and the environment. Possibilities to address dynamic issues and linking changes in biophysical indicators with economic models are important advantages of this method. The integrated framework allows a consistent analysis of technology impacts within a given socioeconomic and policy setting. According to Holden (2005) the main advantages of using bioeconomic models for NRM technologies and policy impact assessment are:

- They allow consistent treatment of complex biophysical and socioeconomic variables, providing a suitable tool for interdisciplinary analysis.
- They allow sequential and simultaneous interactions between biophysical and socioeconomic variables.
- They can be used to assess the potential impacts of new technologies and policies (*ex ante* impact assessment).
- They allow disturbing variation to be controlled (*ceteris paribus* conditions) for evaluation of impacts of certain interactions by isolating effects from other influences.
- They can capture both direct and indirect effects (i.e., the total effect of technology or policy change can be estimated).
- They can be used to carry out sensitivity analyses in relation to various types of uncertainties.

11.3.3.2 Application of bioeconomic model for impact evaluation of watershed development program in semi-arid tropics of India

Even though there have been several case studies of successful watershed development in India (e.g., Kerr *et al.*, 2000; Wani *et al.*, 2002), the impact of the approach in improving the welfare of the poor and the natural resource condition in the semi-arid tropical areas is not fully known. A study was carried to assess the inter-temporal impacts of key integrated watershed management technologies (e.g., high-yielding varieties and soil and water conservation structures) on household income, food security, soil erosion, and nutrient mining in selected micro-watersheds.

Based on the lessons learnt from the success of on-station soil, water, and nutrient management (SWNM) research in watershed, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) developed a new Integrated Genetic and Natural Resource Management (IGNRM) model. In one of the on-farm watersheds in India (Adarsha watershed, Kothapally), a participatory community watershed management program was initiated in collaboration with DPAP of Government of India. Along with ICRISAT, a consortium of NGOs and national research institutes have been testing and developing technological, policy, and institutional options for integrated watershed management in the village (Wani *et al.*, 2002; Shiferaw *et al.*, 2003). A package of IGNRM practices were evaluated on farmers' fields including soil and water conservation, new high-yielding varieties, integrated pest management and integrated nutrient management through participatory approaches.

11.3.3.3 Biophysical and socioeconomic data

ICRISAT has installed an automatic weather station in Kothapally village, which allows regular collection of weather parameters (e.g., temperature, rainfall, sunshine, wind speed and direction, etc.). In 2001, ICRISAT conducted census of all households in Kothapally village and five adjoining villages, i.e., non-watershed/control villages (namely Husainpura, Masaniguda, Oorella, Yankepally, and Yarveguda) located outside the watershed with comparable biophysical (rainfall, soil, and climate) and socioeconomic conditions. Based on the information from the census analysis, a random sample of 60 households from watershed village (Kothapally) and another 60 households from non-watershed villages were selected for detailed survey. Along with other standard socioeconomic data, detailed plot-wise and crop-wise input and output data were collected immediately after harvest from the operational holdings of all the sample households.

11.3.3.4 Bioeconomic modeling

Bioeconomic model combines both socioeconomic factors influencing farmers' decision-making with biophysical factors affecting crop production and natural resource conditions (Barbier 1998; Woelcke 2006). The model consists of three components: (i) a mathematical programming model that reflects the farm household decision-making process under certain constraints; (ii) estimation of crop yield response to soil depth; and (iii) nutrient balances as a sustainability indicator. The results of the marginal yield response for soil depth and estimation of soil erosion under different cropping systems are then incorporated into programming model (for the detailed description of the bioeconmic model refer Nedumaran 2007, 2009).

11.3.3.5 Validation of the bioeconomic model

The challenge in the development of bioeconomic models is to ensure that the results can be trusted and that the model can be reused in similar other settings. The validation of the complex models like bioeconomic models is much debated; for example, Janssen and van Ittersum (2007) reviewed 48 bioeconomic models and found that only 23 studies validated their results using observed qualitative and quantitative data.

Based on McCarl and Apland (1986), the *ex-ante* bioeconomic model was validated by conducting regression analysis between observed and simulated land use values. A regression line was fitted through the origin for the observed land use in 2003 and first year of simulated land use of major seven crops expressed in percentage of total area of these crops in the total cultivated area in the watershed. The comparison was done at watershed level. Figure 11.3 compares the observed with the simulated land use at the watershed level. The parameter coefficients are close to unity at watershed level with an explained variance of 97%, which indicates the model results are almost identical with the 2003 land use trend in the Kothapally watershed.

11.3.3.6 Impact of change in yield of dryland crops

The simulation results showed that the per capita income of all three household groups were above the baseline level when the yields of dryland crops increased (Table 11.8). Increase in area of the dryland crops (sorghum and maize) in the watershed increases fodder production, which in turn enhances the carrying capacity of livestock in the watershed. This increased livestock production and also increased the income from livestock gradually for all the household groups.

The soil erosion under the scenario of increased yield of dryland crops was higher than the baseline level at the initial years and started declining from the fifth year of simulation. The increase in area of dryland crops increased the demand for on-farm labor in the initial years, which reduced the incentive to use the labor for conservation measures and this caused higher soil erosion in the initial year of simulation. However, the population growth in the watershed over the years drove the farmers to use more labor for conservation measures in the field, which declined the soil erosion towards the end of the simulation period. The results revealed that the decline in soil erosion was 6% compared to the baseline in the final year of simulation. Under the decreased dryland crop yield scenario, the soil erosion had not changed much compared to the baseline scenario.

The increase in area under sorghum and maize and decline in the area of high nutrient mining crops like cotton and sunflower under the scenario of increased yields of dryland crops had reduced soil nutrient mining by 4, 1, and 3% of nitrogen, phosphorus, and potassium respectively compared to baseline level. If the yield of dryland crops had decreased by 10%, the results showed that nutrient balances in the watershed were similar to baseline level.

11.3.3.7 Impact of change in irrigated area in the watershed

One of the important objectives of the watershed development program is to conserve rainwater by reducing outflows from the watershed by constructing check-dams and other in-situ soil and water conservation systems. The stored water improves the groundwater table, which in turn helps to increase the area under irrigation in the watershed. In this context, simulation was carried out to assess the impact of changes in irrigated area resulting from adoption of the soil and water conservation measures on household welfare, soil loss, and nutrient balance in the watershed. Hence, the

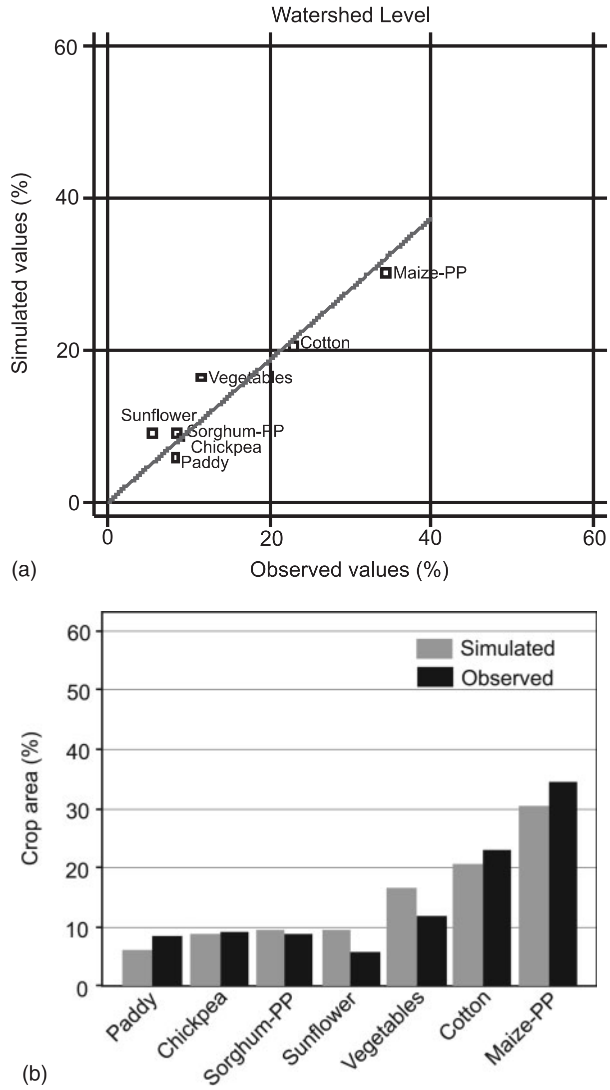

Figure 11.3 Simulated vs observed land use as percentage of total crop area (Note: PP = pigeonpea); Regression line fit: Co-eff = 0.93; SE = 0.51; $R^2 = 0.97$ (Source: Nedumaran 2009)

baseline scenario in the watershed was compared with two alternative scenarios: (1) increasing irrigated area by 25%; and (2) reducing the area under irrigation by 25%. These changes were simulated through comparative adjustments in dryland area so that the total cultivable area in the watershed remained unchanged.

The results revealed that if irrigated area increased, the per capita income of all the three household groups were more than the baseline level (Table 11.8). This was due to higher productivity of crops like cotton, vegetables, and sunflower under irrigation and increasing the area of these crops under irrigation resulted in increased production

Table 11.8 Impact of change in irrigated area in the watershed[a]

Scenario	Per capita income (₹) Small	Medium	Large	Soil loss ($t\,ha^{-1}$)	Conservation labor (person-days)	Nutrient balance (t) N	P	K
Baseline	5080	9110	16160	4.04	4092.2	−11.74	12.25	−94.79
Irrigated area (+25%)	5160	9500	17810	4.13	4374.18	−14.38	11.37	−98.94
Irrigated area (−25%)	4730	8700	16720	3.92	3600.95	−9.2	14.46	−88.98

[a]Average of 10 years simulation.
Source: Nedumaran (2009).

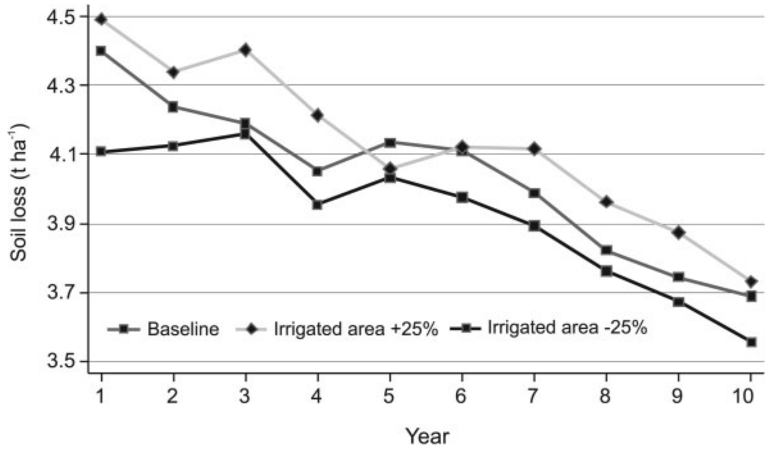

Figure 11.4 Simulated soil loss in the watershed indicating an alternative scenario for change in irrigated area (Source: Nedumaran 2009)

in the watershed. The increased marketable surplus of these crops increased the income of the household groups. The scenario of decreasing the irrigated area by 25% led to reduction in the per capita income for small and medium farm household because the area under commercial crops like vegetables and cotton decreased. The per capita income of the large farmers had not changed much because these farmers were not constrained by irrigated land.

Soil erosion was higher when irrigated area increased in the watershed compared to the baseline level (Figure 11.4). The area under irrigated cotton, sunflower, and vegetables increased because of expanding irrigated land. The increase in the area of erosive crops (wide spaced crops) like cotton and vegetables resulted in higher erosion by 2% compared to baseline level. On the contrary, reduction in irrigated land in the watershed increased the area under less erosive dryland crops like maize and sorghum, reducing the soil erosion by about 7%.

When irrigated area increased by 25%, the labor used for conservation measures was less than the baseline level in the initial years and increased above the baseline

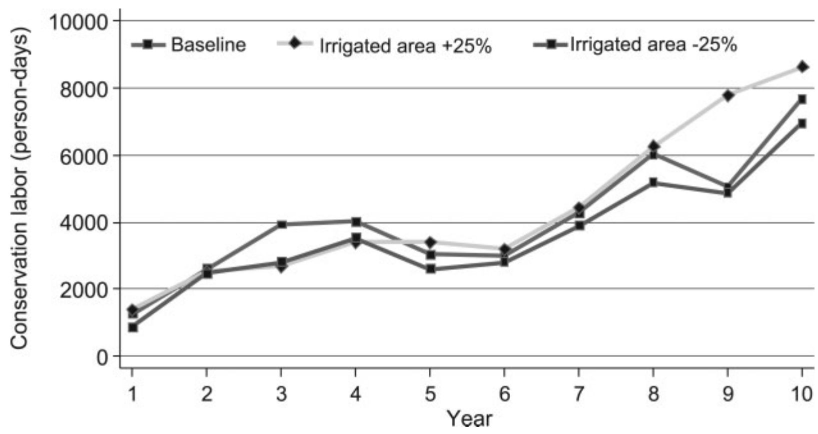

Figure 11.5 Simulated labor used for conservation measures indicating an alternative scenario for change in irrigated area (Source: Nedumaran 2009)

level towards the end of simulation (Figure 11.5). When the irrigated area decreased by 25%, soil erosion was below the baseline level, even though the total labor used for soil and water conservation was lower than the baseline level. This was mainly due to change in cropping pattern, where area under less erosive dryland crops like maize and sorghum increased in the watershed.

The soil nutrient balance indicated that nutrient mining was higher compared to the baseline level when irrigated area increased by 25% (Table 11.8). This was due to increase in the area of high nutrient extraction by irrigated crops like vegetables, cotton, and sunflower compared to baseline level. The reduction in irrigated area increased the area under cereal-legume cropping systems like maize/pigeonpea and sorghum/pigeonpea which removed comparatively less nutrients from the soil and also improved the soil nutrient status through biological nitrogen fixation. Although increase in irrigated area in the watershed improved the welfare of the farmers and the cropping pattern, it caused negative effects on the environment by increasing the erosion level and soil nutrient mining.

Bioeconomic modeling indicated that the introduction of high-yielding varieties and cereal-legume intercropping systems helped to improve the welfare of smallholder farmers by increasing the income and enhancing the sustainability of the natural resource base. It also stimulates sustainable intensification of production by controlling soil erosion and nutrient mining through investment in conservation and adoption of better land use patterns in the watershed. So, it is important to focus more on crop-specific research to develop drought tolerant high-yielding varieties of dryland crops, which are also resistant to pests and diseases. The increase in irrigated area under cotton, vegetables, and sunflower due to the availability of water from community and in-situ soil and water conservation in the watershed improved farmers' income. The erosion level and nutrient mining in the watershed however, increased because of increase in the area under soil erosive and nutrient mining crops like cotton and vegetables. It is important to promote irrigated cereal crops in the watershed, so that erosion level will be minimized and fodder production enhanced to create complementarities with livestock production, leading to increased manure availability for use to replenish soil fertility. The results clearly indicated that care should be taken while developing technologies for watershed development to avoid the promotion of conflicting technologies.

11.3.4 Meta analysis

The economic surplus method and bioeconomic models have demonstrated clearly the use of improved measurement methodologies in watershed evaluation. However, it is also important to examine how in the long run such methods could be applied if the present level of watershed development works is carried out.

Earlier meta analysis was applied to assess the returns on investment in education and understand the implications of certain medical treatments on offspring and the returns to research investment at the global level. Ordinary least square (OLS) approach was employed to estimate the regression equation:

$$BCR = f(L, S, F, R, I, P, T, A, SL) \quad (7)$$

where,
BCR = Benefit-cost ratio;
L = Geographical location of watershed;
S = Size of watershed;
F = Focus of watershed;
R = Rainfall in the watershed area;
I = Implementing agency of the watershed;
P = Peoples' participation;
T = Time gap between project implementation and evaluation;
A = Various activities performed in the watershed area; and
SL = Type of soil in the watershed area as explanatory variables.

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 policymakers, who may be confronted by numerous conflicting conclusions (Joshi *et al.*, 2005).

11.3.4.1 Review of studies on meta analysis

This section is mainly drawn from the recent study made by the ICRISAT-led consortium team (Wani *et al.*, 2008). Reddy (2000) reviewed 22 impact assessment studies conducted across the country from 1967 to 1997. The impact of watershed development projects showed positive impacts on crop yields, cropping intensity, and cropping pattern changes. However, there was a large variation in the magnitude of the impact across regions and crops. The magnitude of the impact is dependent on the nature of activities undertaken in the watershed (i.e., higher the agricultural and livestock interventions, higher will be the overall benefits from the watershed program). In general, net income increase had favorable BCR. The BCR is stable at 1.75, implying positive impacts by the watershed development programs in the country.

Many other studies (Palanisami *et al.*, 2002a; Ramaswamy and Palanisami 2002; Sastry *et al.*, 2002; Sreedharan 2002; Palanisami and Suresh Kumar 2006) employed before and after approaches to assess the impact of watershed development activities. Others (Lokesh *et al.*, 2006; Ramakrishna *et al.*, 2006) adopted with and without approach to asses the impact.

These studies focused on the impact of watershed activities on various impact domains like soil and moisture conservation, water resources development, impact of cropping pattern and yield, and overall economic impacts. These studies found that there is significant impact on soil erosion control, soil moisture conservation, water resources development, and increased crop yields. The watershed development has also produced desired results in terms of improvement in socioeconomic 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 the impact was found to vary across regions and impact domains.

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

11.3.4.2 Biophysical impacts

The watershed development activities have significant positive impacts on various biophysical 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 (Figures 11.6 and 11.7). These include improved conservation of soil and moisture, improvement and maintenance of fertility status of the soil (Sikka *et al.*, 2000; AFC 2001; Ramasamy and Palanisami 2002; Sastry *et al.*, 2002) and reduced soil and water erosion. The organic carbon increased by 37% due to watershed intervention (Sikka *et al.*, 2000). Significant reduction in soil and water erosion (77.78% reduction) was observed by Milkesha Wakjira (2003).

Impact and evaluation study of the soil conservation scheme under DPAP indicates that only marginal impact was realized in land use, cropping pattern, and yield (Evaluation and Applied Research Department 1981). Evidences show that soil conservation improved moisture retention, reduced soil erosion, changed land use pattern, and increased crop yield. Soil loss reduced from 18758 kg ha^{-1} in 1988 to 6764 kg ha^{-1} in 1989. Between 1985–86 and 1989–90, crop yield had increased at 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, and increase in

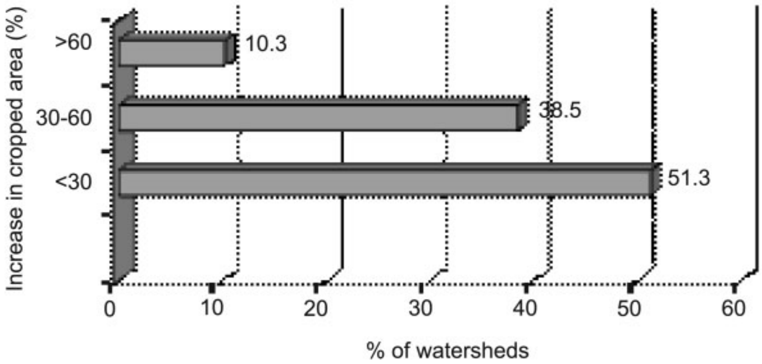

Figure 11.6 Distribution (%) of watersheds by increase in cropped area

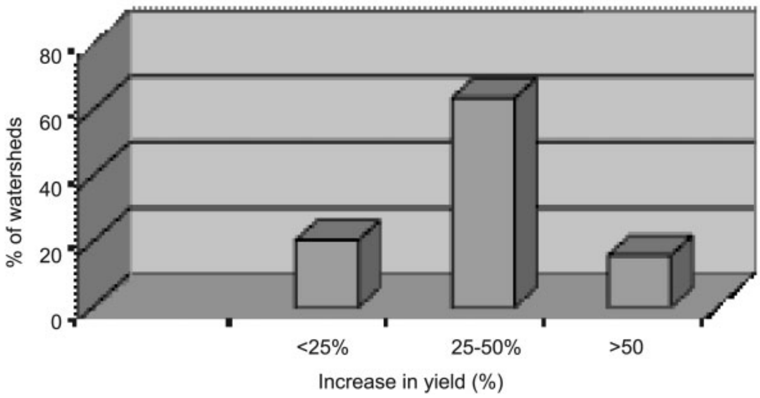

Figure 11.7 Distribution (%) of watersheds by increase in yield

production and productivity of crops. Most of the studies indicated significant increase in cropped area, which ranged from 6.84% (Sreedharan 2002) to 52% (Sastry *et al.*, 2002). The increase in cropped area helped increase production and productivity. The productivity enhancement due to watershed development is a common phenomenon in most of the watersheds (Figure 11.7). The increase in yield of crops ranged from 5% (Shobha Rani 2001) to 91.11% in Karnataka (Milkesha Wakjira 2003).

The cropping pattern changes have taken place both in additional area brought under well irrigation from the fallow lands and in the area under rainfed cultivation. The area under high water consuming crops increased by 25.3% in first crop and 29.4% in second crop period. Similarly, cropping intensity increased from 120% to 146.88% in Kattampatti watershed and from 102.14% to 112.08% 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, 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 biophysical aspects leading to increased soil fertility, cropping pattern changes, and crop production and productivity.

11.3.4.3 Socioeconomic impacts

The watershed development technologies aimed at not only conserving the natural resources but also improving the socioeconomic conditions of the rural people who depend upon these for their livelihood. The impacts of various watershed treatments is however widespread. The changes in various biophysical, and environmental aspects impacts socioeconomic conditions of the people. Watershed development programs are designed to influence the biophysical aspects and environmental aspects and thereby bringing changes in socioeconomic conditions (Deshpande and Rajasekaran 1997).

The socioeconomic indicators like changes in household income, changes in per capita income, consumption expenditure, differences in employment, changes in persons migrated, peoples' 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 labor households in the treated villages derive ₹28732 when compared to ₹22320 in control village, which is 28.73% 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 was 13.17% in Kattampatti and 70.44% 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 from 13 to 50% (AFC 2001). The increased income helps the households to ensure quality food and achieve nutritional security.

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 plowing, crop demonstration, retaining wall, and plantation. Also, the watershed development program reduces out-migration. As sufficient employment opportunities are created due to watershed intervention through expansion in cropped area, the landless rural labor households and other marginal and small farmers get adequate employment to earn their livelihoods. This helps reduce out-migration. Evidences show that out-migration has been reduced by 20–50% in many watersheds (Sastry *et al.*, 2002). In some watersheds, the reduction is up to 43%.

Like all other development programs, watershed development program banks heavily on the participatory approach. Though watershed development program envisages an integrated and comprehensive plan of action for the rural areas, peoples' participation at all levels of its implementation is of critical importance. 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 NRM becomes more and more crucial, it has also become clear that sustainability is closely linked to the participation of the community. This requires sustained efforts

(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 analyze the various institutional and policy aspects of watershed development programs in relation to participatory watershed management.

Experience on the evaluation study of 15 DPAP watersheds conducted in Coimbatore district of Tamil Nadu showed that the overall community participation was 42%. The participation was found to be 55, 44, and 27%, respectively at planning, implementation, and maintenance stages. This suggests that the community participation in watershed development program has to be greater. Similarly, overall contribution for works on private land was found to be 14% and varied from a minimum of 7% for fodder plots to a maximum of 22% for horticulture and farm pond. However, the contribution in terms of cash or kind towards development of structures in common lands such as percolation ponds, and check-dams 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 the level of adoption, with a minimum of 2.4% in farm pond, 30.40% in summer plowing, 36.80% in land leveling, and 44% in contour bunding. Follow-up by farmers was also found to be poor in most of the technologies and it accounted for 5.23% in farm ponds and plowing, 21.58% for contour bunding (Sikka *et al.*, 2000).

The Water Technology Centre at the Tamil Nadu Agricultural University carried out mid-term evaluation of 18 watersheds under Integrated Wasteland Development Program in Pongalur Block of Coimbatore district, Tamil Nadu. The results revealed that Peoples' Participation Index at the planning stage was 52.69%, followed by implementation stage (39.28%). This shows low peoples' participation at both the stages of the project (Palanisami *et al.*, 2002b). In several watersheds, the structures are not maintained due to lack of funds as well as lack of coordination among beneficiaries. Also, many of the presidents of the Watershed Association were not reelected in the local panchayat elections, resulting in lack of coordination particularly during the post-project management. There is a decline in interest in watershed structures during the post-implementation phase attributable to (i) failure or collapse of the new institutions set up to manage watersheds; and (ii) lack of clear norms on how to operate WDFs. Thus ensuring peoples' participation in different stages of watershed implementation and management is crucial for achieving the objectives of watershed development in a sustained manner.

11.3.4.4 Environmental impacts

The watershed development activities generate significant positive externalities including improving agricultural production, productivity, and socioeconomic status of the people who directly or indirectly depend upon the watershed for their livelihoods. 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 imply that watershed development activities generated significant positive

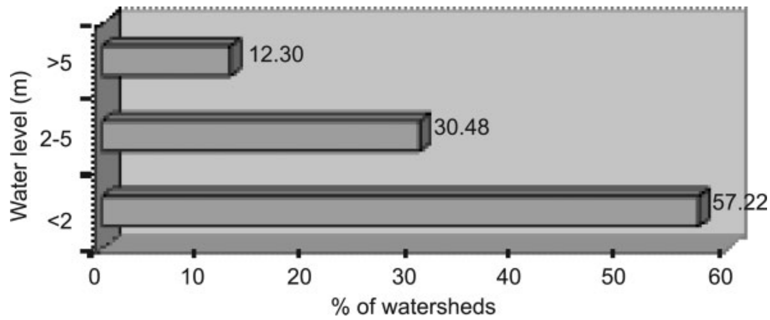

Figure 11.8 Distribution (%) of watersheds by water level in the wells

impacts on the environment. One of the important objectives of watershed development is in-situ water and soil conservation. Water resources development in the watershed village and the treatment activities helped in conservation and enhancement of water resources. Most of the studies report that water level in the wells increased leading to expansion in irrigated area in the watershed. In practice, only a few studies actually measured the water level in the wells. The increase in water level varied across seasons from 0.1 to 3.5 m. Similarly, the expansion in irrigated area due to watershed development activities varied from 5.6 to 68% across region and season. Experiences show that the increase in water level in the wells is observed to be less than 2 m (57.22% of watersheds). About 30.48% of watersheds witnessed an increase of 2–5 m and only 12.3% of watersheds had an increase of more than 5 m increase in water level in the wells (Figure 11.8).

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, 2001). Conservation and water harvesting measures in the watershed helped in improving the groundwater recharge, water availability for cattle and other domestic uses, increasing perenniality of water in the streams, increasing water table in the wells, sediment trapping behind the conservation measures/structures, and stabilization of gully beds (Madhu *et al.*, 2004). The productivity of crops increased from 6.65 to 16.59% in the watershed village.

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

11.3.4.5 Overall economic impacts

Experiences show that watershed development activities have overall positive impacts on the village economy. Thus, it is essential to assess the impact of these activities using key indicators such as NPV, BCR, and IRR (Figures 11.9 and 11.10). Though these

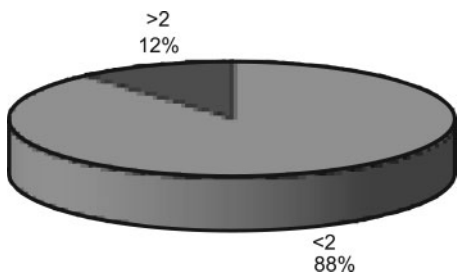

Figure 11.9 Distribution (%) of watersheds by BCR category

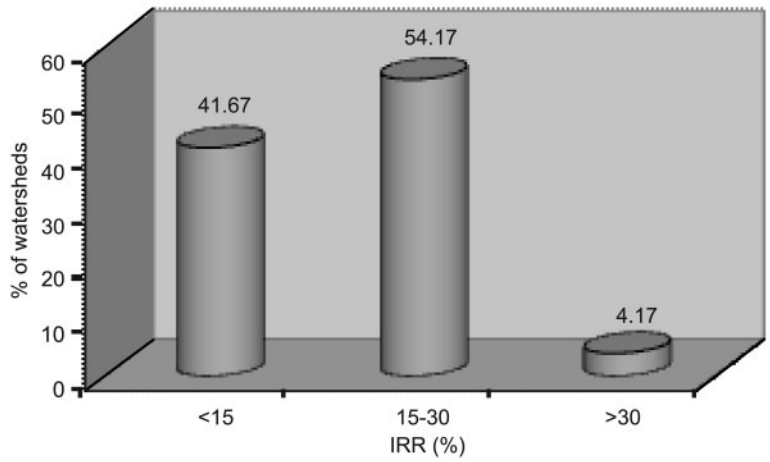

Figure 11.10 Distribution (%) of watersheds by IRR category

indicators show the overall impact of watershed development activities, only very few studies have quantified the benefits and actually estimated the NPV, BCR, and IRR. The reasons for this are: (i) Most of the evaluating agencies are not familiar with the techniques; (ii) Inadequate data availability for quantifying benefits and costs; and (iii) Non-familiarity with computer software used. The overall impact of watershed development activities in terms of NPV, BCR, and IRR are reviewed and discussed hereunder.

A few studies (Palanisami *et al.*, 2002a; Ramaswamy and Palanisami 2002; Milkesha Wakjira 2003; Palanisami and Suresh Kumar 2004, 2006; Lokesh *et al.*, 2006) made attempts to assess the overall impact of watershed development activities through BCR and NPV. The BCR, which is the return per rupee of investment, ranged from 1.27 to 3.7. The size of BCR also depends on the magnitude of the benefits accrued due to the watershed development activities, which in turn critically depend upon the rainfall. The watersheds which have high BCR (>2) received an annual rainfall of 700 to 900 mm. Similarly, the watersheds that receive rainfall <700 mm and

700–900 mm had relatively higher IRR. The analysis also revealed that the BCR is worked out to more than 2 in around 12% of watersheds. About 88% of watersheds have the BCR < 2. Similarly, 41.67% of watersheds showed IRR of 41.67%; 54.17% of the watersheds have IRR ranging between 15 and 30%; and only 4.17% of the watersheds have IRR > 30%.

The BCR varies across regions and depends upon the agroclimatic conditions. For instance, financial analysis of the 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 was 26 and 24%, respectively for Kattampatti and Kodangipalayam watersheds, which is higher than the long-term loan interest rate by commercial banks (12.75%), 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 a fairly high IRR of 38% (Ramaswamy and Palanisami 2002).

Another viable indicator, viz., net returns per rupee of irrigation cost, shows the overall impact of watershed development activities. The net returns per rupee of irrigation cost ranged from 1.4 to 16.32 and varied with type of watershed and season. 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 activities have had differential impacts and varied across size groups. The net return per unit of water (i.e., acre inch of groundwater applied) increased by 3% and 30%, respectively for small and large farmers under watershed development program implementation. Water use and net returns per acre of gross irrigated area (GIA) for farmers in the upstream increased by 68% and 66% respectively and in downstream by 48% and 110% respectively (Mengesha 2000).

The Net Present Worth (NPW) indicates that the watershed development activities produced desired results as evidenced from positive NPV. The NPV of the benefits derived from various watershed treatment activities was ₹1.24 million (Milkesha Wakjira 2003). From these indicators [NPV (positive), BCR (>1), and IRR (>the opportunity cost of capital)], one can speculate that the watershed development activities are financially feasible and economically viable.

11.3.5 Comparison of the methods

The methods discussed above have their strengths and weaknesses (Table 11.9). The major constraints are the non-availability of reliable data and the expertise to analyze and interpret the data. However, depending on the situation and data availability, the method of evaluation can be targeted. For example, in situations where no detailed data is available, simple BCR and IRR will give some idea about the impact of the watershed investment; whereas in regions where detailed information on biophysical aspects are available and the aim of the evaluation is mainly to evaluate the impact of the different biophysical factors, then biophysical modeling will be an appropriate choice. Once some key data on biophysical aspects are available from the model watersheds in each region, the bioeconomic models can be easily targeted. In the case of the economic analysis where only the total benefits of the watersheds should be analyzed,

Table 11.9 Comparison of different watershed evaluation methods

Method	*Major advantage*	*Major limitation*[a]
Conventional Analysis	Quick to estimate	Sensitive to i and n*
Econometric Models	All sectors included	εd and εs sensitive**
Bio economic Models	Whole system included; optimization	Too much experimental details
Meta Analysis	Macro picture given	Aggregation bias

[a] i = discount rate; n = life period; εd = price elasticity of demand; εs = price elasticity of supply

the economic surplus methods will be appropriate as it takes into account both the producers and consumers surpluses.

11.4 CONCLUSIONS AND POLICY RECOMMENDATIONS

With the large investment of financial resources in the watershed program, it is important that the program becomes successful. Hence the challenges in watershed impact assessment should be given due importance in the future planning and development programs. Realizing the potential and importance of watershed development and their likely impact on the economy, enough efforts have been made 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 the monitoring and evaluation of watershed development projects.

This chapter has thus demonstrated the importance of different watershed evaluation methods with adequate explanation with the field data and derived results from the analysis. The results had indicated that watershed development activities have been found to have significant impact on groundwater recharge, access to groundwater and hence the expansion in irrigated area. 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 rainwater and hence groundwater recharge. Thus, the combination of public and private investment will enhance the return to investment in watershed programs. Therefore, the policy focus must be on the development of these water harvesting structures, particularly percolation ponds wherever feasible.

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

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

The watershed development technologies benefit not only the participating farm households but also the non-participating farm and other rural households in the watershed villages. The economic surplus method has emphasized the need for enhancing the farm income through the adoption of alternative farming system combining agricultural crops, trees, and livestock components with comparable profit as both consumers and producers will have enhanced benefits.

In order to strengthen the applicability of the watershed evaluation methods, strong data base is important. The data generation through model watersheds in each region will help strengthen the evaluation mechanism in an effective manner. Also in each implementing department, separate data bank should be maintained starting from the benchmark data on the watersheds. The details should cover all aspects of costs and benefits of the watershed development programs. The staff can be given the needed training on data collection, data storage, and basic analysis. The officials from the government departments, evaluation departments, and research institutions should be sensitized about the use of different watershed evaluation methods including handling of the data from the fields.

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