SOCIO - ECONOMIC ASPECTS OF WATERSHED MANAGEMENT PROGRAMMES IN INDIA

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INTRODUCTION

Depletion of soil and water resources continues to be a major hazard in India. About 52% (173.65 m ha) of the total geographical area of India is subjected to varying forms of soil erosion and yields soil loss to the tune of 5,333 m t/annum (16.35 t/ha/yr.). Declining productivity, under-nourishment and under-employment are direct consequences of our poor land management system. High volume of runoff, soil loss, sedimentation rates and increasing loss through natural calamities (floods, droughts, mass wasting, nutrient losses etc.) are the indirect effects of irrational utilization of natural resources. The monetary value of indirect losses of reservoir sedimentation and nutrient losses were estimated to be Rs. 106 m and Rs. 4800 m respectively (Das, 1994).

Indian scenario

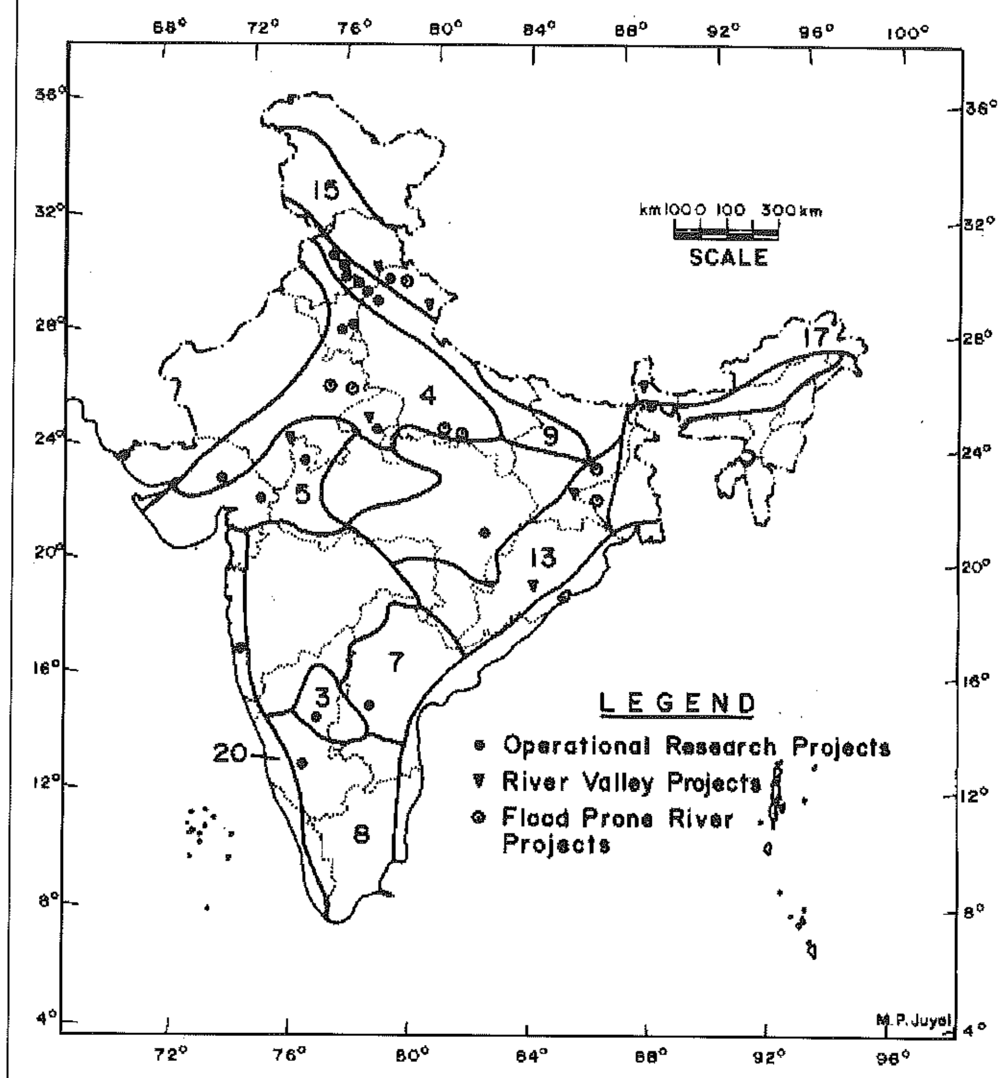
Research was intensified by establishing the Regional Soil Conservation Research, Demonstration and Training Centres during the First Five Year Plan (1951-55) to conserve soil and water resources. Technology packages developed by the centres were demonstrated on farmer's fields as well as on common lands under various soil conservation and watershed management programmes. Upto 1993-94, India has spent Rs. 35915 m to treat 37.34 m ha. Till the early 1980s, the performances of watershed management programmes were below expectations due to the fact that they were single targeted, top-down administrated and insufficiently coordinated (Dhyani and Singh, 1991). The success of three model watersheds demonstrated by the Central Soil and Water Conservation Research and Training Institute, Dehradun during 1970s has opened new vistas of development (Agnihotri et al., 1989; Dhyani et al., 1993 and Ram Babu et al., 1994). Consequently, watershed management has become synonymous to a new developmental approach in rural India. Since then, various rural development and soil conservation programmes are on going on watershed basis; these include River Valley Projects, Flood Prone River Projects, Drought Prone Area Projects or other Watershed Management Programmes. During the Eighth Plan, soil conservation and rural development programmes under various projects are being implemented on a watershed basis with an outlay of Rs. 28,000 m to treat about 6.6 m ha area. The analysis of 32 watershed management projects is presented here.

DESCRIPTION OF WATERSHEDS AND THEIR PROBLEMS

The watersheds selected from the study include 18 Operational Research Projects (ORP), 7 Flood Prone River Projects (FPR), located across 10 agro-ecological zones (arid to humid) and 14 states of the country (Fig. 1). These watersheds vary in size from 90 ha (Nada) to 1.7 m ha (Upper Damodar Valley), have varied annual rainfall (525 to 3000 mm) and are located at elevations from 120 to 3000 m above msl. Ten soil groups represented in the study watersheds are alluvial, black cotton, red, lateritic, red yellow, silty loam, red brown, loam, black red and loamy sand. The problems faced of land degradation are unique for each region. Denudation and mass wasting in Himalayan region; denudation, flash floods, high sedimentation rates and droughts in Shiwalik; sheet, rill, gully and ravines in the Northern Plains

and Central Highlands; sheet, rill and drought in Malwa region; flood, rill and ravines in the Chhota Nagpur plateau and shifting cultivation in the Eastern Himalayas and parts of Orissa are the major types of land degradation problems. In each programme a nodal agency was identified and made responsible for overall planning, coordination, monitoring etc. Programes were implemented by state line departments with the technical support of the Indian Council of Agricultural Research and State Agricultural Universities.

Figure 1: Location of the watesheds - India



Zone	Agro-ecological zone	Zone	Agro-ecological zone
3	Decan Plateau (Hot Arid)	9	Northern Plain (Shiwalik)
4	North Plain & Central High Lands	13	Eastern Plateau (Chhota Nagpur)
5	Central High Lands	15	Wastern Himalaya
7	Deccan Plateau (Telangana)	17	Eastern Himalaya
8	Eastern Ghats	20	Western Ghats

WATERSHED MANAGEMENT PLAN AND ACTIVITIES

A unique comprehensive Watershed Management plan comprising of foundation structure and production system was developed for each watershed. The plan and activities were made compatible to physiography, hydrology, soil, land capability, vegetation, irrigability and socio-economic conditions of the region.

- **Foundation structures**
  These include small dams, tanks, water distributions system, spillways, gully plugs, check dams, silt detention basins, trenching, embankment, terracing, leveling, bunding and dug out ponds. They were constructed on the basis of plans ensuring technical feasibility and economic viability. About 60 to 80% of the total expenditure of watershed was utilized under this sector.

- **Super structure of production system**
  Efficient use of conserved resources was made by putting the land under most suitable productive use. For improved farm technology extension, a large number of demonstrations were conducted on farmers' fields to demonstrate the efficiency and efficacy of available technologies for sustained development. These demonstrations were held in a participatory mode to assure acceptance and make them "a people's programme".

WATERSHED RESPONSES

Production with protection on a sustained basis and generation of gainful employment within the watershed constitute two of the multiple objectives of the watershed management programmes. Responses of selected watersheds on production, protection, employment generation, common property resource management, equity and economies are discussed here.

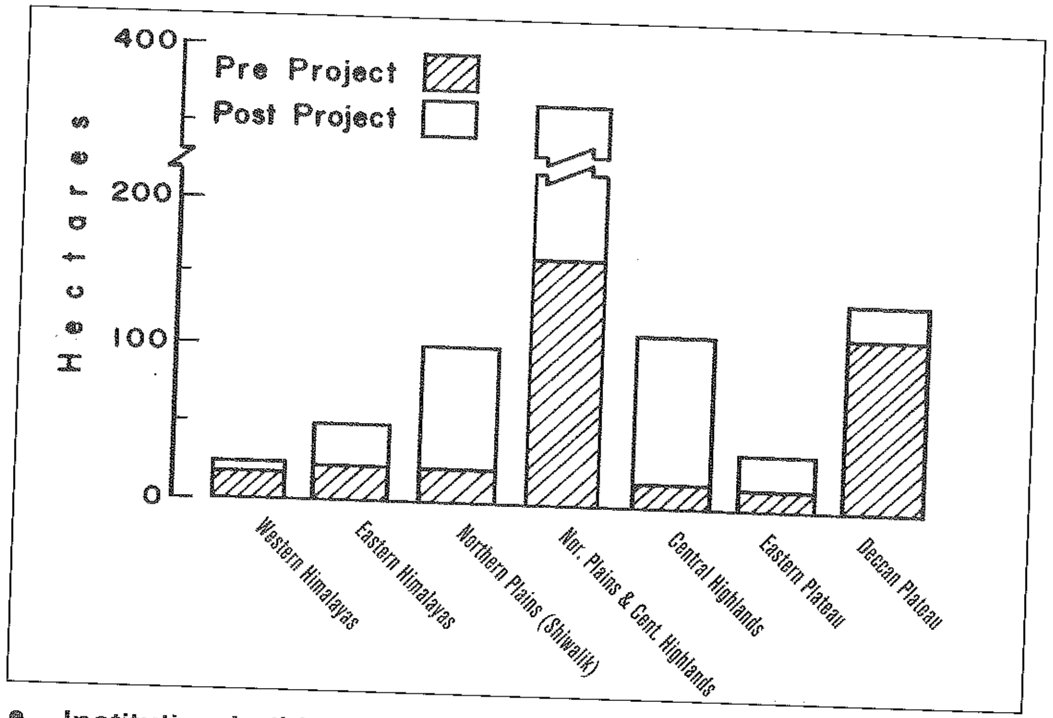
- **Productivity and production**
  Implementation of watershed management programmes enhanced irrigation potential by 40 to 333% with maximum in the Northern Plains and the Central Highlands, improved in-situ moisture conservation and increased cropping intensity by 36% (maximum 90% in Northern Plain). This has increased the productivity of arable land by 4.2 to 15.4 q/ha (average -7.8 q/ha) and of non-arable land by 1.0 to 8.5 t/ha with an overall average of 5.5 t/ha in different agroclimatic regions (Figs. 2 to 4). Milk production has also increased by 40 to 350,000 l/yr due to substitution of low yielding local animals with high yielding animal breeds and availability of good quality fodder.

- **Employment generation**
  Watershed Management programmes may yield productive and protective benefits in perpetuity if they are economically sound, provide gainful employment and become an integral part of the farming system. Implementation of mechanical measures generate casual (short period) employment opportunities. In our study this varied from 46 (Mandavarsa) to 506 (GK3a Gomti) man days per hectare with an average of 215 man days. Enhanced productive potential owing to a change in land and animal husbandry practices from extensive to intensive and traditional to improved, generated regular employment opportunities (20 man days/ha/yr.). On an average, various watershed management activities generated gainful employment at the rate of 2 to 54 man days /hectare /annum (Fig. 5).

- **Protection**
  The protective benefits from watershed management programmes occur in the form of reduction in runoff volume, in peak discharge, in sediment yield and an increase in lean period flows over a longer time and in recharge of ground

water. Data collected from different watersheds indicated that watershed management programmes have succeeded in achieving these objectives (Fig. 6). The reduction in runoff ranged from 2 to 42%, soil loss from 10 to 80% and peak discharge from 20 to 40% in all the watersheds except in Ramganga and Sutlej where soil loss increased about 30% and runoff by 15% (in Sutlej) due to heavy human and biotic interference during the latter part of the project. This resulted in an increase in ground water table 90.8 to 2.0 meters), and volume of lean period flow and minimized the stream widening and other associated down stream environmental degradation. Thus, the ill effects of drought were moderated to a great extent. In addition, it also helped in changing the Indian agriculture by reducing risk and uncertainty, increasing certainty so that the farmer could develop a successful farm plan.

Figure 2: Impact of watershed management programme on irrigation



- **Institution building and common property resources management**
  Participatory watershed management assumes organization of grassroot level institutions for managing community owned or common access resources. Societies were registered with well defined by - laws and financial arrangements. The Watershed Management Society in Bunga watershed in the Shiwalik hills (north-western plain) generated an income of Rs. 6,85,000 from the sale of various common property resources (grasses, irrigation water, fish culture) during the period from 1984 to 1996. An amount of Rs. 4,77,000 was incurred on participatory investment and expenditure on various items (repair and maintenance, watchman, investment on community activities like school, community centre, veterinary hospital, temple etc.) during the same period (Samra, 1997).

- **Equity**
  Watershed management programmes have been designed so as to benefit all sections of the society. In Fakot (western Himalayas) watershed, the total income increased by 44% and farm income by 49% in the treated watershed (Dhyani et al, 1997). The increased income from the watershed development programme was relatively more equitably distributed in the community (Fig. 7).

- **Economic viability**

  The economics of investment in watershed management has been judged by various workers and agencies/organizations in India. Generally, budgeting techniques were employed. The range of project life varied from 10 to 55 years and the discount rate varied from 10 to 15%. The BCR of these projects varied from 1.07 in Nada, 3.42 in Tejpura and 3.94 in GYIJ (Gomti) watershed, considering productive benefits alone (Table 1). Protection benefits like production of Oxygen, conversion to animal protein, addition to soil fertility, improving humidity, protecting birds etc. and control of air pollution were also considered in some of the projects. This improved their BCR (7.06 and 5.16 in case of Sutlej and Ramganga) and computed @ US $ 20 per ton of tree weight per year (ASC, 1991). The internal rate of return (IRR) were higher than 16% indicating economic soundness of the projects.

Figure 3: Increase in productivity in arable and non-arable lands

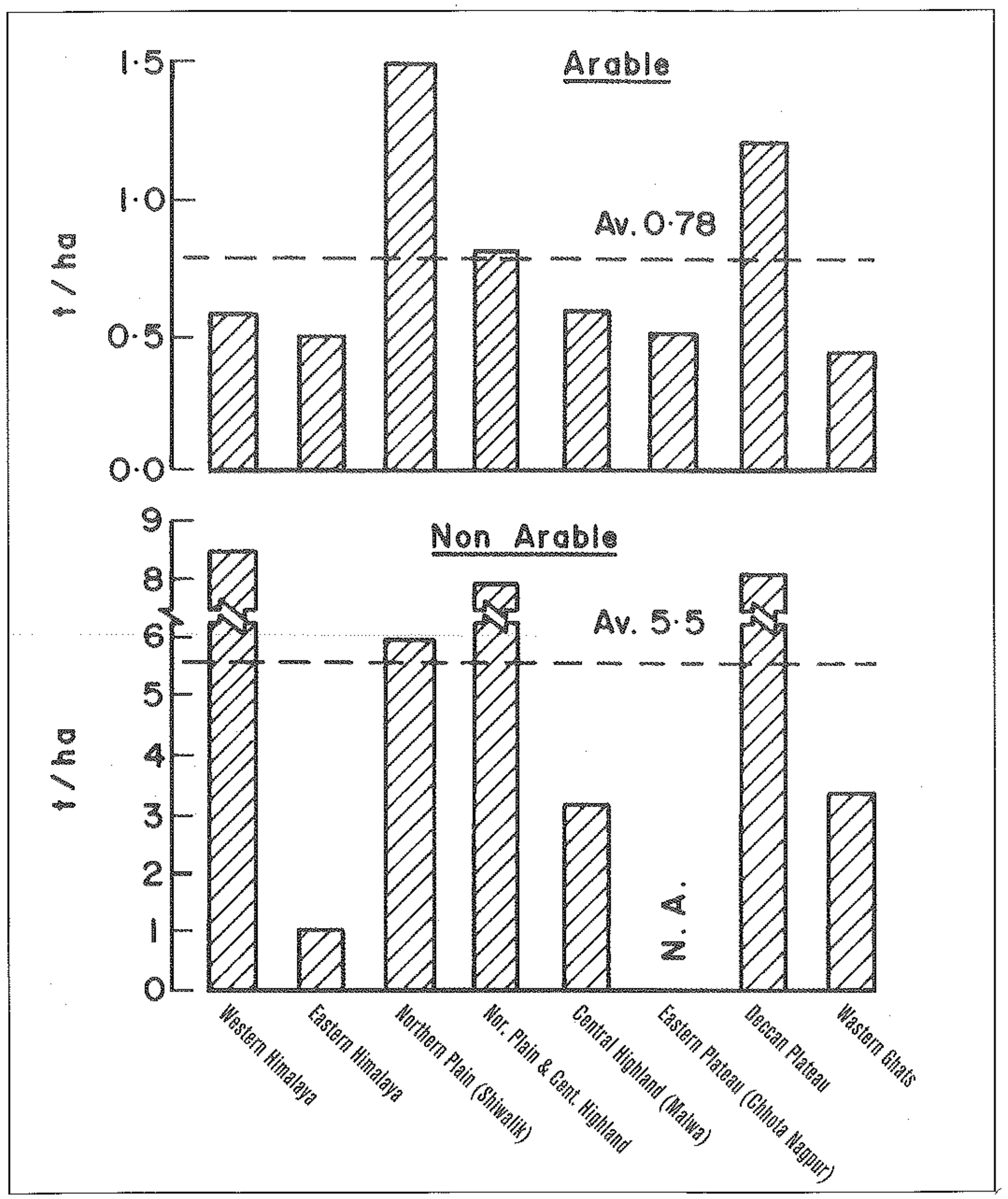


Table 1: Economic evaluation of watershed management programme, India

Watershed	Project life (yrs.)	Discount rate (%)	Benefit cost ratio	Net present value (m Rs)	Internal rate of return (%)
REGION : WESTERN HIMALAYAS					
Fakot	25	10	1.92	0.5	24
Ramganga	45	10	5.16*	1201.5	–
Sutlej	45	10	7.06*	4203.3	–
REGION : NORTHERN PLAINS (SHIWALIK)					
Rel Majra	20	12	1.20	0.7	–
Sukhomajri	25	12	2.06	–	19
Nada	30	15	1.07	–	12.3
Bunga	30	12	2.05	–	–
Mali	50	15	1.10	2.4	–
Chohal	50	15	1.12	1.6	16.8
REGION : NORTHERN PLAINS & CENTRAL HIGHLANDS					
Bajar–ganiya	20	15	1.58	–	17.0
Khar kalan	15	15	6.07	10.9	–
Kishangarh	15	15	2.35	5.8	–
Matatila (U.P)	12 (Agric.)	12	3.80	9.3	41
	20 (Forestry)	12	4.50	–	–
Tejpura	10	10	3.42	–	–
GYIJ (Gomti)	21	15	3.94	12.5	50.0
GK 3a (Gomti)	21	15	1.97	3.7	25.8
Navamota	30	12	2.00	0.8	–
Nartora	55	15	2.25	1.3	44.6
REGION : CENTRAL HIGHLANDS (MALWA)					
Rebari	20	12	2.65	0.9	37.5
Chhjawa	20	10	2.06	–	–
Mandavarsa	20	15	1.97	1264.9	66.5
REGION : EASTERN PLATEAU (CHHOTANAGPUR)					
Damodar Valley (U)	15(#)	15	2.94	–	47.8
	15 (Structures)	15	1.75	–	46.7
	25 (Forestry)	13	2.09	–	31.6
Upper Jayantia	15	15	1.28	0.3	21.4
Taldengra	25 (Agric.)	15	1.62	15.6	41
	25 (Forestry)	15	5.23	16.9	50
Machkund–Sileru	25	10	4.39*	–	–
REGION : DECCAN PLATEAU					
Joladarashi	15	15	1.45	1.7	–
Chinnatekur	15	15	1.88	18.5	–
G.R. Halli	15	15	1.48	0.9	–
REGION : WESTERN GHATS					
Khumhave	20	15	2.10	–	N.A.

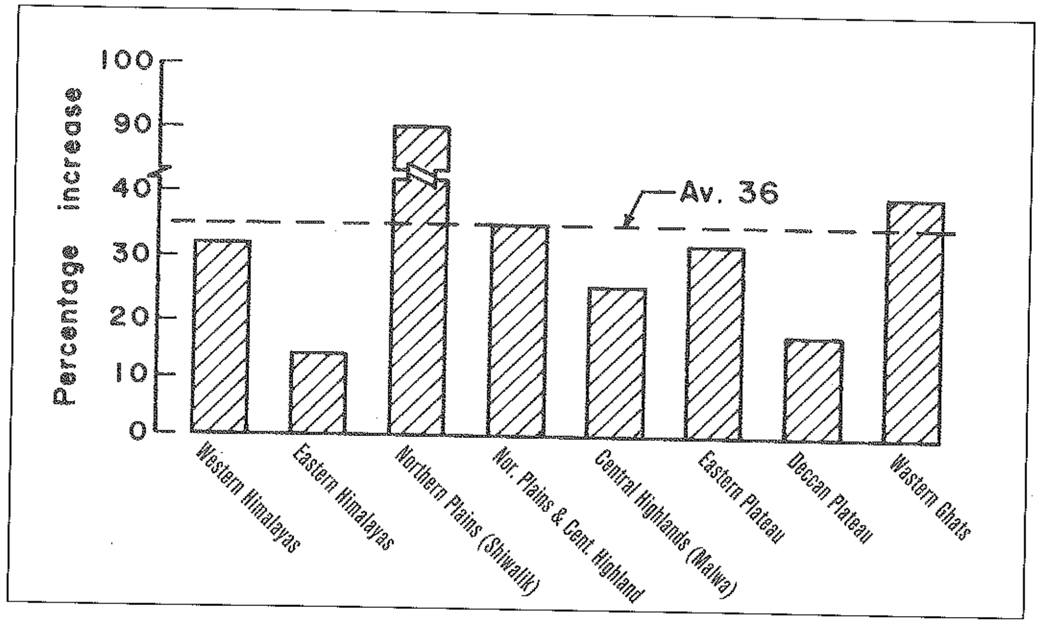
* Includes protective benefits; # (water harvesting structures)

Table 2: Constraints in watershed management programmes

Constraints	Watershed Region					
	Western Himalayas	Northern Plains (Shiwalik)	Northern Plains (Aravali)	Central Plains (Ravine)	Eastern Plateau (Red soil)	Eastern Plateau (Black soil)
A. TECHNOLOGICAL						
- Technology status	4	2	3	2	1	2
- Level of awareness	4	3	3	3	3	3
- Problem identification	3	2	3	2	3	2
B. TRAINING & EXTENSION						
- Availability of skilled manpower	4	3	3	3	3	2
- Implementation capacity	4	2	2	2	2	2
- Training facility	3	2	2	3	3	3
- Educational facility	4	3	3	3	2	2
C. ORGANISATIONAL AND STRUCUTRE						
- Planning	3	3	2	3	3	2
- Coordination	3	2	3	3	2	2
- Motivation & people's participation	4	2	2	2	2	2
- Monitoring & evaluation	3	2	3	3	2	2
D. INSTITUTIONAL AND POLICY ENVIRONMENT						
- Land ownership and tenure	4	3	2	4	2	2
- Agril. support service	4	2	2	3	3	3
- Market opportunities	3	2	2	2	2	2
- Financial	3	3	2	2	2	2
- Policies & legislation	3	2	2	3	2	2
E. FARMERS INTERNAL SOCIOECONOMIC CONDITIONS						
- Goal of farming community	4	4	4	4	3	3
- Economic condition	4	3	3	4	3	3
- Grassroot level organization	4	2	2	4	3	3
- Landholding	4	2	2	3	3	3
- Fragmentation	4	2	2	2	3	2
- Literacy	3	2	2	3	2	2

4 - Very severe 3 - Severe 2 - Moderate 1 - Low

Figure 4: Percentage increase in cropping intensity



CONSTRAINTS

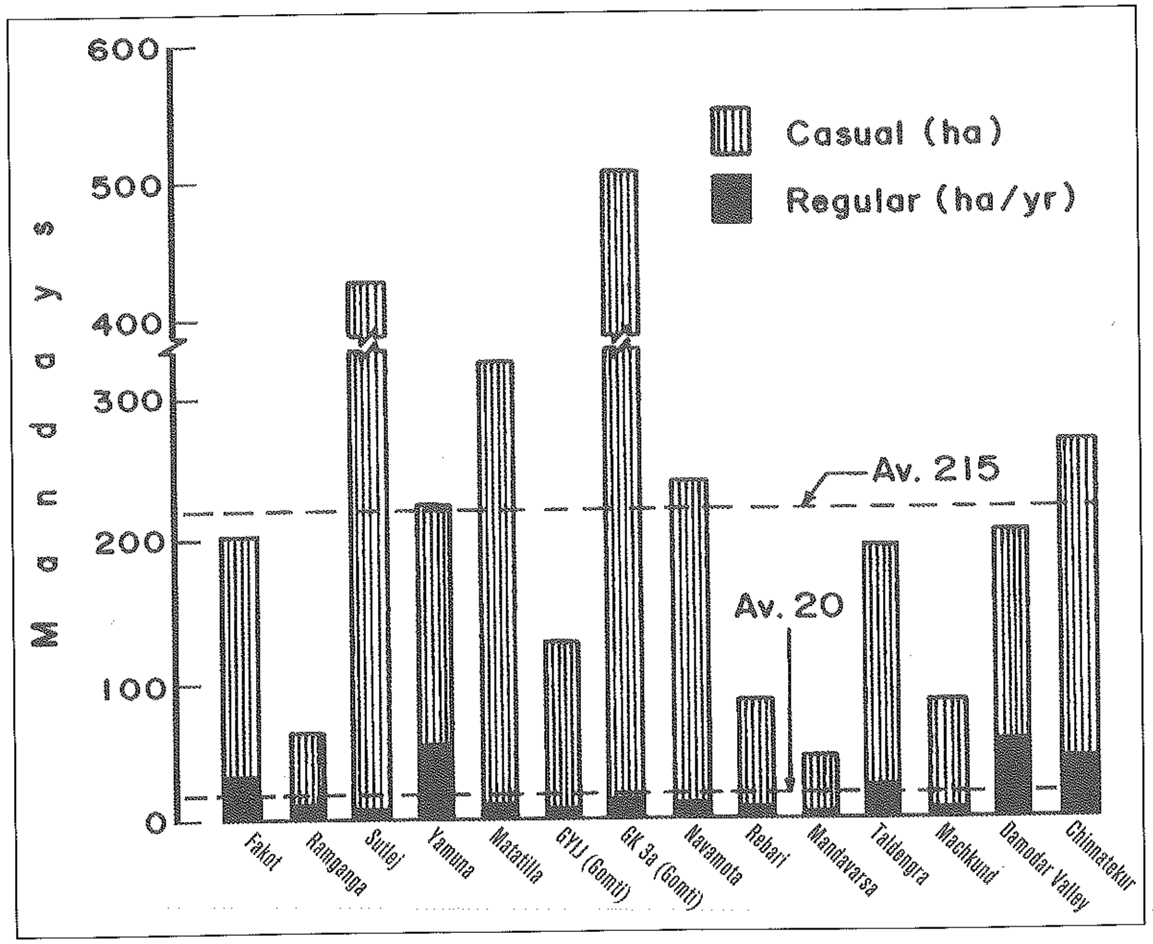
Watershed management is a strategy for the optimal management of land, water and vegetation resources in a given techno-socio-economic and political environment. It is, therefore, the technocrats, administrators, policy-makers, farmers and their groups who are the key factors for the degree of success of the WSM programmes. The issues regarding the betterment of the watershed management programmes have been analyzed earlier (Tejwani, 1986, 1993). By constraints in watershed management, we mean the circumstances which force land users to opt for suboptimal solutions rather than the correct optimal solutions of the problems. The constraints faced in the selected watershed in different regions have been classified in five broad groups: technological; training and extension; organizational and structural; institutional and policy environment; and internal socio-economic conditions of the farmers. These constraints were further classified in sub-groups and measured on a four-point scale (very severe, severe, moderate and low). The results are summarized in Table 2.

- **Technological**
  This group includes the availability of technology for the identification of problems and their solutions at the grassroots level; level of awareness among the farming community about degradation and its management; capability of the planning and implementing agencies to identify the main problems and their possible solutions within a given framework. The technological development process, routed though a careful analysis of the available indigenous techniques, may provide more suitable, socially acceptable and sustainable solutions which may lead to their mass adoption. These constraints were more severe in the Himalayan watersheds (Ram Ganga, Sutlej).

- **Training and extension**
  The outcome of the watershed management programmes depends mainly on how efficiently they are planned, implemented and to what extent they involve the local people. The people involved in watershed management programmes should not only have skill in their own disciplines but also have a sound knowledge of soil-water conservation principles and practices. It has been observed that in most of the programmes, except in the Operational Research

Projects, the benchmark surveys were either not carried out or analyzed from the watershed management perspective, due to a lack of trained manpower, or poor understanding of its importance (Gomti, Khar Khan Kalan watersheds). Trained manpower is lacking in the Himalayan and Deccan Plateau and Eastern Ghats Region in general, and in the RVPs and FPRs, in particular.

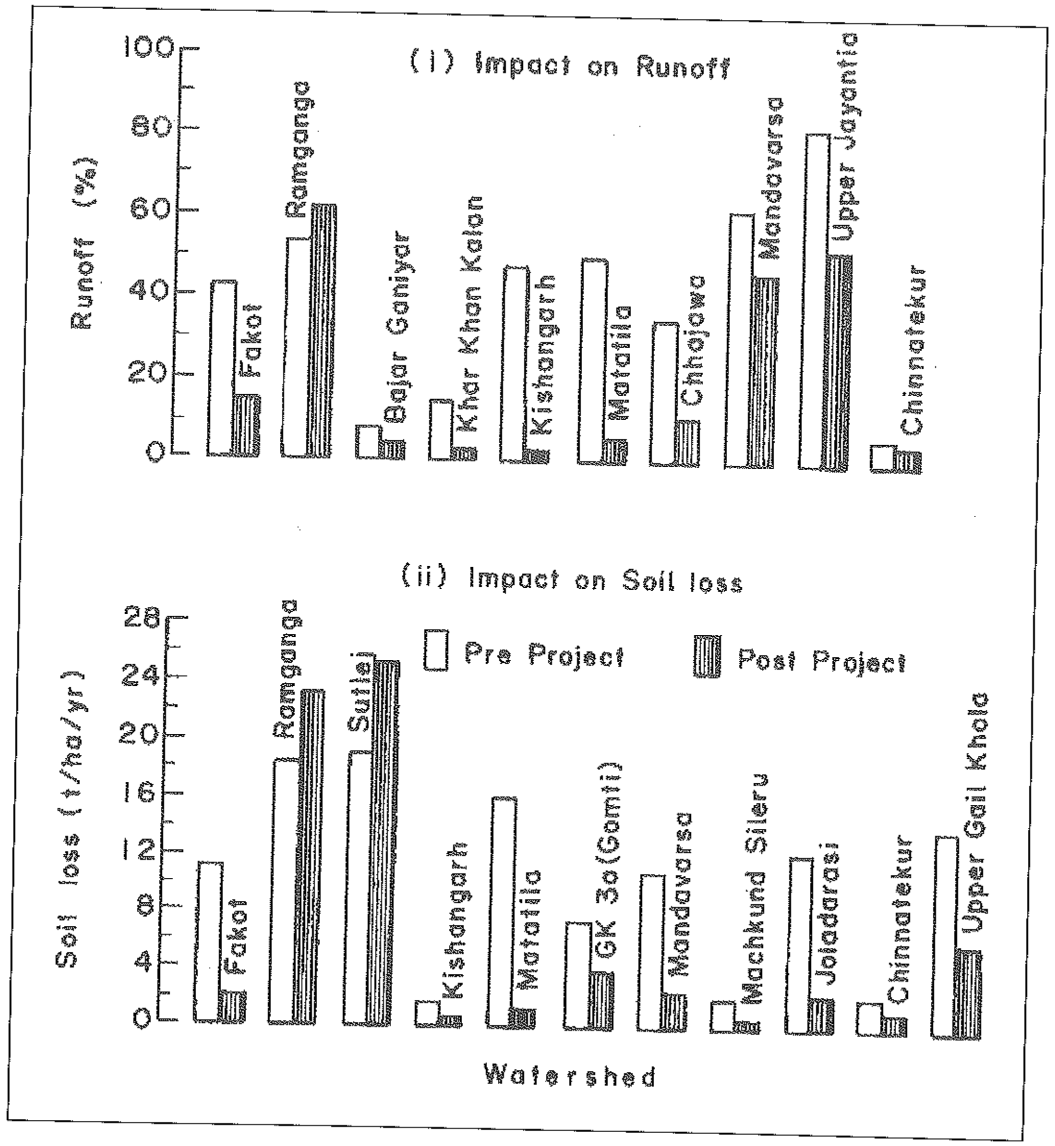
Figure 5: Employment generation through watershed management programmes



- **Training** Training of officers is the responsibility of the Central Government and is being conducted by the Central Soil and Water Conservation Research and Training Institute, Dehradun. Training of the middle and field level executives is the responsibility of the Central and State Governments. A few State Governments have established their own training centres. Even then, there is a shortage of trained manpower which is further compounded by the frequent transfer of trained manpower from Soil and Water Conservation or Watershed Management division to other departments. Trainers' training programme do not include social and economic aspects resulting in poor understanding of watershed management programmes.
- **Extension** Field demonstrations and mass media are widely used for the extension of technology in India. Most of these demonstrations are based on the sectoral approach where technical experts lay out field demonstrations to show the superiority of modern technology over the prevalent practices. In these programmes, farmers work as passive recipients of the demonstrated technology as in the case of RVPs and FPRs. The novel approach of technology extension adopted in the Operational Research Project watersheds was to initially create awareness about the programme. Farmers were made aware about the

programme through group discussions, meetings and field visits before the demonstrations took over. Field demonstrations were modified in consultation with the farmers. Modified demonstrations in an integrated manner were carried out by farmers under the technical guidance of experts. The participatory approach of the demonstration provided sufficient opportunity to the beneficiaries to know about each component of the improved technology, which made them active recipients. It also helped to make the programmes viable and sustainable which resulted in higher productivity of all the land uses in the watershed, and in an overall improvement of the environment and socio-economic conditions of the farmers and society.

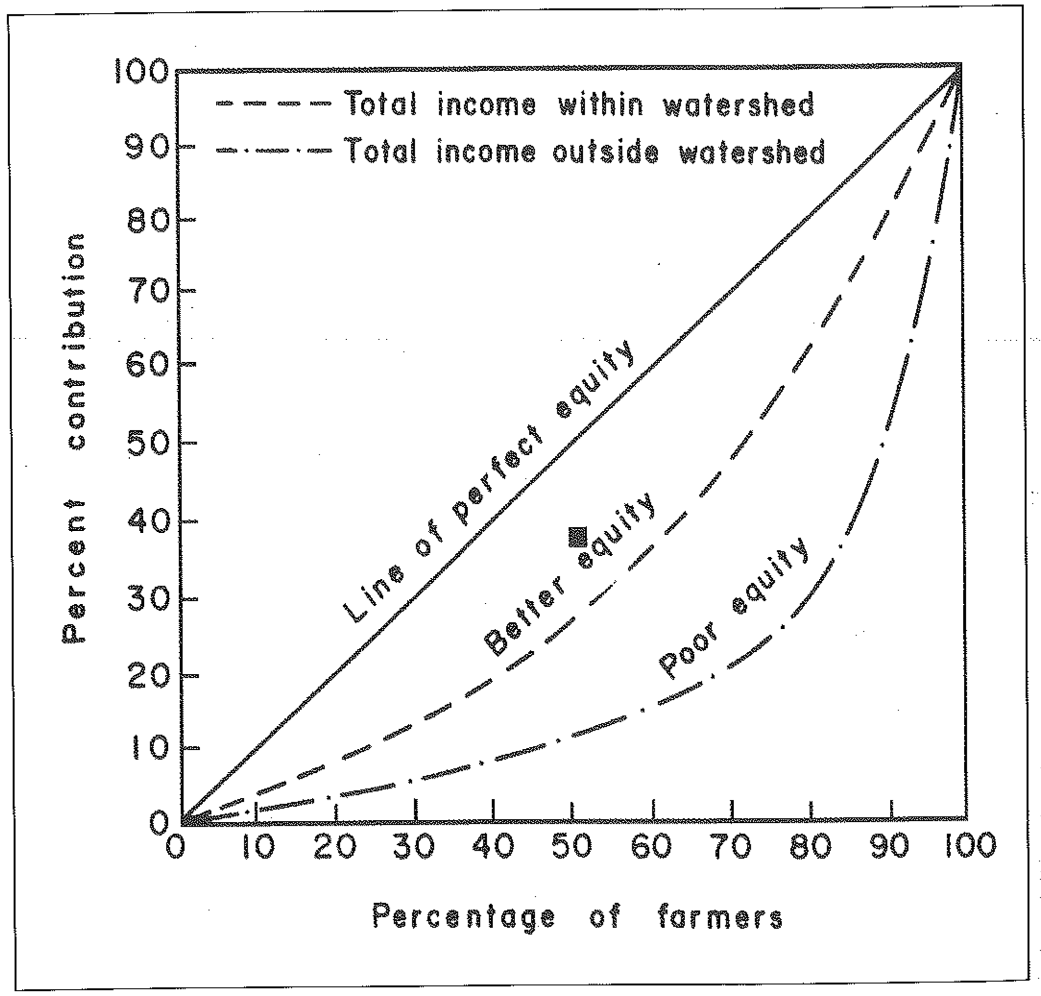
Figure 6: Impact of watershed management on runoff and soil loss



- **Organizational and structural**
In India, the responsibility of the majority of watershed management programmes is given either to the state Forest or Agriculture Departments depending on the major land use in the watershed, and is called the nodal agency (Hufschmidt and Tejwani, 1993; Tejwani, 1993). The planning and implementation is done independently by the respective state departments. The central nodal agency is responsible mainly for the allocation of funds and

monitoring of physical and financial report from the concerned state departments. Weak coordination among state departments (soil conservation, agriculture, forestry, horticulture, minor irrigation etc.) was observed in most of the RVPs and FPRs and resulted in sectoral plans of watershed management projects. The nodal agency merely combines these sectoral plans to prepare a total watershed management plan or a progress report. The involvement of farmers and local bodies in planning and implementation of watershed management programmes has been emphasized (Chandrakanta et al., 1988; Singh and Dhyani, 1992; Prasad et al., 1987). However, it was not adopted even in some of the Operational Research Projects like Kumbhave and Tejpura watersheds (Talashilkar, 1990; Hazra et al., 1987). Watershed management plans of Taldengra, Kishangarh and Upper Jayantia watersheds are based on poor benchmark data when the nodal agency is the forest department (AFC, 1991; IN-RIMT, 1994a). This may be due either to a lack of trained manpower or poor interaction of the forest department with the farmers. Further, coordination between line departments was found to be better when the Development Commissioner or the District Collector worked as the coordinator. Further, the present monitoring system is merely a compilation of physical and financial achievements from the lower to the higher level, mostly without considering the impacts of WSM on the production and protection aspects. It may be due to weak guidelines and poor understanding by the field workers. If these changes are not monitored, accounted and recorded in a proper form, it is difficult to utilize them for impact and evaluation analysis.

Figure 7: Distribution of total income in the Fakot (U.P. Hills) watershed

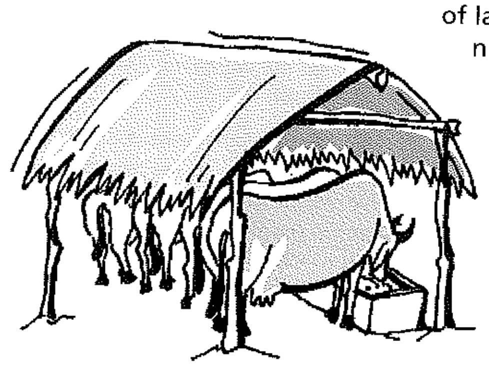


- **Institutional**
  Land degradation represents an externality or market failure of the farming system (Huszar, 1991). These externalities can be internalized through the use of regulations, better policy mix to create a conducive environment and to make people responsive through a system of reward and punishment. It can be done through proper land reforms, better market opportunities, agricultural support services and formulation and enforcement of appropriate legislation. Legislation on soil and water conservation passed and followed by various states of India were reviewed and it was found that these legislation have neither created much interest nor the fear among the landusers. This resulted in more arguments and litigation rather than solutions of the problems and reluctance of people to protect the land and water resources (Samuel et al., 1985; Singh and Dhyani, 1992; ASC, 1987; IN-RIMT, 1994a). Site-specific institutional arrangements like the Hill Resources Management Society in the Shiwalik Hills, the Forest Growers, Cooperatives in Gujarat, Bon-O-Bhumi Sanskar Sthayee Samitee, The Arabari Social Fencing Scheme in Bengal, etc., were found to be much more effective than state or national policies in creating the desired awareness among the local people (Chopra et al., 1988; IN-RIMT, 1994b). It is, therefore, suggested that development and strengthening of local bodies should be given due importance in planning and implementation of watershed management programmes.

- **Farmers internal socioeconomic circumstances**
  More than 30% of our rural population is surviving below the subsistence level and depends on harvesting from natural resources. The majority of the farming community is short of means and cannot afford the risk of losing money (Singh and Dhyani, 1992). The cultivation of marginal and sub-marginal lands, steep slopes beyond 50% leading to heavy soil losses, destabilization of slopes (Juyal et al. 1988), are common features of agriculture in the Himalayas. Increasing population pressure, fragmented holdings, low level of exposure to information (literacy) and goal of the farming community (subsistence agriculture) are the other internal circumstances of the farming community which forces it to adopt practices which are hazardous to natural resource health, regeneration and productivity.

CONCLUSIONS

The implementation of soil and water conservation works on watershed basis is being given great importance in India to cater to the needs of its human and livestock population and to mitigate land degradation and environmental hazards. These programmes have been found to enhance the productivity of all forms of land uses and to reduce runoff volumes and peaks, soil and nutrient losses. Watershed management societies formed in the watersheds also helped in maintaining common property resources. The investment on these projects was found to be a profitable proposition based on productive benefits alone. These watershed management programmes had to face many challenges at the stages of planning, implementation, monitoring and evaluation due to one or more of the constraints identified. The performances of watershed management programmes in India can be considerably improved by minimizing these constraints.



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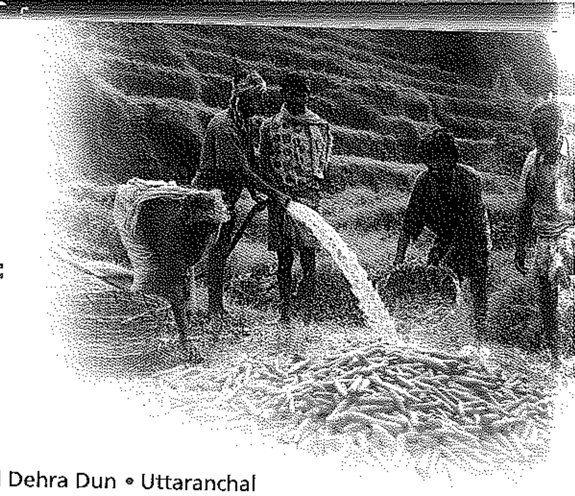

WATERSHED CONDITION ASSESSMENT: INDICATORS AND INDICES FOR MONITORING AND EVALUATION OF IMPACTS

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INTRODUCTION

Watershed development projects affect social, economic and environmental activities. It will be unreasonable to justify such projects on a direct financial basis alone because the flow of social and environmental benefits are of a differing nature and magnitude

Watershed Management is receiving widespread attention as the new paradigm for natural resources conservation and management. The level of concern is evident from the wide variety of national/international programmes and institutions involved in the study and management of watersheds. This holistic approach to resource management is ultimately aimed at understanding the interactive and cumulative effects of a variety of impacts on the watersheds and manage them to protect valued ecosystem functions and improve the overall condition of a watershed. Watershed Condition Assessment (WCA) is a general tool or a method of assessing the environmental conditions of a watershed and has been designed to respond to different needs such as present status and trend of change, watershed prioritization, risk assessment and impact assessment. Watershed impact assessment is essentially a part of the comprehensive process of watershed management.

A major area of concern in the realm of watershed management is the inadequate monitoring and impact assessment of various watershed programmes. Watershed development projects affect social, economic and environmental activities. It will be unreasonable to justify such projects on a direct financial basis alone because the flow of social and environmental benefits are of a differing nature and magnitude. Such projects may generate productive (or direct), protective/reclamative, ecological and employment generation benefits. The monitoring and evaluation in a watershed will help in analysing impacts of current and future activities and accordingly plan area specific management options or alternatives based on the priorities as per the project objectives.

ISSUES

The frequently raised concerns and issues in this regard to assess physical, social, economic and environmental changes caused by watershed management (WSM) interventions are: a) What activities are to be monitored?, b) What frequency?, c) What measures or indices or tools be used? d) How it can be done and e) Who will be responsible?

The paper presents surrogate measures or a set of indicators and indices that could be used to assess changes in watershed condition. A set of biophysical and socio-economic indicators and indices have been demonstrated to summarize the changes in watershed condition or impact as a result of watershed management activities.

MONITORING AND EVALUATION

Monitoring is a process of collecting information/data about certain components, processes or activities for use in designing, appraisal and evaluation. It is done on a regular basis right from the beginning to determine what happened. Baseline survey or benchmark data is a pre-requisite to determine changes during and/or after project implementation. Evaluation is a process which attempts to determine as systematically and as objectively as possible the relevance, effectiveness and impact of the project/activities. Evaluation is done on a periodic basis and serves to analyse a situation to determine why something happened and suggest what might be done to correct an undesirable situation. Evaluation is a discontinuous function whereas monitoring is a continuous or on-line function. Impact assessment essentially involves both, monitoring and evaluation. In a watershed management project, it is necessary to find out the changes in watershed conditions with and without or pre and post project situations.

Impact indicators and evaluation indices

There is no single, definitive indicator or measure or index of overall watershed condition for impact assessment in view of its complexity and diverse /multiple objectives. This can be best explained and examined through direct and/or surrogate indicators or measures. It is usually preferred to select a set or a "suit" of indicators as one indicator alone is not enough to assess impact of watershed activities. Some of the selected indicators may have overlapping interpretations and that would help in cross-checking the conclusions. Ideally, the indicator is a simple, integrative measure that represents watershed condition and usually provides some insight into the process.

A wide variety of indicators are available in the literature that have been used to assess the impact of watershed management programmes specific to their objectives (Arya and Samra, 1995; Dhyani et al, 1997; Samra and Sikka, 1998, Sikka and Samra, 1998; and many more). An exhaustive review of these indicators is given in Bollom (1998). The selection of indicators is very important and should be specific to the project. Kelly and Harwell (1990), Bollom (1998) and our own experience, suggest that the indicators must be simple, easy to measure, have a valued end point, be reliable and valid, sensitive to changes, comparable, replicable, easy to understand and interpret.

MONITORING OF DATA/INDICATORS

Bio-physical data

i) Meteorological: Rainfall and open pan evaporation.

ii) Hydrological: Stream flow/runoff, silt load, periodic groundwater levels through observation wells or piezometers, water quality parameters in relation to use of pesticides and fertilizers, number of wells and their yield and pumping hours.

iii) Tank/Reservoir data: Number of water bodies and their storage capacity, periodic water levels in ponds/tanks/reservoirs, periodic resurvey of submergence area for estimating silt deposition.

iv) Channel morphology: Periodic survey of drainage lines/channels in terms of longitudinal section and cross section for changes in geometry, aggradation or degradation areas and quantification of enroute silt deposition.

v) Arable lands: Area under different crops (single crop/double crop), irrigated/unirrigated, inputs used, crop and fodder yields, fruit yield, biomass.

vi) Soils: Physico-chemical analysis of soil samples before and after treatment from selected sites.

vii) Vegetation: Frequency, density, height, girth and biomass of vegetation at various slope aspect positions.

viii) Land use patterns: Human settlements, cultivation and plantations, grazing, forest, etc.

Socio-economic data

i) Human and cattle population.

ii) Family income from different sources.

iii) Revenue from Common Property Resources (CPR).

iv) Cattle population (type and composition).

v) Milk, meat production.

vi) Changes in housing patterns e.g. mud to concrete.

vii) Source of fuel/energy for domestic uses (for working out dependency on forest for fuel and fodder).

viii) Assets and consumer durables acquired.

ix) Literacy levels (male and female).

x) Growth of agro-based/cottage industries.

xi) Growth of developmental and infrastructural institutions e.g. health care, banks, communication, educational institutions, marketing, etc.

EVALUATION/ASSESSMENT INDICES

Some bio-physical measures/indices

Some measures or indices being used in our watershed management projects are as follows:

A. Hydrological indices

i) **Changes in runoff depth (i.e. fraction)**: Reduction in surface runoff is a direct measure of watershed treatment effect. This is a simple and easy index and requires runoff measurements at pre-determined gauging sites. Table 1 presents the use of this index, suggesting appreciable reduction in runoff after watershed treatment.

Table 1: Impact of watershed management on runoff and soil loss

Watershed	Runoff as % of Rainfall		Soil loss (tonnes/ha)	
	Pre treatment	Post treatment	Pre treatment	Post treatment
Fakot (U.P.)	42.0	14.2	11.9	2.5
GR Halli (Karnataka)	14.0	1.3	3.5	1.0
Behdala (H.P.)	30.0	15.0	12.0	8.0
Joladarasi (Karnataka)	20.0	7.0	12.0	2.3
Navamota (Gujarat)	25.0	3.7	11.7	1.4

ii) **Peak flow indices**: Ratios of peak discharge for storm events can be compared before and after the treatment or with an untreated nearby watershed. Effect of bunding and terracing in agricutual watersheds in reducing peak discharge is presented as an example in Table 2.

Table 2: Reduction in peak discharge as a result of bunding and terracing in agricultural watersheds

Ratios of peak rates of runoff (AW:FW)	
Before treatment	After treatment
2.35	0.10
2.39	0.09
1.69	0.08
2.66	0.13
2.12	0.17
AV. 2.22	0.11

AW = Agricultural Watershed; FW = Forest Watershed

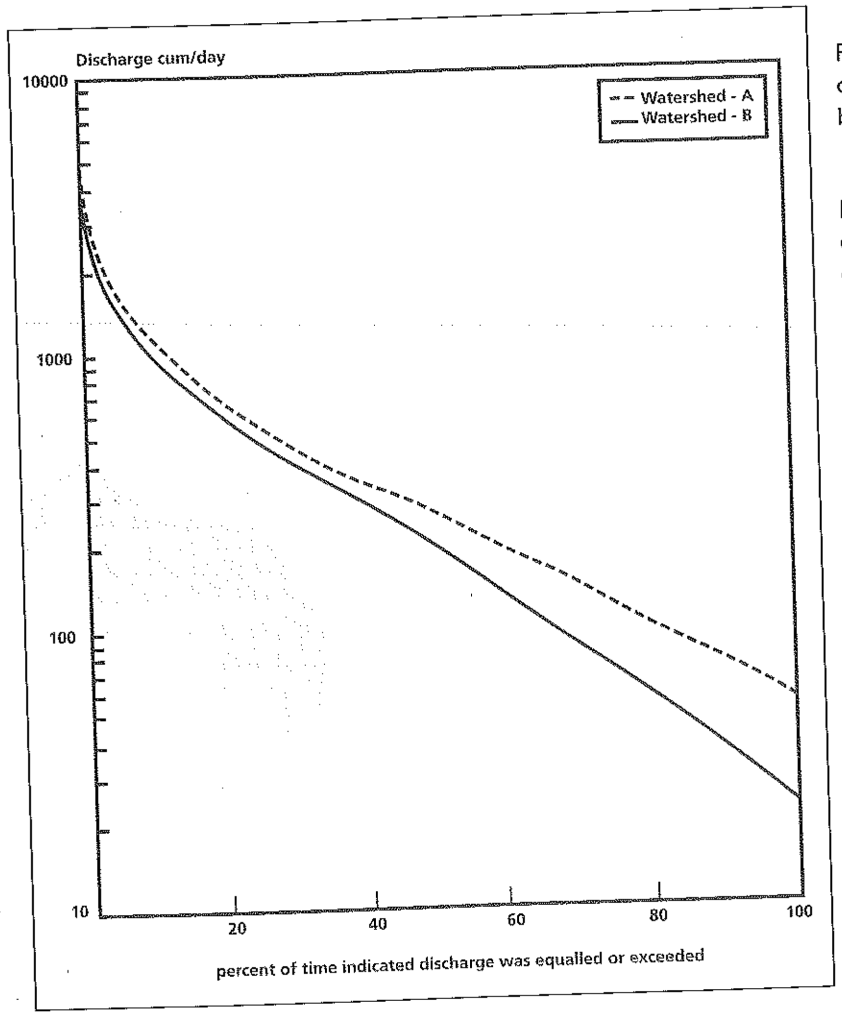


Figure 1: 10 day flow duration curves of grass land (A) and bluegum planted (B) watersheds

Number of peak flow events (above a certain threshold) under different runoff depth classes when compared will give an insight as to how the watershed programmes have increased flow events in lesser depth classes while reducing their occurrence in higher depth class (Table 3). The number of flow events in the lowest depth class i.e., upto 2 mm have increased with a decrease in the number of events in the higher runoff depth class due to treatment (i.e., plantation), suggesting moderation in peak flows.

iii) **Low flow index (LFI)**: This is used as a measure for comparison of low flow (base flow) regime during lean periods. Low flow index of two comparable, adjoining watersheds (A - Control and B - Treated with bluegum plantation) in Nilgiris were found to be as shown in Fig. 1.

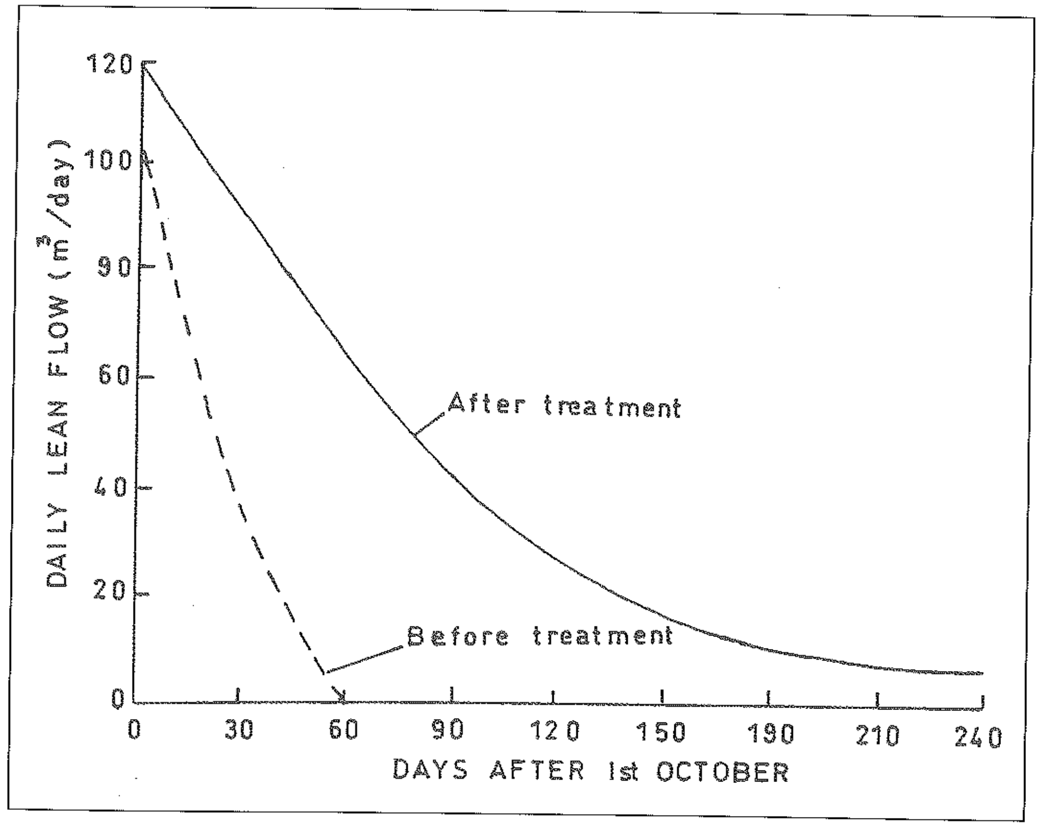
	LFI lit/sec/ha		
	Pre-treatment/ calibration	First rotation	Second rotation
W/S-A	1.30	2.15	1,25
W/S-B	1.25	1.07	0.33
Ratio A/B	1.04	2.00	3.75

Decreased LFI by 2.0 and 3.75 in first and second rotation in Watershed-B explains the effect of bluegum plantation in reducing low flows as compared to a natural grassland watershed. Similar indices can be used to study the impact of watershed management on increased low flows.

Another simple measure of low flow is to compute mean daily flow during the driest month of the year before and after treatment for comparison.

iv) **Increased duration of streamflow (i.e. perennially)**: Watershed treatment measures conserve moisture, help in enhancing infiltration and sustaining base flow over a longer duration. The measured flow data can be arranged and plotted as shown in Figure 2, to demonstrate and quantify the impact of watershed management on enhancing perenniality of flow during the otherwise dry season.

Figure 2: Effect of gully plugs and vegetation on lean flow after cessation of monsoon (i.e. 1st October of the year)



B. Water availability indices

i) **Surface water storages**: Increase in the number and capacity of surface water impoundments, ponds and tanks is a good measure of impact on watershed indicating enhanced water availability. This can be easily done by estimating storage capacity to indicate additional water resources created (Table 4).

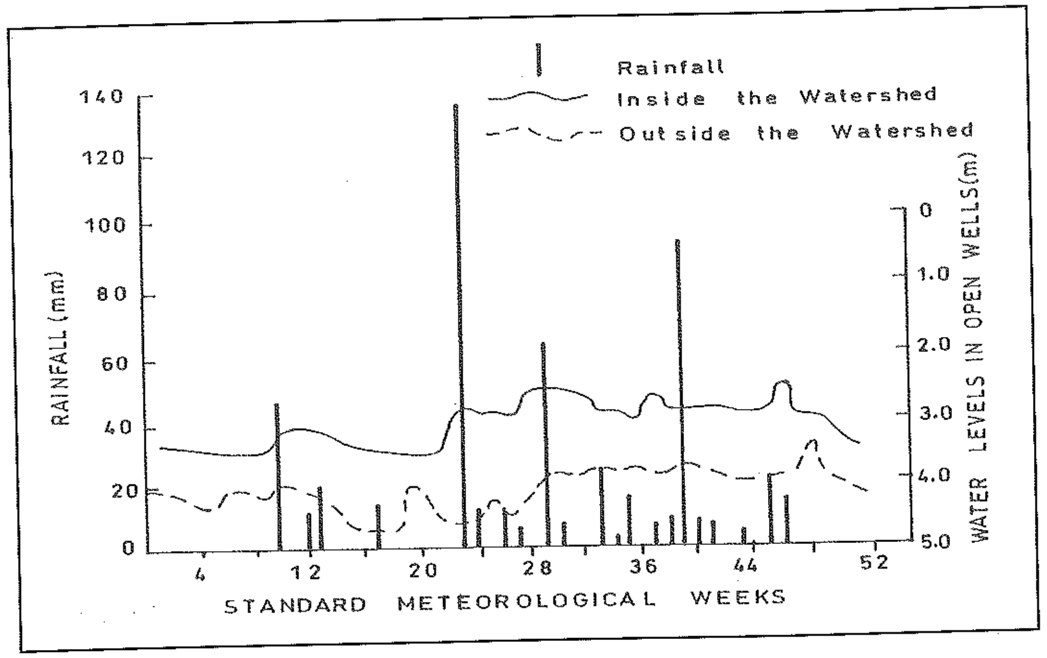


Figure 3: Effect of watershed management programme on ground water recharge in Chinnatekur watershed of Andhra Pradesh (1120 ha)

ii) **Ground water storage**: Increased level of water table is one of the measures to represent impact of watershed management in reducing runoff, inducing infiltration and augmenting ground water recharge. This, in a simple way, can be done by periodically (monthly and/or pre and post monsoon) observing water levels in open wells. It is advisable to observe water level in the morning hours before start of pumping. Ground water levels as observed from open wells can be used to prepare well hydrographs for determining changes. Figure 3 clearly shows the impact of soil and water conservation measures in recharging ground water in Chinnatekur watershed of Andhra Pradesh when its water table is compared with wells outside the watershed (Samra 1997). An increase of about 1 to 2.0m in water table could be observed at different watersheds (Table 4).

Table 4: Effect of watershed management strategies on surface storages and ground water recharge in different regions of India.

Watershed	Surface storage capacity created ha-m	Observed rise in ground water table, m*
Bazar-Ganiyar (Haryana)	79.0	2.0
Bahdala (H.P.)	18.0	1.0
Bunga (Haryana)	60.0	1.8
Chhajawa (Rajasthan)	20.0	2.0
Chinnatekur (A.P.)	5.6	0.8
GR Halli (Karnataka)	6.8	1.5
Joaladarasi (Karnataka)	4.0	0.2
Siha (Haryana)	42.2	2.0
Relmajra (Punjab)	13.7	-

*Difference between pre-project and post-project water table.

Increased ground water storage is computed by knowing change in water table depth and multiplying it by specific yield of the aquifer.

Some indirect measures for groundwater recharge assessment being used are increase in number of wells, increase in irrigated area, cropping pattern, pumping hours before well dries out and hours to recuperate and energy consumption.

C. Soil erosion and sedimentation

i) **Soil loss:** Reduction in the soil loss is a direct measure or index of positive impact on watershed in conserving natural resources. As with other indicators, this can be compared for the period before and after treatment or can be compared with an adjoining/nearby identical watershed as a proxy. Along with the measurement of runoff, soil loss is also measured at specific sites along the stream. Difference in soil loss before and after is taken as an index of this measure (Table 1). It indicates significant reduction in soil loss after the treatment for the respective watersheds.

ii) **Reservoir/pond sedimentation:** This gives a direct measure of loss in pond capacity due to siltation. Results obtained from periodic surveys (before and after construction) of Badholi dam (13.5 m high, 13.7 ha-m storage capacity with catchment area of 59 ha) in Relmajra watershed (Ropar, Punjab) are presented in Table 5 (Samra et al, 1998). These results clearly demonstrate the impact of bio-engineering measures (plantation on slopes with contour trenches, vegetative check dams/barriers/filter strips and loose boulder/gabion check dams in the drainage line) adopted in the dam's watershed area in reducing sedimentation of lake or sediment yield to reservoir by 77% in 3 years. This% reduction in sedimentation can serve as one of the important bio-physical or environmental indices and can be easily obtained by periodic surveys of ponds/tanks.

Table 5: Reduction in reservoir sedimentation at Badholi dam in Relmajra after watershed management

Year (date of survey)	Submergence area		Accumulated storage		Sediment production to reservoir (lake sedimentation)	
	Current	Reduction	Current	Reduction	Current	Reduction
Original 1992	2.954	.....	13.422	.....	N.A.	.....
1992/93* to 1993-94 (July, 1994)	2.115	28.4	8.523	36.5	622.8**	.....
1994-95 (June, 1995)	2.090	0.85	7.960	4.1	142.4	77.1

* Cumulative of 1992-93 and 1993-94, as no survey was done in 1993.
** Average of 2 water years (i.e. 1992 & 1993) after construction of dam.

iii) **Channel bed aggradation/degradation**: Channel aggradation/degradation is determined from periodic surveys (i.e., longitudinal section and cross-section) of channels before and after treatment. These are compared after plotting L-section of different years to determine aggradation and also quantify silt retention behind the structures enroute the channel. This can also be taken as a surrogate measure of performance of drainage line treatment measures. Figure 4 illustrates quick response of drainage line treatment measures in retaining silt