A COMPARATIVE STUDY OF WATERSHED MANAGEMENT PRACTICES OF A FEW WATERSHEDS IN INDIA AND PHILIPPINES

A DISSERTATION

Submitted in partial fulfillment of the
requirements for the award of the degree
of

MASTER OF TECHNOLOGY
in
IRRIGATION WATER MANAGEMENT

By

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CANDIDATE'S DECLARATION

I hereby declare that the dissertation entitled **A COMPARATIVE STUDY OF WATERSHED MANAGEMENT PRACTICES OF A FEW WATERSHEDS IN INDIA AND PHILIPPINES** in partial fulfillment of the requirement for the award of the Degree of Masters of Technology in Irrigation Water Management, submitted in the Water Resources Development Training Center (WRDTC), Indian Institute of Technology, Roorkee, Uttaranchal India is an authentic record of my own work carried out during the period from 16 July 2002 to 30 November 2002 under the supervision and guidance of **DR. S.K. TRIPATHI**, Professor, WRDTC, Indian Institute of Technology, Roorkee.

The matter manifested in this dissertation has not been submitted by me for the award of any other degree.

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SYNOPSIS

The overall objective of watershed management is to utilize natural and human resources in order to achieve specific social and biophysical objectives. Generally, this concept is applied to upstream catchment in a river basin. Watershed management has often been confined as soil and water conservation program. Therefore a watershed management program is needed not only for controlling adverse effect on downstream areas due to human interference in the catchment but also to meet food requirement. Watershed management contributes in increasing productivity and environmental security-the ecological balance between man and the environment.

With the increasing population growth especially in developing countries correspondingly increased the demand for food supplies and thus the demand for irrigated agriculture production necessary to produce sufficient foods proportionately increases. This enormous demand will in turn create serious watershed management challenges where additional supplies of arable land and irrigation water at reasonable cost are almost exhausted. These problems are specially serious where inavailability of water and soil degradation are causing a reduction in the irrigated area due to lack of irrigation water and soil erosion is greatly experienced because of poor and or forgotten watershed management.

In view of the various aspects of watershed management, in this dissertation work a study be undertaken with the following objectives:

1. To study of literature related to watershed management
2. To study measures of various engineering or agronomic structures for the prevention of erosion.
3. To critically examine watershed management practices and approaches adopted by a few watersheds in India and Philippines
4. To illustrate procedure for soil loss estimation
5. To identify major characteristics and treatments adopted by a few watersheds in India and Philippines

In this study, it applies all the gained knowledge to calculate and estimate soil loss using Universal Soil Loss Equation (USLE) and some other empirical formula.

Watershed management approach specifically the few selected watersheds in India and Philippines are critically examined, summarized and system approach using available data.

Recommend and suggest the best strategies, measures and ways and means for the improvement of the watershed management.

INTRODUCTION

1.1 GENERAL

Watershed is that area which is called also as a drainage basin, which is drained by a stream or a system of connecting streams in such a way that all stream flow originated in the area is discharged through a single outlet. Awareness and efforts along watershed management have been considered and implemented globally, however continuous degradation of our natural resources –soils, land, water, forests, minerals etc. mainly because of the very intense use of these natural resources are over exploited and ravaged. Awareness of the varying qualities of watershed or land resources is very essential. The increasing pressure towards the reserved area for watershed due to the increase in human and animal population, due to rapid industrialization and with the consequent improvement in standard of living has a tendency to over utilize the natural resources. With these constraints, plans must be devised in order to use the land optimally and economically. In these aspects watershed management has to be planned strategically so as to judiciously use all these resources i.e. land, vegetations and water of the watershed to achieve maximum production with minimum hazard to the natural resources and for the well being of people. The management should be carried out on the watershed basis. The task of watershed management includes the treatment of land by using most suitable biological and engineering measures in such a manner that the management work must be economical and socially acceptable.

In this dissertation work a case study on two selected watersheds in India and one in Philippines had been selected to evaluate the watershed characteristics and its treatments and identify various problems. It is on this perspective, that a scientific technology be applied to watersheds suitable for its unique characteristics. Typical engineering measures are identified and planning and design of various structures are to be implemented so as to control soil erosion and collect and store rainwater for future use as water is the most essential requirement for human life, plants and animals survival.

1.2 CONCEPT OF WATERSHED MANAGEMENT

Watershed management is the rationalization of land and water resources for optimum production with minimum hazard to natural resources. It essentially relates to soil and water conservation in the watershed which means proper land use, protecting land against all forms of deterioration, building and maintaining soil fertility, conserving water for farm use, proper management of local water for drainage, flood protection and sediment reduction and increasing productivity from all uses.

Soil, water, and vegetation are the most vital natural resources for the survival of man and animals.

To obtain the maximum and optimum production of vegetation, all the three resources have to be managed efficiently.

For their efficient management, one has to look for a suitable units of management so that these three resources are handled and managed effectively, collectively and simultaneously. The watershed is considered the ideal unit for managing these three vital resources of soil, water and vegetation.

1.3 OBJECTIVES:

In view of the various aspects of watershed management, in this dissertation work a study be undertaken with the following objectives:

1. To study literature related to watershed management
2. To study measures of various engineering or agronomic structures for the prevention of erosion.
3. To critically examine watershed management practices and approaches adopted in a few watersheds in India and Philippines
4. To illustrate procedure for soil loss estimation
5. To identify major characteristics and treatments adopted by a few watersheds in India and Philippines

1.4 SCOPE OF THE STUDY

Chapter II, deals with the literature review on watershed and watershed management study. Principles, theory, and the required design parameters and procedures have been carefully discussed. Planning and design of commonly required soil and water conservation structures have been systematically discussed with illustrations and sample problems with solutions using some experimental and sample data provided in some references for better understanding. Also estimation of soil loss have been illustrated with calculations using the commonly wide accepted Universal Soil Loss Equation (USLE). Runoff estimation have been also analytically discussed using some derived empirical formulas.

Chapter 3, deals with checklist of data collection for watershed development and management which serves as a summary of information on proposed watershed. The report serves as the main data input for the present study covering three watershed projects wherein two projects in India and one in Philippines were selected.

Chapter 4 deals with the soil erosion and loss estimation using some empirical formula.

Chapter 5 deals with characteristics and treatments of few selected watersheds in India and Philippines.

Chapter 6 deals with the final results, discussion, and analysis of the study.

Chapter 7 deals with summary along with concluding remarks.

Finally, References are given.

LITERATURE REVIEW

2.1 WATERSHED MANAGEMENT

Watershed Management plays a very significant role in the arid and semi-arid regions which have concentration of eroded and degraded natural resources especially along highlands areas. Loss of vegetative cover followed by soil degradation through various forms of erosion have resulted into lands which are thirsty in terms of water as well as hungry in terms of soil nutrients. All these regions have predominantly livestock-centered farming systems; less biomass for animals not only reduces animal productivity, the inevitable uncontrolled grazing pressure on already eroded lands further worsens the problem and deteriorates the ecological balance. Growing population pressures, higher demand for food and fodder coupled with impact of rapidly changing socio-economic conditions have added fuel to the fire. In order to maximize advantages in developing these watershed areas, all developmental activities should be undertaken in a comprehensive way on watershed basis.

The main principles of watershed management are :

1) To protect, conserve and improve the land resources for efficient and sustained production
2) Utilizing the land according to its capability
3) Putting adequate vegetal cover on the soil during rainy season
4) Conserving as much rain water as possible at the place where it falls
5) Draining out excess water with a safe velocity and diverting it to storage ponds and store it for future use
6) Avoiding gully formation and putting checks at suitable intervals to control soil erosion and recharge ground water
7) Maximizing productivity per unit area, per unit time and per unit of water
8) Increasing cropping intensity and land equivalent ratio through intercropping and sequence cropping

9) Safe utilization of marginal lands through alternate land use systems

10) Ensuring sustainability of the eco-systems benefiting the man-animal-plant-land-water complex in the watershed

2.2 WATERSHED

Chess et al (2000) reported that the issues concerning the requirement for stakeholder involvement alongside government and scientific community participation in watershed management in the USA, including the need for adaptive approaches to participatory processes, are discussed.

Estrada et al (2001) reported that the watersheds are an attractive unit for development in mountainous landscapes. However, watershed analysis usually requires significantly more time, data and funds, and must include more actors. A watershed analysis was conducted by the Consortium for the Sustainable Development of the Andean Ecoregion research and development programme to promote equitable, competitive, and sustainable development in the rural Andes. This paper outlines the stages in the process of making the watershed analysis operational: estimating soil loss and stream flow under current land use patterns; constructing a farm model; characterizing the externalities of upper catchment management on downstream users; testing new scenarios; and evaluating the impact of land use change on employment. The analytical results from their application in Colombia are discussed. Many off-site effects were very difficult to modify without major changes in land use systems. Frequently, these land use changes (e.g. more pasture or reforestation) pitted soil conservation against rural employment. In other cases, sediment, originating on-farm, but primarily appearing in other parts of the landscape, implied civil engineering rather than on-farm solutions. It was found that good maps and valid models were of growing interest to municipal authorities as they consider alternative development plans. Analysis of externalities of current land use practices indicates that it is unlikely downstream users would pay for upstream soil and water conservation activities. It is suggested that natural resource conservation changes in current land use systems will have a negative effect on employment opportunities in the watershed, probably increasing rural poverty.

Gardi (2001) reported that the European union (EU) agricultural policy has induced significant changes in crop rotations, especially in marginal areas. The evaluation of the impact on water quality induced by this new agronomic framework is presented in this paper. The discharge, the sediment content and the concentrations of herbicides and nitrates in the Centonara creek, draining a hilly watershed near Bologna, Italy, were measured from October 1994 to September 1996. A geographic information system (GIS) and the crop simulation model CropSyst were used to characterize the relationships between cropping systems, land use, pedological and morphological properties of the watershed as well as nitrate losses. Hydrological results showed that the Centonara creek discharge was characterized by low base flows and by fast increments during flooding. Herbicide concentrations were above the EU 0.1 æg litre^{-1} limit on several occasions, whereas nitrate concentrations were always below the 50 mg litre^{-1} limit established by EU for drinking waters. It was estimated that more than 30% of the nitrogen input in the watershed is due to atmospheric depositions. The purpose of GIS was to subdivide the watershed in 86 agronomically homogeneous areas, which were then utilized as the basis for the application of CropSyst. Simulations obtained by the model showed that the greatest leaching losses of nitrates were higher than 10 kg ha^{-1} year^{-1} exclusively in the agronomically homogeneous areas characterized by coarser textured soils. Overall, nitrate and herbicide losses were low, mainly due to the differentiation of the cropping systems in the watershed. The combined use of GIS and CropSyst enabled the characterization of the environmental vulnerability in relation to the land use in the watershed by means of pedologic cartography, land use maps and meteorological data. In particular, erosion and herbicide losses were higher in sloping areas planted with spring-summer crops. The increase in row crops cultivations, determined by EU agricultural policy, represents the main impact on water quality of the investigated area.

Gonzales (2000) reported a participatory methods in designing a GIS for facilitating a multiple actor intervention in natural resource management at the local level and articulating the same at the provincial level. The study area was four adjacent barangays of Banaue in Ifugao, Philippines, where the local population work with rice terraces. Chapter 1 describes the problematic context by tracing Ifugao's history that showed: (1) these hardworking people's adherence to collective action was undermined by modern influences, thereby (2) threatening the sustainability of the whole watershed and of a vital source of power and irrigation water of the island. Chapter 2 explains the particular research problem and objectives, highlighting the basic questions and methodological issues in operationalizing a participatory GIS among the Ifugaos in order to aid their community development efforts. Chapter 3 concerns the shift in perspective with regard to the research focus. Chapter 4 examines the state of the art in using participatory methods in the development of a GIS. Chapter 5 is a description of the old and new Ifugao setting with respect to the management of their natural resources. Chapter 6 highlights the step-by-step development of a computerized GIS among the Ifugaos, which was done by using participatory methods. Chapter 7 discusses the particular application of GIS in community development monitoring. Chapter 8 revisits the research objectives in chapter 2 and summarizes salient findings.

Hazra et al (2000) reported that the central plateau and hills region of Uttar Pradesh has experienced severe deforestation, land degradation and erosion. A description is given of a community agroforestry project in seven micro watersheds in the Kharaiya Nala, which together comprised 5395 ha. The holistic management strategy embraced measures to conserve soil and water (through construction of contour trenches and dams, and planting of multipurpose trees, grasses and legumes), improve crop production, regenerate the hills and hillocks that constituted the village common lands, and create an appropriate management plan. The reduction in water and soil loss, changes in soil fertility under silvopastoral and legume pasture systems, improved crop and fodder yield, and changes in domestic livestock to improve milk production are described. Economic analysis showed that virtually the entire expenditure of establishing agroforestry practices was recovered within 3 years. Additional benefits included improved crop productivity on adjoining lands because of reduced scree deposition, aquaculture in impounded runoff water, and employment in basket making.

Kerr et al (2001) reported a chapter that examines factors contributing to incentives for improved agricultural productivity and natural resource management across a broad sample of watershed management projects in India's semi-arid tropics. A variety of factors are found to affect these incentives including population density, infrastructure, social organization and agroclimatic conditions. Importantly, participatory projects that focus as much on social organization as on technology transfer are shown to be generally the most successful.

Kishor (2000) presented an overview of the development of watershed programmes in India. Issues discussed are: problems and prospects of watershed development in India; land and water resources; watershed management and rural development; programmes and progress; people's participation and watershed development; funding of watershed development programmes; and the NABARD IGWDP approach to watershed management.

Lu-ShiangYue et al (2001) reported that few places in the world experience the severity of watershed management problems faced by Taiwan. The island is 74% mountainous regions with steep slopes and weak geologic formations. Each typhoon season brings torrential rainfall, resulting in frequent flooding, debris torrents, and landslides. Seasonal water shortages occur in parts of the island, a problem that will become more severe as Taiwan's population expands from its current 590 people per square kilometer. Despite forest exploitation earlier in this century, Taiwan now manages its 58% forest cover primarily for watershed protection with an emphasis on slope stabilization. Watershed protection in the past has relied heavily on engineering structures on hillslopes and along stream channels, which raises some concern about unwanted downstream effects. Forest clearing for crops, road construction and various development schemes are also of concern because of reduced slope stability, increased sediment and pollutant delivery downstream, and increased peak flows. This paper discusses watershed management needs for the coming century, considering cumulative effects of past land use changes on Taiwan's mountainous watersheds, and the issue of non-structural versus structural engineering solutions to watershed problems. Watershed management implications of institutional and policy changes related to forest lands administration are also discussed.

Nanda (2000) reported a paper that looks at the performance of the agricultural sector in India and the challenges confronting this sector. Topics covered include: the declining profitability of agriculture; the role of subsidies; research needs; extension services; information technology in extension services; dryland farming; watershed development; environmental issues; credit; World Trade Organization issues; and the national agricultural policy.

Nidumolu et al (2001) presented the concept and methodology of the Integrated Mission for Sustainable Development (IMSD). The objective of the mission is to generate plans for land and water resource development to be used by resource managers at the district level in India. The resource themes are integrated and analysed using a geographical information systems (GIS) environment. The GIS provides the basis for generating management plans for locale-specific land and water resources development. These plans include alternate land use based on resource potential, groundwater exploration and recharge, surface water harvesting and soil conservation. The IMSD is one of the largest geo-information projects undertaken in India with respect to the geographical extent, the number of data layers generated and the generation of management plans for resource management. It is concluded that the spatial data on resources can be used to optimize land and water utilization decision making in watershed management.

Novotny et al (2001) reported that the ecological impairment and flooding caused by urbanization can be expressed numerically by calculating the risks throughout the watershed (floodplain) and along the main stems of the streams. The risks can be evaluated in terms of the present and/or future. This article describes the methodologies for ascertaining the risks in the Geographical Information Systems (GIS) environment. The objectives of urban flood controls and ecological preservation/restoration of urban waters are often conflicting and, in the past, the sole emphasis on flood control led to destruction of habitat and deterioration of water quality. An optimal solution to these two problems may be achieved by linking the risks to the concepts of risk communication, risk perception, and public willingness to pay for projects leading to ecological restoration and ecologically sustainable flood control. This method is appropriate because, in each case, public funds are used and the projects require approval and backing of policy makers and stakeholders. This article briefly describes a research project that attempts to resolve the conflict between the flood protection and stream ecological preservation and restoration and suggests alternative ways of expressing benefits of urban stream flood control and restoration projects.

Qi-Shi et al (2000) reported the problems, countermeasures and development of management of the Huangjiaercha small watershed in the Ningxia Hui Autonomous Region of China in different control stages are introduced. The watershed management and agriculture sustainable development model could be divided into three stages: comprehensive control stage, strengthening, promoting, stabilizing stage and a sustainable development stage. The issues related to long-term policy making, population, scientific research and technology extension, and markets should be addressed.

Ramanathan (2000) reported various factors involved in land degradation in India are reviewed (soil erosion by wind and water, water logging, salinization, deforestation, removal of vegetation, overgrazing, inappropriate agricultural practices, including misapplication of fertilizer's and biocides), and the classification of degraded land into cultivatable wasteland and uncultivatable wasteland using GLASNOD (Global Assessment of Soil Degraded) and its relationship to catchment hydrology is discussed. Agenda's are presented for the Wasteland Development Programme (WLDP), which aims to bring into cultivation wasteland which is cultivatable, and the Watershed Management Programme (WSMA), which aims to promote activities which conserve as much rainfall as possible in situ in the soil profile or through controlled runoff collection, storage and reuse according to land capabilities.

Rao (2000) presented a paper that discusses the experiences of the Drought Prone Areas Programme in India and raises important issues on the sustainability of watershed development as the programme comes to an end. Following an outline of the present watershed development strategy; prospects for agriculture in 2020; the social, economic and environmental impact of the programme; and the factors accounting for good performance, five major issues are considered : (1) institution-building and leadership formation for ensuring effective participation of people on a sustained basis; (2) capacity building through training at various levels; (3) expert and independent evaluation of the programme; (4) convergence of agriculture development programmes with watershed development; and (5) according high priority to the strategy for the development of rainfed farming in the country.

Reddy (2000) reported that a review of studies pertaining to the economic and ecological impacts of watershed technology in India is presented. The paper attempts to lay the theoretical ground for a detailed and rigorous empirical work through collective action (CA) theories and their adaptability in the context of watershed management. Its objectives are to examine the issues involved in different aspects of watershed development and management, and identify the important strategies that need further attention. Important issues in this regard include: economic and ecological viability of watershed technology; the theoretical framework for collective action in watershed management; and strategies for sustainable watershed management. The proposed empirical study is introduced along with its objectives and methodology. Points to consider include: (1) there is a need to recognize watershed technology as a common good, which needs participatory development; (2) the approach is to recognize CA as a primary objective in watershed development programmes; (3) the state should supply institutions according to demand (at the grassroots level) and these institutions should minimize transaction costs through conductive policy and political environment; (4) there is a need for an interdisciplinary approach to integrating technology (watershed development) and philosophy (CA); and (5) along with the issues of economic viability, equity in the distribution of economic gains among the participants is required.

Reddy (2000) reported that the Rural Development Trust (RDT) is a voluntary organization working in Anantapur District of Andhra Pradesh, India. There has been a committed effort within the RDT to follow the participatory approach to watershed development in the true spirit of the government-funded new Guidelines. The following reflections are based on their experiences through working with people and the Government administration. Issues discussed are: people as the main actors; people's attitudes; the paternal attitudes of government functionaries; divisive and party-political leadership; corruption; inadequate involvement of personnel; the centralized philosophy of management; physical and financial monitoring; cost-sharing (criteria and process in selection of a watershed village; pre-conditions for village selection; and provision for de-selection and penal action); and the future.

Reddy et al (1999) reported that watershed development programmes have been implemented in India for over 20 years. An integrated approach to the programme as a strategy was initiated during the period 1975-83. By the Ninth Five-year Plan a number of agencies have been involved in initiating and implementing the programme in almost all the agro-climatic zones in the country. Furthermore, the programme has been receiving high priority from the Union Government, the state governments, multi-lateral and bilateral agencies and the NGOs. Thus, watershed approach has been identified as a major route and a promising area for development of agriculture. Over the last 20 years of experience in implementation of this programme several areas of successes and shortcomings have been identified. However, for sustainable development of agriculture, the paper argues that unifying the multiplicity of watershed programmes within the framework of an overreaching national initiative is desirable in national interest.

Schreier et al (2000) reported a case study on the World Overview of Conservation Approaches and Technology (WOCAT) programme of the World Association of Soil and Water Conservation (WASWC), the aim of which is to contribute to sustainable use of soil and Water through the collection, analysis, presentation and dissemination of soil and water conservation technologies and approaches worldwide.

Seth (1999) described that after 50 years of development, watershed management in India appears to be both fantastic and frightening. Reasons are briefly given for this appearance, and the paper then discusses: the retrospect of the situation; the shift in the development paradigm; the approach and strategy; perspective planning and financing of watershed management project; the guiding principles.

Shah (1999) reported a study that tries to assess the qualitative impact of the National Watershed Development Project for Rainfed Areas (NWDPRA) in 2 micro watersheds, namely, Danta (Saraswati) of Banaskantha district and Dayapur (Lakhpat) of Kutch district in Gujarat state, India. The data for the study were collected from 50 beneficiary households and 25 non-beneficiary households of each watershed during the year 1993-94. The study shows that the Danta watershed was more effective in generating positive impact in moderate to good rainfall situation compared to Dayapur with very low rainfall condition. The NWDPRA turned the cropping pattern in favour of more profitable commercial crops and induced increased use of fertilizer, high-yielding variety and improved seeds. Productivity and cropping intensity has also increased. The construction of check dams, vegetative contour bunds, and embankment to harvest rain water, and the planting of trees, shrubs, and grasses have greatly helped in reducing soil erosion. It is concluded that a watershed management programme is economically viable, feasible and holds key to the development of rainfed areas.

Shah et al (2001) reported a study that seeks to examine the initial experiences of some watershed development programmes in the predominantly dry region of Gujarat, India, in terms of their benefits and their sustainability. Such initiatives have remained limited in terms of coverage of land as well as households. The analysis brings out some useful policy implications with respect to better sharing of irrigation and/or water resources, enhancing the actual benefits from farm economy and cost recovery, as well as cross-subsidization. The early lessons may help improve the implementation, equitable impact and sustainability of future watershed development programmes.

Singhal (1999) reported that People's participation in watershed management decrease the perpetual dependence of the people on the government thereby making the programme self-sustaining and gaining access to control of the resources. The paper is based on an empirical study of Nada watershed development project situated in Shivalik hills of Haryana, India. The study tried to elicit the level of people's participation in planning, implementation and monitoring of watershed activities. Besides the role of village people in protection of hill resources through Hill Resource Management Societies (HRMS) was also studied. The Participatory Rural Appraisal method was used to elicit information from small and marginal farmers, members of HRMS, Panchayat and Government officials of forest department. The views of women were also taken.

Tucker (2000) noted that with the watershed development approach nearing 30 years, the Government of India has introduced the Revised Guidelines. Using the specific case study of Andhra Pradesh, the impact of the Guidelines is examined. Issues discussed are: the status of watersheds in the state of Andhra Pradesh; the introduction of pre-watershed stage; and the Andhra Pradesh Rural Livelihoods Project.

Venkateswarlu (1999) reported a paper that describes the watershed development programme from the Ministry of Rural Development, India. The discussion focuses on: the programme content; expected gains; development of action plan; execution of the plan; and the scientific philosophy in the programme. It is argued that this is the people's movement, and the government and voluntary agencies are only motivators at best. It needs to be an endeavour to see that the watershed programme develops on a gradual basis. The technologies need to be simple and achievable at the farm level. Stakeholders need to be assisted in their capacity building and create awareness of the details of the programme through training at different levels from policy makers to actual doers. To achieve this, indigenous knowledge has to be the starting point.

Wang (2001) reported the spatial relationships between land uses and river-water quality were examined for the Little Miami River watershed, Ohio, USA using biological, water chemistry and habitat indicators. Data from relevant federal and state agencies were integrated using Geographic Information System spatial analysis functions. Twenty-two catchments for river segments near headwaters and with water quality monitoring data were delineated and digitized for referencing to the river network. Results are presented from 3 aspects - the impact of waste water treatment plants, the spatial patterns of river-water quality, and the relationship between land uses in the catchments and water quality of the receiving water. The Index of Biotic Integrity measurement from the closest sites to the discharge points demonstrated a statistically significant decrease of water quality downstream from the waste water treatment plant discharges. Spatial distributions of the urban land use shows that there are 2 major urban areas and a few smaller settlements scattered within the LMR watershed. Among the 22 catchments, urban land percentages varied from 1 to 58% and agricultural land percentages varied between 12 and 95%. The relationship between the water quality of receiving waters and land uses in a watershed indicated that increasing population pressure resulted in increasing pollutant loads and integration pf water quality management and land-use planning was required to protect the river system and promote ecologically and economically healthy land development.

2.3 PLANNING AND DESIGN OF SOIL AND WATER CONSERVATION STRUCTURES

Planning and design of soil and water conservation structures such as bunds and terraces, waterways, gully control and water harvesting structures, calculations of runoff, soil loss calculation using Universal Soil Loss Equation (USLE), peak discharges, time of concentration and etc. are the major important interventions in the development of the watershed. Above all, watershed development offers a unique possibility to reverse land degradation and to promote more favorable ecological balance leading to healthy environment.

2.4 SOIL AND WATER CONSERVATION TREATMENTS

As an evident from a review of traditional practices and also supported by the recent research experiences, different mechanical structures are dependable means in checking soil erosion and increasing rain water infiltration opportunity time. Such steps show their effectiveness in preventing the land degradation as soon as they are formed.

2.4.1 Bunding

Bunds -small earthen barriers are provided in agricultural lands with slopes raging from 1 to 6 percent. They control the effective length of slope and thereby reduce the gain in velocity of runoff flow to avoid rill and gully erosion.

Important objectives of the bunding are:

i.) To increase the time of concentration of rain water where it falls and thereby allowing more opportune time for rain water to be absorbed in the soil profile

ii.) Converting a long slope into several short ones so as to minimize velocity and thereby reducing erosive power of runoff water

iii.) To provide field to field access for man and animals for undertaking agronomic activities

iv.) To divert runoff water either for water harvesting purposes or for saving lower lands from excessive sand deposition or getting severely eroded.

Specific site conditions:

Generally, bunds have been classified into two categories:

1) Graded bunds -bunds which are constructed in medium to high rainfall having annual rainfall of 600 mm above and in soils having poor permeability or those having crust formation tendency.

2) Contour bunds -bunds which are constructed in relatively low rainfall areas having annual rainfall of less than 600 mm; particularly in the areas having light textured soils.

In general, both graded and contour bunds are usually constructed with some deviations and they are adjusted with field boundaries. Extra care should be taken to keep such deviations within permissible limits-not more than 30 cm across valleys and 15 cm on ridges.

Design criteria and procedures:

a) Graded bunds

Graded bunds maybe further classified into two broad classes (i) bunds with channel, and (2) bunds without channel. According to recent studies, bunds without channel have been found superior, in case there are given longitudinal grades of 0.2% or more; the biggest plus point in favor of these bunds is their easy maintenance. The design criteria for construction of such graded bunds is based on the concept of stable channel design. However, minimum cross section of these bunds is $0.5m^2$, which is reduced to $0.3m^2$ in shallow soils. For heavier soils, the cross sections of these bunds should be $0.75m^2$.

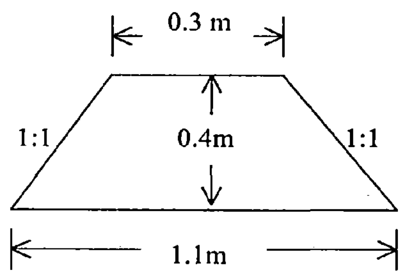
The spacing between two bunds is based on the formula,

$$V.I. = (S/a+b)0.3$$

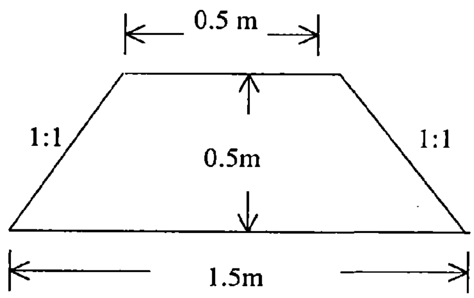
Where

V.I.	=	vertical interval, m
S	=	slope, %
a	=	constant value ranging from 3.0 to 4.0 for good permeable soils
b	=	constant with average value of 2.0

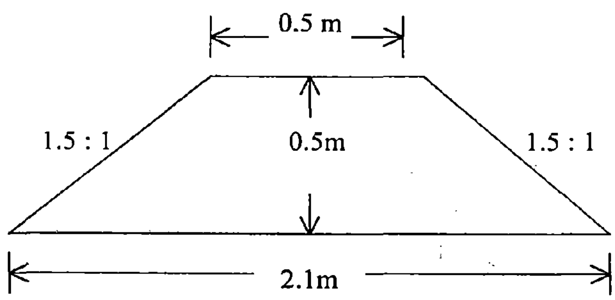
Design details for minimum bund sections for different soil situations are given in figure 2.1. In situations where adequate vegetative protection to the bunds is expected, bund section can be reduced considerably.



(a) FOR SHALLOW SOILS, C.S. AREA=0.28m^2



(b) FOR RED AND ALLUVIAL SOILS, C.S. AREA=0.5m^2



(c) FOR HEAVIER SOILS, C.S. AREA=0.675m^2

Fig. 2.1 Graded bund sections for different type of soils

Sample Case Study -Bunding Manneguda Watershed (A.P.)

Design:

Maximum length of terrace, L		=340 m
Average slope of watershed, S		=2 %
Vertical interval,	D	=1.2 m
Average of terrace ,	W	=D/S x 100
		=60 m
Inter-terrace area,	A	=340 m x 60m
		=2.04 ha
Runoff coefficient,	C	=0.25
Longitudinal gradient		=0.4 %
Length of run	=340 + 60	=400 m
Fall	=1.2 + 1.36	=2.56 m
Time of Concentration (Tc)		=15 min
Design intensity, I : for 10 years		=96.4 mm/hr

Frequency and duration of 15 min.(from the intensity-duration-frequency formula)

Peak discharge, Q	=CIA/360	=(0.25 x 96.4 x 2.04)/360	=0.137m^3/sec
Top width	=0.3 m		
Assume height	=0.6 m		
Side slope	=1 : 1		
Bottom width	=1.5 m		
Slope in channel	=0.4 %		
Area of cross section	=(1.5 + 0.3)/2 x 0.6	=0.54 m^2	

Assuming a watersheet flowing along bund with 0.15 m depth, the flow area becomes 0.57 m^2 (Fig. 2.2)

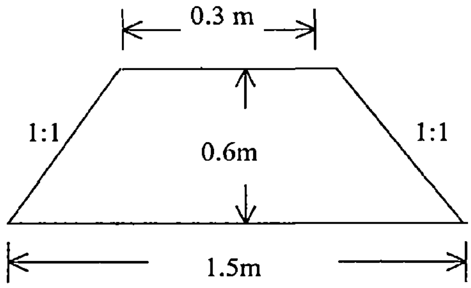


Fig 2.2 Graded bund (0.54 m^2)-Manneguda Watershed

The wetted perimeter for this section will be 7.57 m and the hydraulic radius will be 0.075 m. The longitudinal grade of bund is 0.4 %.

Using Manning's formula,

$$V = \frac{R^{2/3} S^{1/2}}{n}$$

Where V =Velocity, m/sec

R =Hydraulic radius, m

S =Slope

n =Manning's coefficient

$$= \frac{(0.075)^{2/3} x (0.004)^{1/2}}{0.04}$$

=0.28 m/sec

This velocity is within safe limits.

Discharge, Q =A X V =0.57 x 0.28 =0.16 m^3/sec

Hence bund section is safe.

b) Contour bunds

Contour bunds are essentially meant for storing rain water received during a period of 24 hours at 10 years recurrence interval. The major considerations are maximum depth of water to be impounded, design depth of flow over waste weir and desired free board.

The depth of water expected to be impounded against the bund will largely depend upon rainfall factors, rate of infiltration of the soil and vertical interval between bunds. The following equation is used in arriving at the maximum depth of water to be impounded.

$$F = \sqrt{DR/500}$$

Where F =depth of water to be impounded, m

D =vertical interval, m decided more or less on same principles as explained in case of graded bunds, m

R =maximum rain water on area basis to be stored, mm

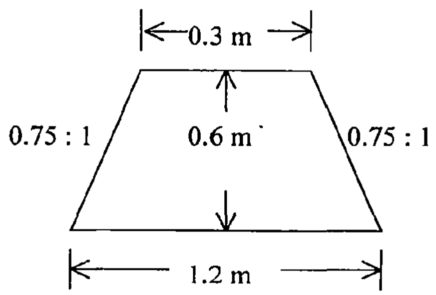
The actual height of the bund is decided after allowing adequate free board nearly 20 % of the depth. Usually water storage equivalent to 50 mm of rainfall is considered adequate for design of contour bunds at most of the places.

Sample Case Study - Contour bund –Chevella Watershed

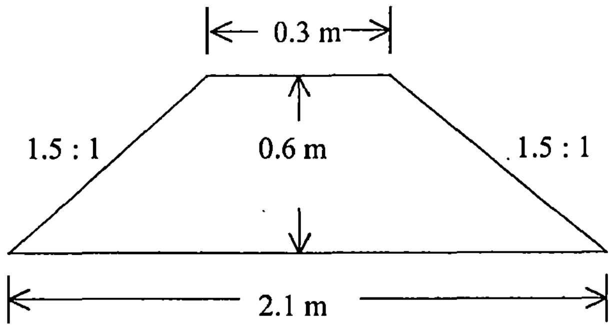
Design:

Slope =2 %

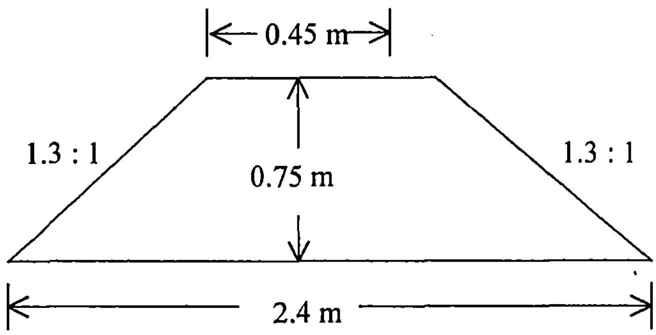
Vertical interval =1 m



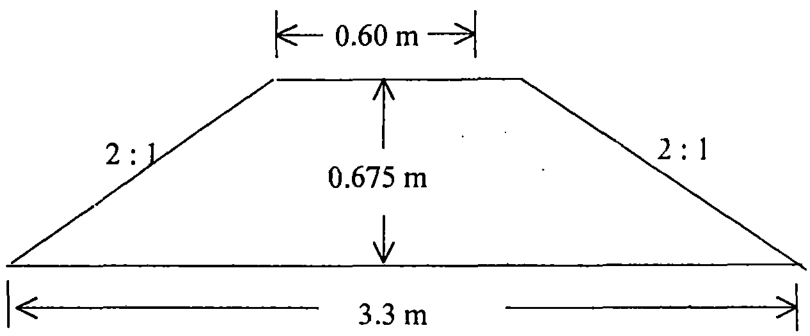
(a) FOR GRAVELLY SOILS C.S AREA=0.45 m^2



(b) FOR RED SOILS C.S. AREA=0.72 m^2



(c) FOR SHALLOW TO MEDIUM BLACK SOILS C.S. AREA=1.07 m^2



(d) FOR DEEP SOILS C.S. AREA=1.32 m^2

Fig.2.3 Contour bund sections for different soils

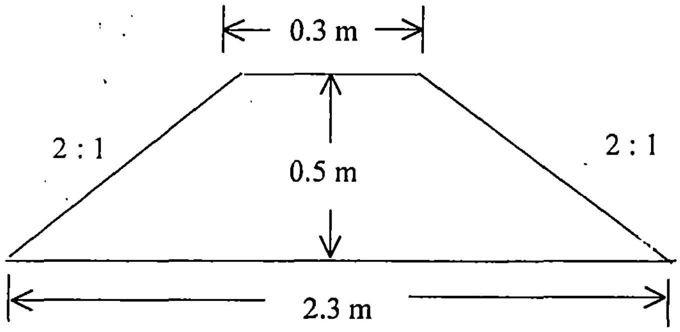


Fig. 2.4 Contour bund (0.65 m^2)–Chevella Watershed (A.P.)

Maximum rainfall to be stored , R =50 mm

Maximum water depth, F $=\sqrt{DR/500}$

$=\sqrt{1X50/500}$

=0.32 m

Allowing a free board of 0.15 m,

Height of bund =(0.32 + 0.15) m

=0.47 m Say 0.50 m

Top width = 0.3 m

Side slopes = 2 : 1

Bottom width =2.3 m

Cross section area =0.65 m^2

Length of bund (B_L) =100S/D

Where S =land slope, %

D =vertical interval, m

Substituting the observed values, $B_L = \frac{100x2}{1}$

= 200 m

Cross section of bund =0.65 m^2

Volume of earthwork/ha =0.65 x 200

=130m^3

Average no. of outlet weirs/ha = 1 No.

2.4.2 Trenching

Contour trenches are made in non-agricultural areas for providing adequate moisture conditions in order to raise tree and grass species.

Objectives:

i) To cut down the velocity of overland flow

ii) To store rain water for the benefit of plants

Specific site conditions:

Contour trenches are made in non-cultivable areas having silvi-pasture, silvi-horticulture or agro-horticulture programmes at a spacing of 10 to 30 m.

Design criteria:

For designing trenching system, factors like soil type, slope and suitable tree species for the area are to be considered. Usually they are designed to hold one day rainfall at 2 year frequency. Generally, trenches are made with a minimum depth of 0.40 m. Similarly, minimum width of 0.45 m is also maintained. In rocky areas, trenching may be difficult because of hard soil strata. In such situations, gabbion-crescent bunds made of loose boulders are adopted. Usually there is no maximum limit for length of contour trench and mostly it is decided considering waterway location. However, staggered trenches are constructed across the slope with lengths varying from 5 to 15 m.

2.4.3 Bench terracing

The bench terraces are usually constructed for cultivating sloppy areas by converting the land into series of platforms one above the other (Fig. 2.5). These measures are popular in hilly areas.

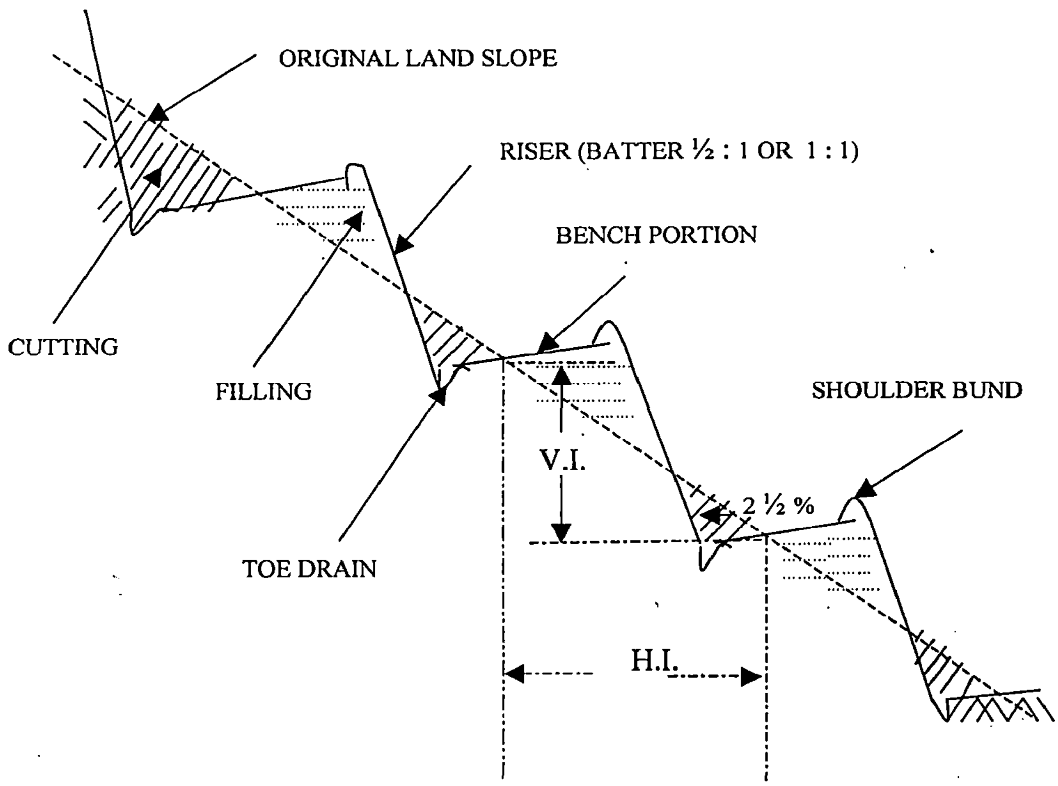


Fig. 2.5 Cross section of bench terrace

Objectives:

i) To control the velocity of overland flow and to check soil erosion on hill slopes

ii) Optimum rain water utilization by increasing infiltration opportunity time for it

iii) To ensure equitable soil moisture distribution and for providing required drainage

Specific site conditions:

Normally, bench terracing is adopted for slopes ranging from 16 to 33%. Because of the increasing population pressure on cultivated lands, even steeper slopes are put under cultivation with bench terracing. A good top soil depth is required so that proper depth of cut and consequently suitable width of terrace can be adopted without exposing the unproductive subsoil.

Design criteria:

i) Vertical interval, which is usually decided considering soil depth and slope conditions and may vary from 1.5 to 2.5 m.

ii) Net width of the benches, which depend upon the land slope and farm power available for undertaking agronomic operations. In steep sloping hilly areas, the bench width can vary from 5 to 10 m; however, 3 m width is minimum.

The following equations are used for designing bench terraces having inward slope or being table top:

$$VI = 2\,(T - 0.15)$$

Where VI =vertical interval, m

T =top soil (solum) depth, m

$$VI = \frac{WS}{100 - S}$$

Where VI =vertical interval, m

W =net width of the bench in meter for 1 :1 batter in the riser

S = slope, %

Similarly, for 0.5 : 1 batter, the equation would be as follows:

$$VI = \frac{2WS}{200 - S}$$

As a general practice, 1 % longitudinal grade is given for the removal of excess runoff. In case of inward sloping benches, 2.5 % inward slope is provided, whereas no cross slope is given in the table top benches. The length of terrace is generally limited to 100 m for better moisture distribution. The bench risers are protected with permanent vegetation. For efficient removal of excess runoff, a toe drain (15 cm deep) is provided at the toe of the riser. For safety of the benches against gully formation along the major slope during heavy downpours a shoulder bund, limited to 0. 3 m^2 section., is maintained at the upper edge of the bench. The bench terrace are also provided with properly designed grassed outlets, mostly known as vertical drains in the hilly areas. These vertical drains are designed on the lines of grassed waterways.

2.4.4 Vegetative Barriers

Vegetative barriers are closely spaced grass hedges or plantations- usually a few rows of grasses or shrubs grown along contours or with little grade for erosion control in agricultural lands. Of late, opinions are gaining ground that vegetative barriers (eg. Vetiver hedge rows Leucaena, lemongrass, Cenchrus ciliares) alone at suitable interval may be sufficient for runoff and erosion control in relatively flat and slightly undulating topography. But it is, safer to have vegetative barriers only as inter-terrace treatments.

Objectives:

i) To act as a barrier to moderate the velocity of overland flow and as a trap for silt, in that soil quality is maintained

ii) To reduce the cost on terracing as vegetative barrier are relatively cheaper

iii) To augment production of food, fuel, fodder of fiber from farm lands by growing suitable species as vegetative barriers

iv) To add to the income of farmers

Specific site conditions:

Vegetative barriers can be easily established across a wide spectrum of soil-climatic conditions except in class VII lands and desert conditions. Selection of species depends upon site specific conditions, particularly soil and climatic variables. The major constraint experienced in their sustenance is stray cattle grazing.

Design criteria:

The main item of design is the spacing of the barriers which depends on the vertical drop of the field to be treated. Species to be grown, number of rows, plant to plant spacing, and method of planting, etc. are also to be decided in advance. The functional requirement of the vegetative barriers is that it should act as a filter to trap the silt and cut down the velocity of runoff flow. Therefore, the plants will have to be closely spaced.

2.4.5 Grass Waterways

Grass waterways are drainage channels either developed by shaping the existing drainage ways or constructed separately for effecting the drainage of agricultural lands. They are aligned along the major slopes to handle runoff discharge from contour/graded bunds, bench terraces, contour trenches and contour furrows.

Objectives:

i) To provide drainage to agricultural fields by safely disposing the excess rain water

ii) To convert gullies or unstable channels into stable channels by providing vegetal protection to the soil surface

iii) For channelising and regulating runoff flows for water harvesting purposes

Specific site conditions:

As far as possible, waterways are located along valley lines. But, sometimes it may be necessary to construct waterways along field boundaries for safe disposal of excess rainfall from agricultural fields. Waterways may be located in all classes of lands except bare rocks, where construction may be difficult. However, vegetative waterways should not be used for handling continuous flows, like that from tile drains as problem of wetness may result in poor vegetal growth and soil protection.

Design criteria and procedures:

Design procedures for waterways are essentially similar to those of open channels. But they are generally constructed with shallow depth and flat side slopes to facilitate crossing of the channels by bullocks and farm machinery. The cross section of the waterway may be trapezoidal, triangular or parabolic; in most situations, broad bottom trapezoidal or parabolic channels are used. The depth of waterway may range from 0.15 to 0.50 m and side slopes are kept flatter 4 : 1. The gradient of the waterway is generally decided by the existing slope of the ground. The design cross sections should be such that the computed velocities are within permissible limits and the capacity of the channel is sufficient to carry the peak discharge for a 10-year frequency. Generally, flow velocities are computed using Manning's formula.

The permissible velocity in a grass waterway depends on nature of soil and type of vegetation. In most light soils, the maximum velocity may be 1.5 m/sec, whereas the velocity can be exceeded even up to 2.5 m/sec in erosion resistant soils having a good sod cover.

The final channel dimensions are arrived at after allowing a free board of about 0.15 m. For general field works, the carrying capacities of waterways for different flow depths and channel gradients are given in Table 2.1 . The capacities given in the table are based on assumption of a good grass cover. If the waterways are very long, variable cross sections may be adopted for economy in such conditions. A typical example of the design of grass waterway is given under case study.

Table 2.1 Values of discharge in m^3/sec per meter width of grass waterway

Depth of Flow (m)	Slope (%)			
	2.0	*1.0*	*0.75*	*0.5*
0.075	0.030	0.020	0.020	0.020
0.150	0.093	0.067	0.057	0.047
0.225	0.180	0.133	0.103	0.093
0.300	0.293	0.207	0.170	0.150
0.375	0.417	0.293	0.237	0.207
0.450	0.567	0.407	0.330	0.283
0.525	0.660	0.520	0.427	0.370

(Source: Hudson, 1971)

Case study -Design of grass waterway -Manneguda Watershed (A.P.)

Design discharge = $2.5 m^3$/sec

Channel slope = 4 %

Step-1

Assumed bottom width, b = 1.0 m

Assumed depth of flow, d = 0.4 m

Assumed side slopes (X : 1) = 4 : 1

Cross sectional area, A $= bd + xd^2$

$= 1.0 \times 0.4 + 4\ (0.4)^2$

$= 1.04\ m^2$

Wetted perimeter, P $= b + 2d\ \sqrt{x^2+1}$

$= 1.0 + 2\ (0.4)\ \sqrt{4^2+1}$

$= 4.3$ m

Hydraulic radius, R $=A/P = \frac{1.04}{4.3} = 0.24$ m

Channel slope , S $= 0.04$

Mean velocity, V $= \frac{R^{2/3} S^{1/2}}{n}$

$$= \frac{(0.24)^{2/3} (0.04)^{1/2}}{0.04}$$

= 1.93 m/sec

Capacity of the channel, Q = A x V

= 1.04 x 1.93

= 2.007 m^3/sec

Step-2

The capacity of the channel computed above is less than the peak flow of 2.5 cumec. Hence, try a flow selection with a bottom width of 1.5 m and flow depth of 0.4 m.

Cross sectional area, A $= 1.5 \times 0.4 + 4 \times (0.4)^2$

= 1.24 m^2

Wetted perimeter, P $= 1.5 + 2\,(0.4)\,\sqrt{4^2 + 1}$

= 4.8 m

Hydraulic radius, R $= \frac{1.24}{4.8} = 0.258$ m

Mean velocity, V $= \frac{(0.258)^{2/3} (0.04)^{1/2}}{0.04}$

= 2.026 m/sec

Capacity of the channel, Q = 1.24 x 2.026

= 2.512 m^3/sec

The capacity is almost equal to the peak flow rate. Hence, the section assumed in step-2 is adopted with the following specifications considering a free board of 0.15 m.

Channel depth, D	= 0.4 +0.15 =0.55 m
Bottom width, b	= 1.5 m
Top width, T	= b + 2 X d
	= 1.5 + 2 x 4 x0.55
	= 5.9 m

2.5 WATER HARVESTING STRUCTURES

Supplemental irrigation at times becomes essential for survival of horticultural and agricultural crops in drought-prone areas with undependable and erratic rainfall. In order to accomplish this, excess rainwater has to be conserved/stored in soil profiles and in different storage structures.

2.5.1 Farm ponds

Farm ponds are bodies of water; made either by constructing an embankment across a water course or by excavating a pit or the combination of both.

Objectives:

i) To provide water storage for life saving irrigation in a limited area

ii) To provide drinking water for livestock and human beings in arid areas

iii) To serve as water storage for providing critical irrigations to limited number of fruit plants for establishment

iv) To moderate the hydrology of small watersheds

Specific site conditions:

Dugout ponds are generally created by excavating pits in area having flat topography and mostly in situations where water table is close to the ground level. On the other hand, impounding type of farm ponds are common feature wherever there are well defined waterways with rolling type of topography.

Design criteria:

Farm pond size is decided on the total requirement of water for irrigation, livestock and domestic use. If the rainfall in the region is very low, the capacity of the pond will only include the requirement for livestock and domestic use. An allowance of 20 % is always added to the pond capacity towards storage losses.

Pond =Irrigation requirement + Livestock requirement + Domestic requirement + 20 % of the sum of the above towards evaporation and other losses

The size of farm pond is also decided upon the amount of anticipated runoff water entering the pond. The pond size should be one half or less than the total amount of annual runoff expected from catchment so that more than one filling can be obtained during the year. In low rainfall areas, 1 ha catchment may provide 100 m^3 of runoff for pond designs. In medium rainfall regions 1 ha catchment can yield 200 m^3 of water for storage purposes.

Whereas design features of embankment type ponds are governed by physiography, excavated ponds may be constructed either square or rectangular in shape.

Once the capacity of the pond is determined taking into account the total requirement of water for irrigation, livestock and domestic use and the same is estimated to be equal or less than runoff availability; the next step is to work out the dimensions of the pond. The permissible depth of the pond, on the selected site, is to be determined first for ease in excavation and better retention of water;

the side slope are decided later depending on the capacity of pond and soil type. To save the side walls from caving in, the side slopes are also made flatter than the natural angle of repose of the material (soil) being excavated. In most cases the side slopes should be flatter than 1 : 1.

All farm ponds must have the provision for removal of excess runoff water when the pond is full. The kind of spillway to be used will depend on the size of watershed and other site characteristics. Generally, ponds having watersheds ranging from 4 to 12 ha require a combination of mechanical and vegetative spillways; for ponds having drainage area less than this a good vegetative spill may suffice.

The commonly used spillway with farm ponds is the drop inlet spillway. In some cases, this type of spillway may also be used to supply the water for irrigation by having sluice gate arrangement at different heights of inlet well/riser. Small diameter pipes are particularly susceptible to clogging with trash and rodents. For this, the size of barrel and riser should be kept more than 15 and 20 cm in diameter respectively.

Farm ponds must be provided with a sod spillway or emergency spillway to dispose the over flow water after heavy rains. This spillway should discharge into a grass waterway or a natural drain which does not have steep grade to cause excessive erosion. The required width of spillways depends on the size of the watershed areas; sod spillway is essentially a grassed waterway having flat grades.

2.5.2 Minor Irrigation Tanks/Low Earthen Dams

Low Earthen Dams, designed on the basis of engineering principles, are constructed across the streams for creating water reservoirs for providing one or two irrigations to the crops at critical periods.

Objectives:

i) To provide irrigation source for the crops grown under its command

ii) For irrigation of drought by providing much needed water.

Design criteria and procedures:

Following aspects are considered as basic requirements for designing earthen dams:

i) Hydrologic data

ii) Information on soils and geology

iii) The nature and properties of the soils in the command area, and

iv) Profile survey and cross sectional details of the stream

In order to arrive at proper design of the earthen dam, site selection is very crucial. As far as possible, a narrow gorge should be selected for erecting the dam in order to keep the ratio of earthwork to storage at minimum. Runoff availability for the reservoir should be computed on the basis of rainfall-runoff relationship for the locality. In case such data are not available, the runoff availability may be worked out based on Strange's table (Table 2.2)

Table 2.2 Proportion of estimated runoff to rainfall (Strange's table)

Total monsoon rainfall (mm)	Percentage of runoff to rainfall		
	Good catchment	Average catchment	Bad catchment
250	4.3	3.2	2.1
375	9.4	7.0	4.7
500	15.0	11.25	7.5
625	20.6	15.4	10.8
750	26.3	19.7	13.1
875	31.9	23.9	15.9
1000	37.5	28.1	18.7
1125	43.1	32.3	21.5
1250	48.8	36.6	24.4
1375	54.4	40.8	27.2
1500	60.0	45.0	30.0

(Source: Singh, 1957)

Depending upon the assumed depth of ponding and the corresponding area to be submerged, suitable height of dam may be selected to provide adequate storage in a given topographic situation; such dams are constructed with height ranging from 5 to 15 m.

The cross section of dam is decided by trial and error; selection and other specifications are finalized considering the following criteria:

i) There should be no possibility of the dam being over-topped by flood water
ii) The seepage line should be well within the toe at the down stream face
iii) The upstream and downstream faces should be stable under the worst conditions
iv) The foundation shear stress should be within safe limits
v) There should be no opportunity for free flow of water
vi) The dam and foundation should be safe against piping and undermining
vii) The upstream face should be properly protected against possible wave action.

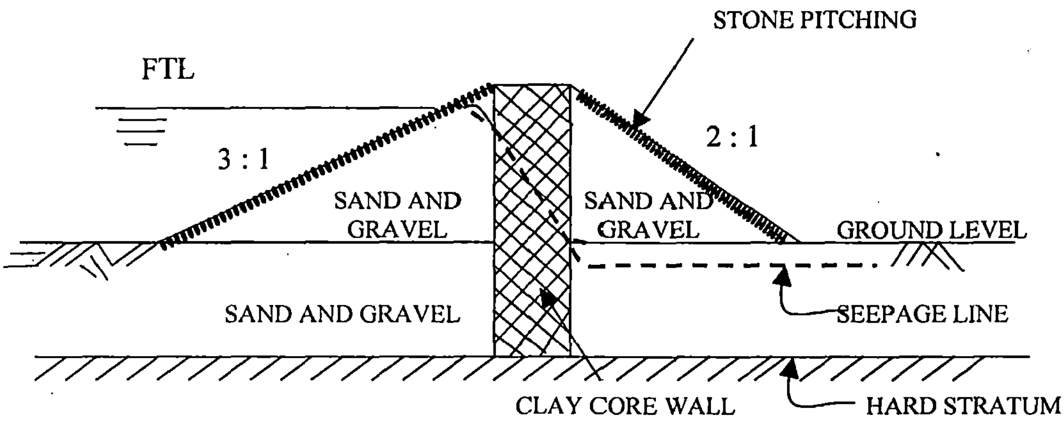
Typical cross section of earthen dams are as follows (*Figure 2.6*) :

Case I : If only sand and gravel are available at the site, a 3 to 5 m thick clay core wall is a must; soil for this can be brought from nearby old tanks. The core wall should extend from the hard stratum up to the top of the dam (*Fig. 2.6 a*)

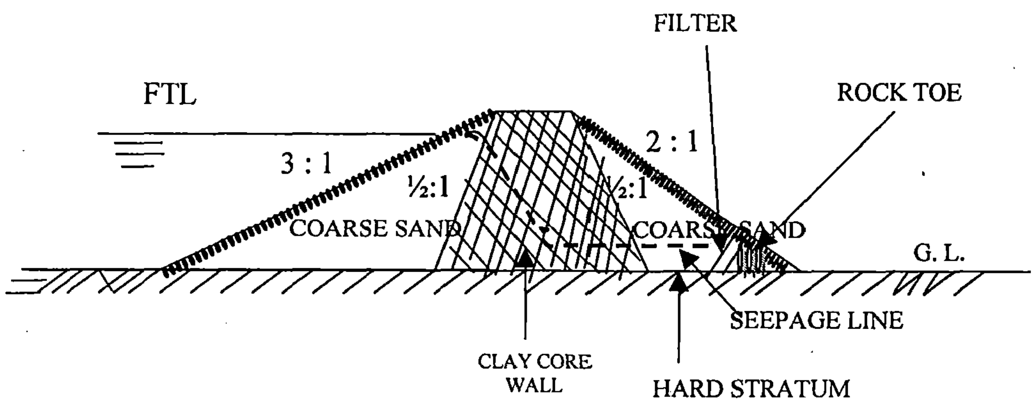
Case II : If both clay and silt in top soil and sub-soil but mostly coarse sand in shallow sub-soil layers are available and the foundation is impervious; it may be necessary to provide rock-toe drains at the downstream to keep down the seepage line (*Fig. 2.6 b*)

Case III : If both sand and gravel is plenty as well as silty-clay in fair proportion are available at the site but foundations are very pervious; a suitable arrangement in the form of a horizontal blanket may be necessary (*Fig. 2.6 C*)

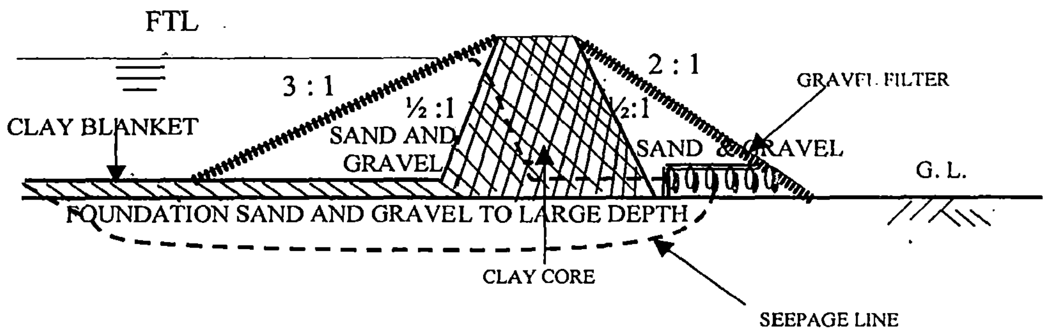
In general, the capacity of the dam is worked out by finding out the water-spread area and the expected impounded depth of water. The top width of the bund (dike) is decided depending upon the use of the dam as a road or path. Where it is not used as a road, a minimum width of 1.5 m may be adequate.



(a) CASE I



(b) CASE II



(c) CASE III

Fig. 2.6 Typical cross sections of earthen dams with different types of materials and on different types of foundations

Height of the dam:

The height of dam is arrived at by working out the difference between the reduced levels of the top of the bund and the bed level of the Nala. The maximum dam height should not exceed 20 m; height of each segment depends upon bed levels of Nala along the cross section.

Side slopes:

Side slopes of the bund are governed by the material used for construction. Minimum side slopes are 3 : 1 on the upstream side and 2 : 1 on the downstream side; steeper side slopes may sometimes be adopted in case of lower bund heights but these should be restricted up to 2 : 1.

Free board:

A minimum free board of 1.5 m is usually provided for all small irrigation tanks.

Emergency spillway:

All the irrigation tanks are provided with emergency spillway s to remove peak rate of runoff at 50 years recurrence interval. These can be masonry structures in case suitable site is not available for locating a vegetative emergency spillway.

Mechanical spillway:

Earthen dams are provided with a mechanical spillway for frequent removal of runoff before it touches emergency spillway. The minimum size of the spillway may be between 0.5 to 1.5 m depending upon the size of the dam.

Sluice arrangement:

The sluice is kept at the dead storage level and the gate is designed for regulating quantity of water required to irrigate the command area.

2.6 SOIL EROSION AND LOSS

Soil is one of the very important resources for agricultural production and it is vulnerable to erosion by flowing water and wind.

Soil erosion is caused by various factors such as clearing of forests in order to get more land for cultivation, improper use of land, shifting cultivation and the logging for timber and fuel production. Especially the land on steep slopes without appropriate protection is susceptible to erosion.

Increase of population and development of nature for industrialization tend to accelerate the process of erosion. Soil erosion resulted to loss in the fertile top soil causing agricultural production to decrease. Soil erosion in catchment area removes vegetation and organic matters from the surface and decrease the intake rate of the soil. Thus, increased surface runoff brings flood which is not able to be coped with the conventional river channel. Moreover, soil erosion leads to silting of irrigation and drainage canals, insufficient irrigation and drainage, aquatic weed growth and declining fish production in the rivers and lakes. Soil erosion aggravates the environment and gives much harm to the local population both the economic and social aspects.

The main factors affecting soil loss are rainfall intensity and duration, types of soil, land slopes and ground surface condition.

In order to solve and minimize all these problems and to conserve the environment soil conservation is to be adopted and implemented. Soil conservation is to keep the soil from continuous loss and utilize it without waste for high level agricultural production. Soil conservation prevents lowering of soil productivity and occurring of sediment problems which causes land damage, flood damage, water quality and environment problem.

2.6.1 Estimation of Soil Loss

The Universal Soil Loss Equation (USLE) is the most widely accepted method of estimating sediment loss. This equation was developed from more than 40 years of data measured from small plots located in many states. It is useful to determine the adequacy of conservation measures in farm planning and to predict non point sediment losses in pollution control program.

The average annual soil loss as determined by Wischmeier (1976) can be estimated from the equation:

$$A = 2.24\ R\ K\ L\ S\ C\ P$$

Where A =average annual soil loss in Mg/ha (metric tons/ha)

R =rainfall and runoff erosivity index by geographic location as given in Table 2.3

$= E = 12.1 + 8.9 \log i$

where E=kinetic energy in m-Mg/ha-mm

i =intensity in mm/hr

K =soil erodibility factor (see Table 2.4) which the average soil loss in ton/acre per unit of erosion index for a particular soil in cultivated continuous fallow with an arbitrarily selected slope length L of 22 m (73 ft) and slope steepness S, of 9 percent (if K is Mg/ha, change constant 2.24 to 1.0)

LS =topographic factor

L =slope length factor; the ratio of soil loss from the field slope length to that from a 22 m length on the same soil type and gradient

$=(l/22)^x$

where x = a constant, 0.5 for slopes >4 percent, 0.4 for 4 percent, and 0.3 for <3 percent

l = slope length in m

S =slope gradient factor, the ratio of soil loss from the field gradient to that from a 9 % slope, on the same soil type and slope length.

$$= \frac{(0.43 + 0.30s + 0.043s^2)}{6.574}$$

where s = field slope in percent

C =cropping management factor, which is the ratio of soil loss for given conditions to soil loss from cultivated continuous fallow as given in Table 2.5

P =conservation practice factor, which is the ratio of soil loss for a given practice to that for up and down the slope farming as given in Table 2.6

Table 2.3 Frequency of Annual and Single-Storm Erosion Index, R

Location	Return Period in Years			
	2	5	10	20
ANNUAL EROSION INDEX , R				
Little Rock, Ark.	308	422	510*	569
Indianapolis, Ind.	166	225	275*	302
Devils Lake, N.D.	56	90	120*	142
SINGLE-STORM EROSION INDEX, R				
Little Rock, Ark.	69	115	158	211
Indianapolis, Ind.	41	60	75	90
Devils Lake, N.D.	27	39	49	59

Source: Wischmeier and Smith (1965)
** Interpolated values*

Table 2.4 K, Soil-Erodibility Factor by Soil Texture in t/a *

Textural Class	Organic Matter Content (%) 0.5	2	4
Fine sand	0.16	0.14	0.10
Very fine sand	0.42	0.36	0.28
Loamy sand	0.12	0.10	0.08
Loamy very fine sand	0.44	0.38	0.30
Sandy loam	0.27	0.24	0.19
Very fine sandy loam	0.47	0.41	0.33
Silt loam	0.48	0.42	0.33
Clay loam	0.28	0.25	0.21
Silty clay loam	0.37	0.32	0.26
Silty clay	0.25	0.23	0.19

* *Selected from USDA-EPA, Vol. 1 (1975)* and are estimated averages of specific soil values. For more accurate values by soil types use local recommendations of Soil Conservation Service or state agencies.

(1 ton/acre =2.24 Mg/ha)

Table 2.5 Ratio of Soil Loss from Crops to Corresponding Loss from Continuous Fallow[a] (C Factor)

Cover, Sequence, and Management	Crop Yields: Meadow (tons)	Corn (bu)	Crop-Stage Period[b]: 0 (%)	1 (%)	2 (%)	3 (%)	4 (%)
Ist-yr corn after meadow, Rdl [c]	2	60	15	30	27	15	22
2nd-yr corn after meadow, Rdl	3	70	32	51	41	22	26
2nd-yr corn after meadow, RdR [d]	3	70	60	65	51	24	65
3[rd]- or more yr corn, RdL	-	70	36	63	50	26	30
Small grain w/ meadow seeding:							
(1) In disked corn residues							
After Ist-corn after meadow	2	60	-	30	18	3	2
After 2nd-corn after meadow	2	60	-	40	24	5	3
(2) On disked corn stubble, RdR							
After Ist-corn after meadow	2	-	-	50	40	5	3
After 2nd-corn after meadow	2	-	-	80	50	7	3
Establishes grass and legume meadow	3	-	-	-	0.4	-	-

[a] Portion of 100-line published table *(Wischmeier, 1960)*

[b] Crop-stage periods are defined below:

0 Turnplowing to seedbed preparation

1 Seedbed- first month after seeding

2 Establishment-second month after seeding

3 Growing cover- from 2 months after seeding to harvest

4 Stubble or residue-harvest to plowing or new seedbed

[c] RdL, crop residues left and incorporated by plowing

[d] RdR, crop residues removed

Source: *Smith and Wischmeier (1962)*

Table 2.6 Recommended Conservation Practice P[a]

Percent Slope	P_c Contouring (Maximum slope length in m)	P_{sc} Strip Cropping[b]	P_{tc} Terracing and Contouring[c]
Parallel to Field Boundary	0.8[d]	-	-
1.1-2	0.6 (150)	0.30	-
2.1-7	0.5 (100)	0.25	0.10
7.1-12	0.6 (60)	0.30	0.12
12.1-18	0.8 (20)	0.40	0.16
18.1-24	0.9 (18)	0.45	-

[a] Factor for up and down slope is 1.0

[b] A system using 4-year rotation of corn, small grain, meadow, meadow. Use with terraces for farm planning.

[c] Recommended only for computing soil loss from the field or loss to the terrace channel with upslope plowing.

[d] For slopes up to 12 % only

Source: *Wischmeier and Smith (1965)*

Example:

Determine the soil loss from a single 10-year return period storm for the following conditions: Location Memphis, Tennessee, K=0.1 t/a, L=122 m (400ft), s=10 percent. The storm came during the second year in the rotation and during the first month (period 1) after seeding. All residue from the previous crop was left and incorporated by plowing.

Solution: From Table 2.3 read R=158 for nearest station at Little Rock , Ark., and from Table 2.5 read C= 0.51, and from Table 2.6 read P_c =0.6, therefore :

$$A = 2.24\ R\,K\,LS\,C\,P = 2.24 \times 158 \times 0.1 \times 2.7 \times 0.51 \times 0.6$$

$$= 29.2 \text{ Mg/ha } (13.1 \text{ ton/acre})$$

2.6.2 Runoff Estimation

Conservation structures and channels must be designed to handle natural flows of water from rainfall or melting snow. Runoff constitutes the hydraulic load that the structure or channel must withstand.

Runoff defines as the portion of precipitation that makes its way toward stream channels, lakes, or oceans as surface or subsurface flow. The term runoff usually means surface flow.

Runoff process:

Before runoff can occur, precipitation must satisfy the demand of evaporation, interception, infiltration, surface storage, surface detention, and channel detention.

Factors affecting runoff:

Rainfall duration, intensity, and areal distribution influence the rate and volume of runoff. Total runoff for a storm is clearly related to the duration for a given intensity. Infiltration will decrease with time in the initial stages of a storm. Thus a storm of short duration may produce no runoff, whereas a storm of the same intensity but of long duration will result in runoff.

Rainfall intensity influence both the rate and volume of runoff. An intense storm exceeds the infiltration capacity by a greater margln than does a gentle rain; thus a volume of runoff is greater for the intense storm even though total precipitation for two rains is the same. The intense storm actually may decrease the infiltration rate because of its destructive action on the soil structure at the surface.

Watershed factors affecting runoff are size, shape, orientation, topography, geology, and surface culture. Both runoff volumes and rates increase as watershed size increases.

Predicting runoff:

Methods of runoff estimation necessarily neglect some factors and make simplifying assumptions regarding the influence of others. Methods presented here are applicable to small agricultural watersheds less than a few hundred hectares.

Design runoff rates:

The capacity to be provided in a structure that must carry runoff may be termed the design runoff rate. Structure and channels are planned to carry runoff that occurs within a specified return period. Vegetated controls and temporary structures are usually designed for a runoff that may be expected to once in 10 years. Expensive, permanent structures will be designed only once in 50 or 100 years.

2.6.2.1 Rational Method

The rational method of predicting a design peak runoff rate is expressed by the equation,

$$q = 0.0028\, CiA$$

where q =the design peak runoff rate in m^3/sec

C =the runoff coefficient

i =rainfall intensity in mm/h for the design period and for a duration equal to the time of concentration of the watershed.

A =watershed area in acres

The time of concentration of a watershed is the time required for water to flow from the most remote (in time of flow) point of the area to the outlet once the soil has become saturated and minor depressions filled. One of the most widely accepted methods of computing time of concentration was developed by Kirpich (1940),

$$T_c = 0.0195\, L^{0.77}\, S^{-0.385}$$

Where T_c =time of concentration in min.

L =maximum length of flow in m.

S =the watershed gradient in m per m of the difference in elevation between the outlet and the most remote point divided by the length, L.

Rational method is considered sufficiently accurate for runoff estimation in the design relatively inexpensive structures where the consequences of failure are limited. Application of rational method as presented here is normally limited to watersheds of less than 800 ha (2000 acre).

Table 2.7 Runoff Coefficient, C for Agricultural Watersheds (Soil Group B)

Cover and Hydrologic Condition	Coefficient C for rainfall rates of		
	25 mm/h (1 iph)	100 mm/h (4 iph)	200 mm/h (8 iph)
Row crop, poor practice	0.63	0.65	0.66
Row crop, good practice	0.47	0.56	0.62
Small grain, poor practice	0.38	0.38	0.38
Small grain, good practice	0.18	0.21	0.22
Meadow, rotation, good	0.29	0.36	0.39
Pasture, permanent, good	0.02	0.17	0.23
Woodland, mature, good	0.02	0.10	0.15

Source : Horn and Schwab (1963)

Table 2.8 Hydrologic Soil Group Conversion Factors

Cover and Hydrologic Condition	Factors for converting the runoff coefficient C from group B soils to [a]		
	Group A	Group C	Group D
Row crop, poor practice	0.89	1.09	1.12
Row crop, good practice	0.86	1.09	1.14
Small grain, poor practice	0.86	1.11	1.16
Small grain, good practice	0.84	1.11	1.16
Meadow, rotation, good	0.81	1.13	1.18
Pasture, permanent, good	0.64	1.21	1.31
Woodland, mature, good	0.45	1.27	1.40

[a] Factors were computed from Table 2.9 by dividing the curve number for the desired soil group by the curve number for group B

Table 2.9 Runoff Curve Numbers for Hydrologic Soil-Cover Complexes for Antecedent Rainfall Condition II, and $I_a = 0.2\ S$

Land Use or Cover	Treatment or Practice	Hydrologic Condition	*Hydrologic Soil Group			
			A	B	C	D
Fallow	Straight row	-	77	86	91	94
Row Crops	Straight row	Poor	72	81	88	91
	Straight row	Good	67	78	85	89
	Contoured	Poor	70	79	84	88
	Contoured	Good	65	75	82	86
	Terraced	Poor	66	74	80	82
	Terraced	Good	62	71	78	81
Small grain	Straight row	Poor	65	76	84	88
	Straight row	Good	63	75	83	87
	Contoured	Poor	63	74	82	85
	Contoured	Good	61	73	81	84
	Terraced	Poor	61	72	79	82
	Terraced	Good	59	70	78	81
Close-seeded legumes or rotation meadow	Straight row	Poor	66	77	85	89
	Straight row	Good	58	72	81	85
	Contoured	Poor	64	75	83	85
	Contoured	Good	55	69	78	83
	Terraced	Poor	63	73	80	83
	Terraced	Good	51	67	76	80

Land Use or Cover	Treatment or Practice	Hydrologic Condition	*Hydrologic Soil Group			
			A	B	C	D
Pasture or range		Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
	Contoured	Poor	47	67	81	88
	Contoured	Fair	25	59	75	83
	Contoured	Good	6	35	70	79
Meadow (permanent)		Good	30	58	71	78
Woods (farm wood-lots)		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	25	55	70	77
Farmsteads		-	59	74	82	86
Roads and right-of-way (hard surface)		-	74	84	90	92

*Soil Group	Description	Final Infiltration Rate (mm/h)
A	Lowest Runoff Potential. Includes deep sands with very little silt and clay, also deep, rapidly permeable loess.	8-12
B	Moderately Low Runoff Potential. Mostly sandy soils less deep than A, and loess less deep or less aggregated than A, but the group as a whole has above-average infiltration after thorough wetting.	4-8
C	Moderately High Runoff Potential. Comprises shallow soils and soils containing considerable clay and colloids, though less than those of group D. The group has below-average infiltration after pre-saturation.	1-4
D	Highest Runoff Potential. Includes mostly clays of high swelling percent, but the group also includes some shallow soils with nearly impermeable sub-horizons near the surface.	0-1

Source: U.S. Soil Conservation Service, National Engineering Handbook, Hydrology, Section 4 (1972) and U.S Dept. Agr. ARS 41-172 (1970)

Example :

Determine the peak runoff rate for a 50-year return period storm from a 40.5 ha (100-ac) watershed near Chicago III with the following characteristics:

Ha	Subarea (ac)	Topography percent slope	Soil group (See table 2.9)	Land Use, Treatment and Hydrologic condition
24.3	(60)	Flat	C	Row crop, contoured good
16.2	(40)	10 to 30	B	Woodland, good

The maximum length of flow is 610 m (2000 ft) and the difference in elevation along this path is 3 m (10 ft).

Solution: The watershed gradient gradient is (10/2000) 100 =0.5 percent

T_c $=0.0.195\ L^{0.77}\ S^{-0.385}$

$=0.0195\ (610)^{0.77}\ (3/610)^{-0.385}$

=20 min.

Say for a 50-year return period near Chicago, the 20-min rainfall is 97 mm/h (3.8 iph).

The runoff coefficient C from Table 2.7 for row crop, good practice and woodland is 0.56 and 0.10, respectively, and the factor correcting hydrologic soil group C to Group B for the 24.3 ha subarea from Table 2.8 is 1.09.

C $=(24.3/40.5) \times 0.56 \times 1.09 + (16.2/40.5) \times 0.10 \quad =0.41$

There fore,

q $=0.0028\ C\ I\ A$

$=0.0028 \times 0.41 \times 97 \times 40.5$

$=4.51\ m^3/sec$ (159 cfs)

2.6.2.2 Soil Conservation Service Method

This method describe by U.S. SCS (1973) was originally developed for uniform rainfall using assumptions for a triangular hydrograph as shown below in Fig. 2.7. The time to peak flow,

$T_p \quad =D/2 + T_L \quad =D/2 + 0.6\ T_c$

Where T_p =Time to peak

D =duration of excess rainfall

T_L =time of lag

T_c =time of concentration

Time of concentration is the longest travel time and is not the time of peak as in the rational equation. Time of lag is an approximation of the mean travel time. The time of peak is necessary to develop a design hydrograph for routing runoff through a storage reservoir or for combining hydrographs from several watersheds. For some small watersheds the time of peak may exceeds the time of concentration. The time of recession for the triangular hydrograph is taken as 1.67 T_p, thus the total time of flow is 2.67 T_p. The peak runoff rate derived from the triangular hydrograph is,

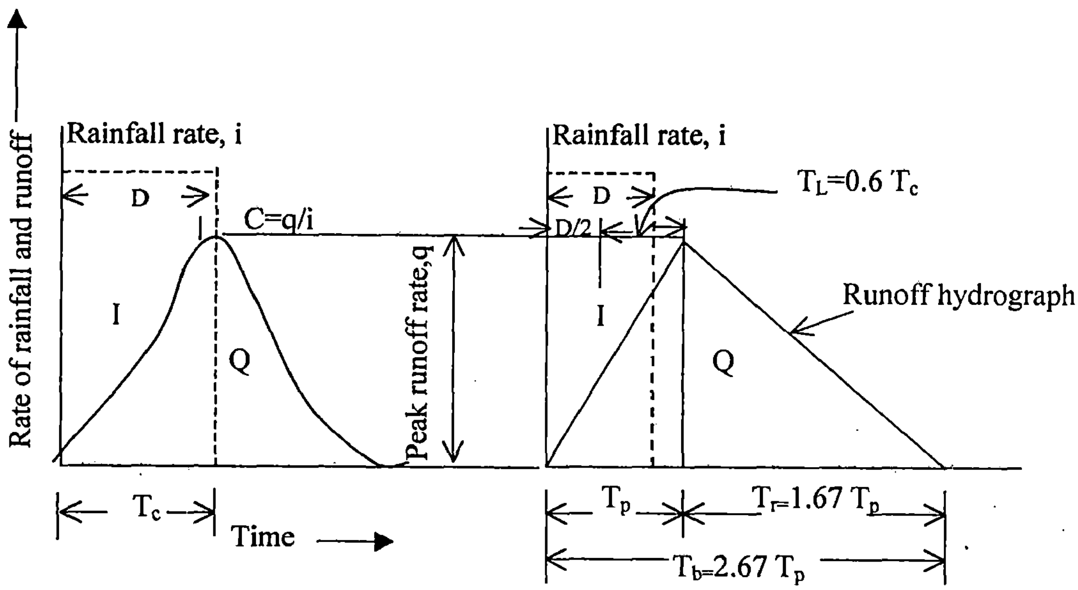
$q = 0.0021\ Q\ A/T_p$

where Q =runoff volume in mm depth (area under the hydrograph)

q =runoff rate in m^3/sec

A =Water shed area, in ha

T_p =time of peak in hours



(a) Rainfall and runoff with assumptions for the rational equation

(b) Soil Conservation Service triangular hydrograph method of runoff estimation

Fig. 2.7 Triangular Hydrograph

Example:

Using SCS method, determine the peak runoff rate from a 100-ha (247-ac) watershed from a uniform 36-min (0.6-h) storm that produce 10 mm (0.39 in.) of runoff volume. Assume T_c for the watershed is 0.5 h.

Solution:

Substituting to T_p $=D/2 + 0.6\ T_c$

$=0.6/2 + (0.6 \times 0.5)$

$=0.6$ h

Substituting to q $=0.0021\ QA/T_P$

$=0.0021 \times 10 \times 100/0.6$

$=3.50\ m^3/sec$ (124 cfs)

Runoff Volume:

It is often desirable to predict the total volume of runoff that may come from a watershed during a design flood. Total volume is of primary interest in the design of flood control reservoirs.

Estimation of runoff volume using SCS Method:

The Soil Conservation Service Method (SCS) was developed from many years of storm flow records for agricultural watersheds in many parts of United States.

The SCS equation is represented by:

$$Q = \frac{(I - 0.2S)^2}{I + 0.8S}$$

Where Q =direct surface runoff in depth in mm

I =Storm rainfall in mm

S =maximum potential difference between rainfall and runoff in mm starting at the time the storm begins.

For convenience in evaluating antecedent moisture, soil conditions, land use, and conservation practices, the U.S. soil Conservation Service (1972) defines

$$S = \frac{25400}{N} - 254$$

Where N =an arbitrary curve number varying from 0 to 100. Thus, if

N =100, then S =0 and I = Q

Curve numbers can be obtained from Table 2.9 . These values apply to antecedent rainfall condition II, which an average value for annual floods. Correction factors for other antecedent rainfall conditions are listed in Table 2.10.

Table 2.10 Antecedent Rainfall Conditions and Curve Numbers (for I_a =0.2S)

Curve Number for Condition II	Factor to Convert Curve Number for Condition II to: Condition I	Factor to Convert Curve Number for Condition II to: Condition III
10	0.40	2.22
20	0.45	1.85
30	0.50	1.67
40	0.55	1.50
50	0.62	1.40
60	0.67	1.30
70	0.73	1.21
80	0.79	1.14
90	0.87	1.07
100	1.00	1.00

Condition	General Description	5-day Antecedent Rainfall (mm): Dormant season	5-day Antecedent Rainfall (mm): Growing season
I	Optimum soil condition from about lower plastic limit to wilting point	<13	<36
II	Average value for annual floods	13-28	36-53
III	Heavy rainfall or light rainfall and low temperatures within 5 days prior to the given storm	>28	>53

Source: *U.S Soil Conservation Service, National Engineering Handbook, Hydrology, Section 4 (1972).*

Condition I is for low runoff potential with soil having low antecedent moisture suitable for cultivation . Condition III is for wet conditions prior to the storm. As indicated in Table 2.10 no upper limit for antecedent rainfall is intended. The limits for the dormant season apply when the soil are not frozen and when no snow is on the ground.

Example:

Determine the estimated maximum volume of runoff during the growing season for a 50-year return period that may be expected from the watershed. Assume that antecedent moisture 5 days prior to the storm was 40 mm (1.6 in.) of rainfall; and the critical duration of the storm is 6 hours.

Solution:

Given the rainfall for a 6-hr storm is 107 mm (4.2 in.) at Chicago. From Table 2.9 for Antecedent Rainfall Condition II, read the approximate curve number and calculate the weighted value as follows:

Sub area, A ha (ac)	Soil Group	Land Use, Treatment, and Condition	Curve Number, N	NA
24.3 (60)	C	Row crop, contoured, good	82	1993
16.2 (40)	B	Woodland, good	55	891
40.5 (100 ac)			Total	2884

Weighted curve number, N $=2884/40.5 \quad =71.2$

Substituting to S $=25400/71.2-254$

$=103$ mm

Then substitute to Q $=\dfrac{\{107-0.2x103)^2}{107+(0.8x103)}=39$ mm (1.54 in.)

Q =(39 mm x 40.5) /1000 mm/m

=1.58 ha-m (12.8 ac-ft)

CHECK LIST OF DATA COLLECTIONS FOR WATERSHED DEVELOPMENT AND MANAGEMENT

3.1 CHECKLIST OF WATERSHED RESOURCE DATA

3.1.1 Topographic Maps

Topo sheets which give details of contours, streams, rivers, etc. of the watershed, aerial photos, Soil and Land Capability maps of the watershed, and Land Use maps and all important land features of the watershed.

3.1.2 Location of Watershed

To describe the location of watershed any available maps, aerial photo coverage that shows the clear picture of watershed location will suffice the requirement.

3.1.3 Climate

In general all available meteorological parameters are very essential in the study of watershed viz. temperature, rainfall distribution and intensity, evaporation, wind speed, droughts and floods, etc. Climatic factors are very necessary in the determination of the runoff rate and volume, sediment yield, susceptibility to erosional hazards, productive potential of the land, etc.

3.1.4 Geology

The geologic characteristics of watershed is also considered as an important factors to describe the watershed undertaken for management.. It includes the geological information such as: nature of parent rocks, fractures, faults, weathering, and ground water recharge. Geology is very essential to determine the erosion susceptibility,, infiltration of surface runoff, seepage etc.

3.1.5 Water Resources

Information on water resources is most important. It is assessed on the basis of various hydrological happenings such as rainfall, movement of water into the soil profile by infiltration process and contribution of seepage water from various water bodies like ponds, reservoirs, canals etc.

3.1.6 Natural Vegetation

Data about type and distribution of natural vegetation should be recorded.

3.1.7 Land Use Pattern

The land use pattern and land management practices used have great effect on the runoff yield. For example, an area which is under forest cover, where a thick layer of mulch of leaves and grasses etc. has been accumulated, there form a little surface runoff, due to the fact that more rain water is absorbed by the soil. While in barren field, where not any type of cover is available, a reverse trend is obtained.

3.1.8 Soil, Land Capability and Fertility Status

3.1.8.1 Land Capability Classification

The common parameters such as soil texture, depth, slope and erosion, which are recorded on survey map for land capability, form the basis of classification. However, local limitation e.g. salinity, alkalinity, water-logging, climate, etc. are also taken into account. The objective of classification is to recognize the land into a unit with similar kinds and degree of limitations. The basic unit is capability unit which consists of group of soil types of sufficiently similar conditions in respect of soil depth, profile, slope and degree of erosion as to make them suitable for cultivation of crops and to warrant the use of similar conservation measures. The system recognizes the whole land into eight classes from Class I to Class VIII, for which class I to IV are suitable for cultivation, while V to VIII are unsuitable for cultivation.

3.1.8.2 Soil Fertility Status

The condition and status of soil fertility is also an important data requirement to verify the productivity on various land uses within the watershed.

3.1.8.3 Quality of Irrigation Water

The condition and attributes of water is very essential requirement in the study of watershed.

3.1.9 Socio-economic Status

Socio-economic status and traditions of the people within the area of coverage form an integral requirement in the study of watershed.

3.2 WATERSHED DATA IN STUDY AREA

In this dissertation, three watersheds projects have been considered for the purpose of the comparative study. Two selected watershed projects in India (Navamota and Chevella Watershed) and one watershed in Philippines (Mount Balatukan Range Natural Park Watershed).

3.2.1 Navamota Watershed (Gujarat, India)

3.2.1.1 Introduction

A watershed was selected in Sabarkhanta, the backward and tribal district of Gujarat. Management plan for development of Navamota watershed was prepared in 1984. The execution of works started in 1985. Gujarat State Land Development Corporation, Gujarat State Forest Department and Gujarat State Agriculture Department were the execution agencies in the early years. Scientific and technical personnel of Central Soil and Water Conservation Research and Training Institute, Research Center, Vasad provided full technical guidance for the execution of the development programme. Throughout monitoring of progress and assessment of the impact of the project was also done by the Vasad Research Center.

3.2.1.2 Location of Watershed

Navamota watershed is located in Khedbrahmma taluka of Sabarkantha district in Gujarat State at 23^0 13' N latitude and 73^0 01' E longitude, at a height of 203.91 m above mean sea level. The total area of the watershed is 313 ha. It is 266 km north of Vasad and 168 m away from Ahmedabad. The watershed drains into Sabarmati river, which is nearly 1 km downstream. (*Figure 3.1*)

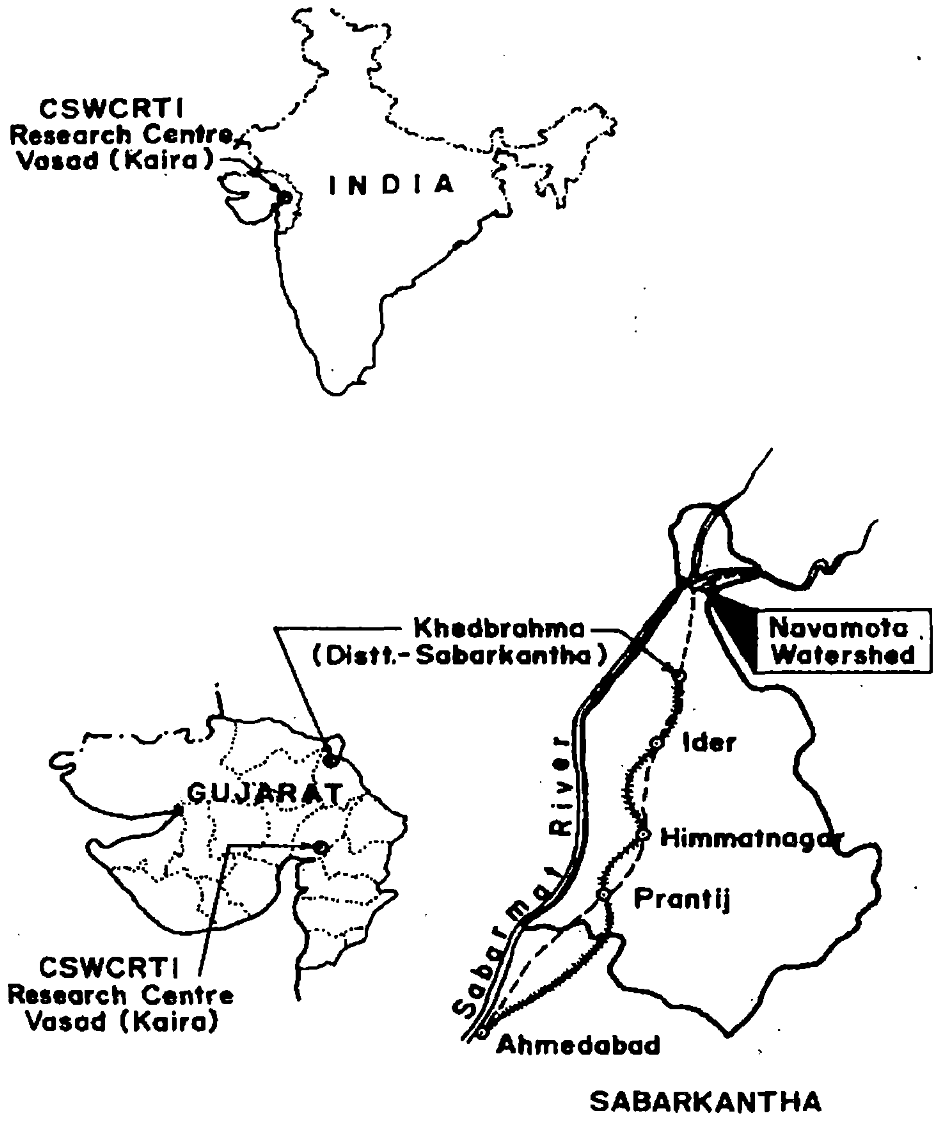


Figure 3.1 Location map of Navamota Watershed-Sabarkantha District, Gujarat, India

3.2.1.3 Climate

The climate is subtropical and semi-arid. There are 3 distinct season ie. summer from March-June, rainy from July-October and winter from November to February. The hottest month is May and coldest month is January.

3.2.1.4 Rainfall

Rainfall in the area is irregular and erratic accompanied by gusty winds. The rainfall in the district in general, increase from the south-west to the north-east up to Idar taluka and thereafter decreases. Almost the entire rainfall during the rainy season from June-October. Only few showers are experienced during October-December.

The rainfall data from 1981 to 1996 collected at Kheroj in Navamota watershed are presented in Table 3.1. Although the rainfall is 665 mm, year to year variation is quite pronounced. During last 16 years the maximum rainfall was received in 1992 (1134 mm) and the minimum rainfall in 1987 (221.6 mm). Computed standard deviation for the annual rainfall was 278 mm. This wide variation highlighted the uncertainty of the rainfall in the area.

3.2.1.5 Temperature

The seasonal variation in temperature is quite wide. Temperature data for 1979-1983 are given in Table 3.2. Average maximum and minimum temperature during this period were 39.3 ^{0}C in the month of May and 16.3 ^{0}C for January.

3.2.1.6 Geology

The rock formations met within the district are: Ajabgarh series, Alwar series, Idar granite, Deccan trap and Aravali system. The Aravali system of formations occurring extensively in the district comprises of calcium gneiss, mica and horn-blende, schist, chlorites and chlorites schist, biotite-gneiss, slate, phyllites, quartzites and limestones.

3.2.1.7 Water Resources

Major, medium or minor irrigation projects were non-existent in the watershed at the beginning of the project. The tract had very little ground water resources and therefore, deep tube wells were not successful. 36 kuchcha shallow wells and 12 pucca wells were the main source for drinking water with little possibility of irrigation.

3.2.1.8 Natural Vegetation

The semi-arid, sub-tropical climate of the area supported dry deciduous type of vegetation. The floristic composition can be generally classified as an associate formation of mixed deciduous species. The 52 ha forest land and 43 ha Government /Panchayat land was devoid of trees and grasses due to over exploitation of vegetation.

3.2.1.9 Land Use Pattern

Agriculture and mining were the main occupation for the majority of the population of Khedbrahmma taluka. The land holdings being small, cultivation was practiced even on hill slopes. 217 ha of watershed land was privately owned. Only one crop was generally taken in the monsoon season. Major crops grown were maize-97.7 ha, cotton 46.4 ha, pigeonpea-44.5 ha, blackgram –8.5 ha, kodra (Paspalum scrobiculatum - 6.2 ha and paddy-2.3 ha. In rabi, as per irrigation facilities, maize and wheat were grown on 13.7 ha and 8 ha respectively. Whole agriculture was primitive without high yielding varieties, fertilizers, plant protection or conservation considerations on slope. No orchard was noticed. Few scattered trees of mango and ber could be seen. The 52 ha land in the watershed though devoid of any vegetation was named as forest. There was only 6.13 ha gochar/gram Panchayat land in the watershed which was already over exploited. There was 37 ha of government wasteland in the watershed.

3.2.1.10 Soils, Land Capability and Fertility Status

Detailed soil survey of the watershed was done by digging soil profiles and auger holes in different physiographic areas of the watershed. Features like soil texture, soil depth, land slope and erosion, etc. were studied in field and physico-chemical properties analyzed in the laboratory for determining soil series and land capability classes.

The soils of watershed are mainly light to medium textured. The area has five soil series viz. Chandpur, Umbora, Udhania, Hansara and Navamota. Distribution of the five soil series is given in Table 3.3. Umbora series is the most predominant in the watershed with an area of 100.3 ha followed by Udhania-77.6 ha. Nearly 57 % watershed area is covered by these two soil series. The drainage of the soil is generally good.

3.2.1.10.1 Land Capability Classification

The land capability classes based on (i) the inherent soil characteristics (ii) the external features, and (iii) the environmental factors that limit the use of land are broad grouping indicated by Roman numeral I to VIII which show progressive increase in the limitations for sustained use of soils. Out of the total area of 313 ha, nearly 218 ha falls in land capability classes II to IV. The major limitations of these soils is the shallow depth which is due to excessive erosion. Most of these area is currently under agriculture but yields were very low. Proper soil and water conservation measures and improved agriculture were necessary to increase yields on sustained basis. The distribution of area as per their capability classes is given in Table 3.4.

3.2.1.10.2 Soil Fertility Status

More than 250 soil samples (0-15 cm) were collected from different soil series of the watershed and analyzed for pH , EC, Organic carbon, available P_2O_5, available K_2O and micro nutrients like Fe, Zn, and Mn.

Most of the soils of the watershed have low organic carbon, high available P_2O_5 and K_2O, pH and EC of all soil was neutral and low respectively. Soils of the watershed are low in Zn, however Cu and Mn contents are high.

3.2.1.10.3 Quality of Irrigation Water

Very few of the water samples are collected from wells of watershed showed signs of salinity hazard. Sodium hazard was not found in the irrigation water.

3.2.1.10.4 Socio-economic Status

The poor land and primitive agriculture resulted in economic backwardness of the area. The watershed having been over exploited, was high in state of degradation. The literacy was only 16 percent. The literacy rate among women was lower than men. Most of the farming families had marginal and small holdings with very simple implements like plough and sickles, etc. A large number of village people workers as casual labor in the stone and lime quarries and stone crushing units. There was no other source of economic growth and people were socio-economically very backward.

Table 3.1 Monthly rainfall distribution at Kheroj (Navamota Watershed), Rainfall mm

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Annual**
1981	0	0	0	0	0	10.4	169.9	259.1	93.8	0	0	0	**533.2**
1982	0	0	0	0	0	0	146.5	121.7	11.8	0	0	0	**280***
1983	0	0	0	0	0	88.8	414.8	378.7	76.2	122	0	0	**1080.5**
1984	0	0	0	0	0	4	244.5	425.5	42	0	0	0	**716**
1985	0	0	0	0	0	0	251.5	183	0	79	0	0	**513.5**
1986	0	0	0	0	0	165	126.5	111.7	0	0	0	0	**403.2***
1987	0	0	0	0	0	87	17.2	86.4	4	0	0	27	**221.6***
1988	0	0	0	7.4	0	36.7	255.2	374.2	77.2	17	0	0	**767.7**
1989	5.5	0	0	0	0	59.3	225.6	240.6	65.5	0	0	0	**596.5**
1990	0	5	0	0	70	37	316.7	284.8	108.6	0.6	0	0	**822.7**
1991	0	0	0	0	0	17.2	381.2	83.8	7.7	0	0.5	0	**490.4***
1992	0	0	0	0	0	29	380.3	306.4	418.3	0	0	0	**1134**
1993	0	0	0	0	0	0	24.2	617.8	18.7	0	0	0	**660.7**
1994	0	0	0	0	0	85.8	392.3	388.7	259	0	0	0	**1125.8**
1995	0	0	0	0	0	69.2	327.7	79.8	60.4	0	0	0	**537.1**
1996	0	0	0	0	0	114.2	302	98.6	223.4	20	0	0	**758.2**
Ave.	**0.3**	**0.3**	**0.0**	**0.5**	**4**	**50**	**249**	**253**	**91.7**	**15**	**0.03**	**1.7**	**665.1**
Std. Dev.	1.4	1.3	0.0	1.9	17.5	48.3	124.6	156.7	115.5	34.9	0.1	6.8	278

Source: Kurothe et al (1997)

* Drought years.

Table 3.2 Temperature (°C) at Khedbrahmma (1970-1983)

Months	Average Maximum	Average Minimum	Monthly Average
January	25.6	16.3	21.0
February	27.3	18.4	22.0
March	33.4	22.9	28.2
April	37.3	27.1	32.2
May	39.3	30.0	34.7
June	38.0	30.3	34.2
July	33.6	28.1	30.9
August	32.6	27.6	30.1
September	32.4	27.6	30.0
October	32.3	23.7	28.0
November	29.3	20.3	24.8
December	27.0	18.6	22.1
Average	**32.3**	**24.2**	**28.3**

Source: Kurothe et al (1997)

Table 3.3 Area under different Soil Series

Soil Series	Area (ha)	% Area
Umbora (Uba)	100.3	32.0
Udhania (Uda)	77.6	24.8
Chandpur (Cdp)	50.4	16.1
Hansara (Hsr)	39.5	12.6
Navamota (Nmt)	4.9	1.6
Total	**272.63**	**87.1**
Ravines	26.6	8.5
Miscellaneous	13.8	4.4
Grand Total	**313.0**	**100.0**

Source: Kurothe et al (1997)

Table 3.4 Area under different land capability classes

Land capability classes	Area (ha)	Percent
III	16.5	5.3
III	57.5	18.4
IV	144.4	46.1
VI	8.9	2.8
VII	45.4	14.5
Total	**272.63**	**87.1**
Gullies and Nalas	26.6	
Miscellaneous	13.8	
Grand Total	**313.0**	

Source: Kurothe et al (1997)

3.2.2 Chevella Watershed (Jogipet in Medak District of Andhra Pradesh)

3.2.2.1 Location

A watershed located in Chevella and Pothulaboguda village about 30 kms from Jogipet in Medak district of Andhra Pradesh was taken up by CRIDA for development in collaboration with State Department of Agriculture, Government of Andhra Pradesh (Figure 3.2). This was one of the 47 Model Watersheds operated during VII plan period in different parts of the country.

MAP OF THE WATERSHED AREA
(IN CHEVELLA AND POTHULABOGUDA villages, MEDAK Dist)
area : 673 ha.

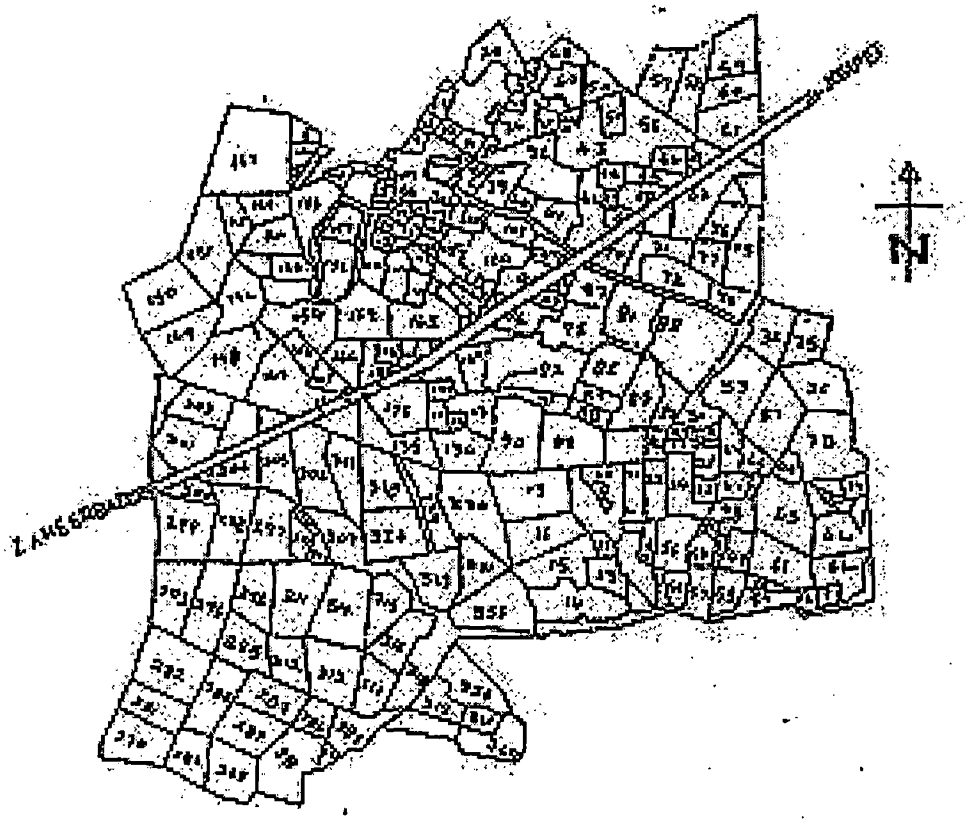


Figure 3.2 Location map of Chevella Watershed

3.2.2.2 Climate

The watershed is located in sub-tropical climate and receives about 870 mm rainfall per annum which occurs mostly through the South-West monsoon (Table 3.5).

Table 3.5 Monthly rainfall at Jogipet during 1978-1982
along with average rainfall during the last 100 years

Months	Rainfall (mm)					Average of five years	Average of ten years
	1978	1979	1980	1981	1982		
January	6.0	0.0	0.0	3.0	0.0	1.8	0.0
February	28.5	33.0	0.0	0.0	0.0	12.3	0.0
March	0.0	0.0	0.0	38.0	0.0	7.6	6.1
April	51.5	0.0	19.5	0.0	0.0	14.2	23.6
May	20.0	113.0	0.0	66.0	46.0	49.1	26.5
June	181.4	91.5	218.0	237.0	185.0	182.0	115.6
July	392.9	141.5	102.0	93.5	290.0	205.7	244.2
August	359.7	78.0	407.5	187.5	116.0	229.7	167.3
Sept.	141.5	254.0	140.5	266.0	296.0	219.0	220.7
October	59.0	25.0	0.0	52.0	58.0	36.8	42.7
November	36.5	0.0	0.0	12.0	0.0	9.7	10.5
December	0.0	0.0	0.0	0.0	0.0	0.0	5.9
Total	**1277.0**	**736.5**	**887.5**	**955.0**	**991.0**	**969.0**	**871.1**

Source: Katyal et al (1995)

The monsoon normally starts around 10th of June and terminates by first week of October. Pre-monsoon showers are often received at the end of May to early June. High intensity rains are common.

On an average, 244 mm rainfall is received during July which is highly dependable. As a result of heavy rains weeding of June sown crops like sorghum and greengram gets delayed. July rains also produced significant runoff which is collected in community tanks for raising irrigated rice.

The rainfall in August is comparatively lower (167 mm) than that of July. It is also erratic and undependable. Although heavy rains are received during September (221 mm), year to year variations are higher than that of rains during July. High runoff is a familiar feature of September rains.

The South-West monsoon normally withdraws by early October. On an average 43 mm of rainfall is received during October which is highly undependable. During certain years the South-West monsoon may withdraw before the middle of September. Such a situation may affect the yield potential of long duration crops and also create difficulties in seeding of rabi crops in dry lands.

Rainfall analysis has revealed that the crop productivity is influenced by:

- Delay in onset of monsoon
- Long dry periods during August
- Early termination of rainy season
- Continuous cloudy weather during October- November

3.2.2.3 Soils

The watershed area is located in black soil (Vertisol) region of Medak district. The surface texture varies from sandy clay loam to clay loam. Clay content is usually higher in the subsurface layers.

Soil depth is highly variable. Nearly 20% of the total area is shallow in depth (<25 cm) in the upper reaches of the slope. Medium to deep soils (>50 cm) are mostly found towards the middle and lower half of each sub-watershed. These occupy about 62% of the total cultivated area (Table 3.6).

Table 3.6 Soil depth description of Chevella Watershed

Soil depth (cm)	Total area (ha)
Up to 10	9.8
10-25	123.0
25-50	123.2
Above 50	416.6
Total	**672.6**

Source: Katyal et al (1995)

Black soils of Chevella watershed are poor in organic carbon (0.25%) and above average in P (available P_2O_5 22.9 kg/ha) availability. They are well supplied with K (K_2O 356 kg/ha); slightly alkaline (pH 7.5) in reaction, and almost free from salt problem.

3.2.2.4 Vegetation

There is very little natural vegetation in the watershed area due to the intense biotic interference. The overgrazed area is left with few trees and shrubs like "babool" (Acacia nilotica), "dhak" (Butea monosperma), "custard apple " (Annona squamosa) and "neem" (Azadirachta indica).

Judging from eco-climatic view point the dominant pasture community for the area ought to be "Dichanthium" – "Sehima" – "Cenchrus" type. But due to over-grazing and over-exploitation the degraded vegetation consists of poverty grass. (Aristida funiculata), "dub grass" (Cynodon dactylon), "button grass " (Elnisive compress), Sehima and Cryspogon. In the cultivated fields perennial weeds like "nut grass (Cyprus rotendus), "dub grass" (Cynodon dactylon), "gunjars" (Ischaemum bracatum) "gharks" (Aristolaches bracatum) etc., are noticed over a large area inspite of a long history of cultivation.

3.2.2.5 Crop production level and practices adopted

On Vertisols of the watershed area crops are grown both during kharif and rabi.

Table 3.7 Cropping patterns in the Chevella Watershed

Cropping pattern	Area (ha)	Major crops
a) Khariff cropping		
Early sown	474.0	Sorghum, Greengram, Pigeonpea
Late sown	30.0	Chili
b) Kharif fallow and rabi cropping	121.1	Sorghum , Coriander
Total	**625.5**	

Source: Katyal et al (1995)

3.2.2.6 Animal Management

The total livestock population at the time of baseline survey of the watershed was 1172. The entire livestock belong to local non-descript categories with poor animal draught power and low milk yields. The natural pastures yielded between 400 kg-1000 kg forage/ha due to predominance of unmanaged native species and low fertility and shallow depth of soils. About 35 ha of the watershed area was under pastures. It was, thus, apparent that productivity of pastures can be substantially improved by the introduction of improved farm forestry programme.

3.2.2.7 Socio-economic Conditions

Watershed villages had 469 families with a total population of 2500. More than two thirds of the families belonged to small and marginal groups (holding size less than 2 ha.) At the time of survey there was no functional cooperative society in the villages. The credit requirement was met primarily through a rural branch of State Bank of India which is located at Alla Durg.

3.2.3 Mount Balatukan Range Natural Park (Misamis Oriental, Region 10, Northern Mindanao)

3.2.3.1 Introduction

Mt. Balatukan Range Natural Park plays an important role toward economic and environmental well being of Northeastern part of the province of Misamis Oriental. It serves as watershed area of several rivers that are vital to the province of Misamis Oriental.

The wide range of elevation of Mt. Balatukan Range made possible the presence of several habitats for various wildlife including the endangered Philippine Eagle, Rufuos Hornbill, tarsier, Phil deer and other endangered species.

The socio-economic survey indicates that one indigenous community resides in the area. Tenured migrants from the province of Misamis Oriental are also present. These occupants mostly engaged in farming, and are now encroaching on the forested portion of the proposed protected area. Surveys conducted within the occupied areas also shows that some of these areas are not suitable for intensive cultivation. These areas have steep slopes ranging from 30 to greater than 50 % and are highly prone to erosion.

The inclusion of Mt. Balatukan Range to the National Integrated Protected Area System (NIPAS) will ensure the implementation of appropriate protection and conservation efforts in the area.

3.1.1.1 Location of the Watershed

The Mount Balatukan Range Natural Park is a mountain range located southwest of Gingoog City. It covers portions of Gingoog City and of the municipalities of Claveria, Balingasag, and Medina all are located in the Province of Misamis Oriental. (Figure 3.3)

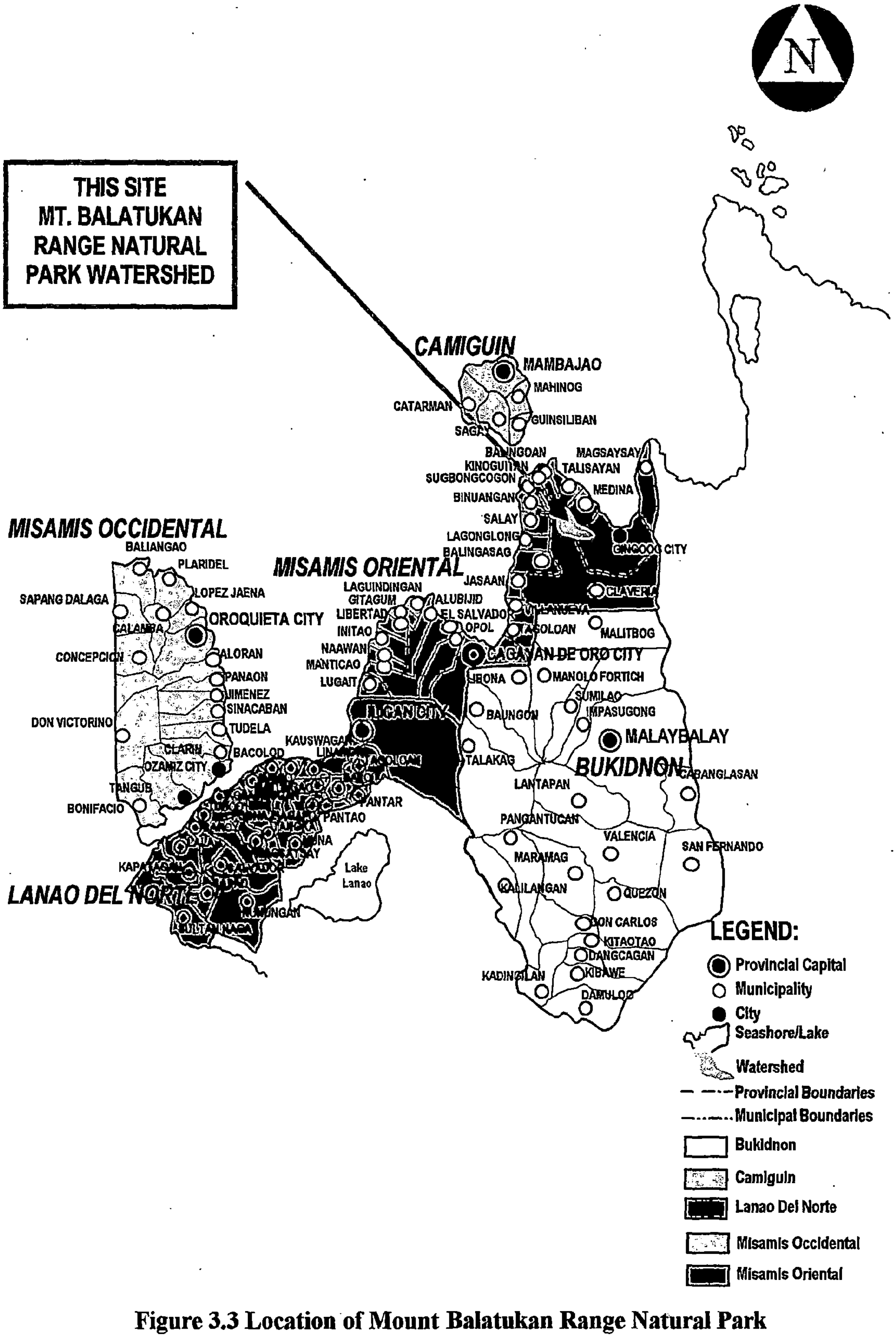


Figure 3.3 Location of Mount Balatukan Range Natural Park Watershed, Philippines

The most prominent view of the proposed Natural Park is the summit of Mt. Balatukan that stands at Two Thousand Three Hundred Twenty Eight (2,328) meters above sea level with an altitude of One Thousand Eight Hundred (1,800) meters.

3.2.3.3 Area

The proposed Mt. Balatukan Park covers an area of Eleven Thousand Six Hundred Eighty Three (11,683) hectares, of which virgin forests covers about 6,500 hectares.

3.2.3.4 Climate

The proposed Mt. Balatukan Natural Park belongs to the Type III of the Corona System of Philippine Climate Classification. Its seasons are not very pronounced but relatively dry from November to April and wet during the rest of the year. Rainfall is evenly distributed throughout the year.

3.2.3.5 Topography

Generally, Mt. Balatukan Range has a very rugged terrain made up by numerous mountain peaks and deep ravines with its slope gradient ranging from 8 % to above 45 % distributed as follows:

Slope Gradient (Percent)	Area Covered (%)
8-18	5
18-30	20
30-45	25
>45	50

Its elevation ranges from 600 m to 2328 m above sea level of which the highest point is Mount Balatukan summit.

3.2.3.6 Soils

The soils in the foot slopes are of the clayey types that are generally deep. However, in steep areas where erosion is active, shallow layers occurs. Soil in these areas is well drained but relatively acidic. Higher rainfall and faster lateral movement in these areas contribute to higher leaching of soil.

3.2.3.7 Vegetative Cover

The elevation range of the proposed Mt. Balatukan protected area provides different habitat to a diverse species of flora and fauna.

Of its total area of 11,683 ha hectares, about 80 % is covered by lowland residual dipterocarp forest, 15 % by mossy or montane forest and 5 % by cogonal vegetation.

The southern portion of the proposed protected area at Claveria side has been logged-over by MAC International Co., Inc. under TLA No. 349. Its license was cancelled on March 30, 1989.

Lowland residual dipterocarp forest dominates the landscape from the base of the mountain or from elevation at 750 m to 1,350 m above sea level. In this transitional type of forest, there is an abundance of very tall dipterocarp trees like Lauan, Nato, Tanguile, and Makaasim with heights reaching 35 meters having diameter of above 100 cm.

At 1,000 m to 1,350 m level the very tall trees of the first storey disappear and the two-storey character of the vegetation begins to be noticeable. The forest here is a moist, tropical rain forest.

At 1,350 m to 1,650 m above sea level, the two-storey character of vegetation become apparent. Giant ferns are abundant at these elevations starting at about 1,700 m, the trees develop heavy growth of moss suspended from their branches, but there is not much moss on the trunk of the trees nor on forest floor. At about 1,800 m above sea level the trees become stunted and twisted. Even Podocarpus species, which grow taller at lower elevations, become stunted and is only about 2 m high

3.2.3.8 Socio-economic Information

The area covered by the proposed Mt. Balatukan Range protected area is under the political jurisdiction of the three (3) municipalities of Misamis Oriental including the City of Gingoog.

There are 17 barangays within the immediate vicinities of the park, namely:

Municipality/City		Barangays
1. In Gingoog City	-	Minbuntong, Bakid,Bakid, Bantaawan, Kalagonoy, Kibuging, Kipuntos, Murallon, Pigsaluhan and Lunotan
2. Medina	-	Dig-aguyan, San Isidro and San Jose
3. Balingasag	-	So. Lantad, Kibanban
4. Claveria	-	Tipolohon, Parmbugas, Bulahan and Pelaez

The 17 barangays have an estimated total number of 1,331 households with 9,841 individuals. Of the total population, about 200 individuals are residing within the protected area. They belong to the indigenous cultural communities.

They have their own language and religious practices. They are gentle and hardworking people. Because they want to avoid conflict, they have been exploited by the Dumagats (lowlanders). They are now extremely marginalized with very few holdings, without any strong tenure on the land they till. Their method of farming is still slash and burn (kaingin).

Other ethnic group present in the area includes the Cebuanos, Boholanos, and Camiguingnons.

The Local Government Units (LGUs) are present and very active in all communities. In almost all cases, the LGU has a stronger community influence than the tribal community structure of leadership.

Table 3.8 Monthly rainfall distribution at Gingoog Agrometeorological Station (Mt. Balatukan Range Natural Park Watershed), Rainfall mm

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1987	100	75	55	30	150	250	260	200	190	170	100	95	**1675**
1988	95	80	50	35	175	255	265	300	250	150	95	85	**1835**
1989	85	60	50	25	150	200	175	210	225	130	80	35	**1425**
1990	65	50	35	28	135	185	155	185	201	115	65	27	**1246**
1991	115	95	58	38	165	275	390	305	205	155	175	38	**2014**
1992	135	110	75	45	185	227	395	325	425	195	185	97	**2399**
1993	55	45	28	22	125	175	151	315	180	122	75	35	**1328**
1994	75	105	32	32	137	180	395	398	255	125	85	45	**1864**
1995	66	103	31	29	133	165	335	105	235	115	69	48	**1434**
1996	61	98	33	24	115	124	317	133	238	125	77	51	**1396**
Ave.	**85**	**82**	**44.7**	**31**	**147**	**204**	**284**	**248**	**240**	**140**	**101**	**56**	**1661.6**
Std. Dev.	25	23	14.5	6.6	21.3	44.7	93.1	89.6	66.1	25	41	25	346.6

Source: Mt. Balatukan Range Natural Park Initial Protected Area Plan (2002)

Table 3.9 Temperature (°C) at Mount Balatukan Range Natural Park (1987-1996)

Months	Average Maximum	Average Minimum	Monthly Average
January	29	25	27.0
February	31	26	28.5
March	*35*	*27*	31.0
April	*36*	*31*	33.5
May	33	29	31.0
June	32	28	30.0
July	32	27	29.5
August	32	28	30.0
September	33	29	31.0
October	34	30	32.0
November	30	27	28.5
December	26	22	24.0
Average	**31.9**	**27.4**	**29.7**

Source: Mt. Balatukan Range Natural Park Initial Protected Area Plan (2002)

SOIL EROSION AND LOSS ESTIMATION

4.1 GENERAL

Soil is one of the vital resources for agricultural production and it is vulnerable to erosion by flowing water and wind.

Soil erosion is caused by a complex factors such as clearing of forests in order to get more land for cultivation, inappropriate use of the land, shifting cultivation and the logging for timber and fuel production. Especially, the land on steep slopes without appropriate protection is vulnerable to erosion.

The increase and pressure in population and development of nature for industrialization tend to accelerate the process of erosion resulting in the loss of fertile top soil causing agricultural production to decrease and the changing of river regime causing flood damage. Soil erosion in catchment area removes vegetation and organic matters from the surface and decrease the intake rate of the soil. In addition, soil erosion leads to the silting of irrigation and drainage canals, aquatic weed growth and declining fish production in the rivers and lakes. Soil erosion aggravates the environment and gives much harm to the local population both in the economic and social fields.

Soil conservation is to keep away soil from loss and utilize it without waste for high level agricultural production. Soil conservation prevents lowering of soil productivity and occurring of sediment problems which cause land damage, flood damage, water quality and environment problem.

The main factors affecting soil erosion are rainfall intensity and duration, types of soil, land slope, vegetation and ground surface condition.

4.2 SOIL LOSS ESTIMATION

The basic equation for the estimation of soil loss is Universal Soil Loss Equation which is a mathematical model used to predict soil losses due to aerial erosion.

$A = R K L S C P$

Where all the notations/symbols had been clearly defined and thoroughly discussed in Chapter II.

4.3 CALCULATIONS

4.3.1 Navamota Watershed (Gujarat, India)

Table 4.1 Annual Rainfall and Calculated Runoff Erosivity Index at 30-min. maximum rainfall intensity, 1988-1996

Year	Annual (mm)	Runoff Erosivity Index, R *
(1)	(2)	(3)
1988	767.7	40.46
1989	596.5	39.48
1990	822.7	40.72
1991	490.4	38.73
1992	1134	41.97
1993	660.7	39.88
1994	1125.8	41.94
1995	537.1	39.08
1996	758.2	40.41
Ave.	665.1	39.90

*Column 3, $R=12.1+8.9 \log I$,

Where:

R=rainfall and runoff erosivity index

I= intensity of rainfall, mm/hr.

Table 4.2 Topographic Factor, LS

Slope Class (%)	LS-Factor
0-3	0.3
3-5	0.7
5-8	1.38
8-20	4.16
20-30	10.4
30-40	16.4
>45	19.8

Wischmeier and Smith (1978)

*LS Factor obtained from Slope-Effect Chart using slope length of 100 m

Table 4.3 Rainfall, Runoff and Soil Loss of the Navamota Watershed

Year	Rainfall	Runoff (mm)	Runoff %	Soil Loss (ton/ha)
Pre-project*		220.0	25.0	11.67
1988	767.7	12.6	1.6	-
1989	596.5	8.1	1.4	0.29
1990	822.7	16.0	1.9	0.99
1991	490.4	14.6	2.9	2.26
1992	1134	90.7	8.0	4.03
1993	660.7	23.6	3.5	1.08
1994	1125.8	55.0	4.9	2.00
1995	537.1	9.6	1.8	0.27
1996	758.2	11.9	1.6	0.51
Average	878.7	26.9	3.7	1.43

Source: Kurothe et al (1997)
*Estimated

Monitoring of runoff outflow and water loss from the watershed was done by a Stage Level Recorder installed in the masonry check dam. Year-wise rainfall, runoff and soil loss are summarized in Table 4.3.

It is estimated that from highly undulating topography of the watershed and denuded slopes prior to the project about 25% runoff occurred from the watershed. This was now reduced to only 3.7 percent by in situ soaking and storage behind dams. Now only part of runoff produced from storms of >50 mm is lost from the watershed. This is the welcome effect of conservation practices and structures. Less runoff and more rainwater retained within the watershed recharges the ground water. This is very well reflected by the water table readings recorded in open wells of the area.

4.3.2 Chevella watershed (Medak District of Andhra Pradesh, India)

Table 4.4 Annual Rainfall and Runoff Erosivity Index of Chevella Watershed, 1978-1982

Year	Annual (mm)	Runoff Erosivity Index, R
(1)	(2)	(3)
1978	1277.0	42.42
1979	736.5	40.29
1980	887.5	41.02
1981	955.0	41.30
1982	991.0	41.44
Ave.	969.0	41.36

Table 4.5 Value of C factor for different Regions of India (Crop Management Factor C)

Station	Crop	Soil Loss (ton/ha)	Value of C
Agra	Cultivated fallow	3.80	1.00
	Bajra	2.34	0.61
	Dichanthium annulatum	0.53	0.13
Dehradun	Cultivated fallow	33.52	1.00
	Cymbopogon grass	4.51	0.13
	Strawberry	8.89	0.27
Hyderabad (Ave. of 4 years)	Cultivated fallow	5.00	1.00
	Grass	0.59	0.12
	Bajra followed by cowpea	1.91	0.38
	Bajra	2.00	0.40
Rehmankhera (Ave. of 4 years)	Cultivated fallow	9.95	1.00
	Jowar-Arhar	2.73	0.28
	Til-gram	4.50	0.45

Source: Gurmel Singh et al (1999)

Table 4.6 Computed value of soil erodibility factor, K
from various research stations in India

Station	Soil	Computed K
Agra	Loamy sand alluvial	0.07
Dehradun	Dhulkot silt loam	0.15
Hyderabad	Red chalka sandy loam	0.08
Kharagpur	Soils from lateritic rock	0.04
Kota	Kota-clay loam	0.11
Octacamund	Laterite	0.04
Rehmankhera	Loam. Alluvial	0.17
Vasad	Sandy loam, alluvial	0.06

Source: Gurmel Singh et al (1999)

Table 4.7 Values of P factors at various station in India (Conservation Practice Factor)

Station	Practice	P factor
Dehradun	Contour cultivation on maize	0.74
Ooctacamund	a) Potato up-and-down	1.00
	b) Potato on contour	0.51
Hazaribagh	a) Up-and-down utilization of maize	1.00
	b) Cultivation of maize along contour	0.31
Kanpur	a) Up-and-down cultivation of jowar	1.00
	b)Contour utilization of jowar	0.39
Chandigarh	Contour bunding	0.28
Dehradun	a) Up-and-down cultivation	1.00
	b) Contour farming	0.68
	c) Channel terraces with contour farming	0.38
	d)Channel terraces (at 1.5 times VI) with graded furrows	0.35
	e) Strip cropping 3:1 (maize-cowpea)	0.51
	f) Terracing and bunding in agricultural watershed	0.03
	g) Brushwood checkdams in forest (Shorea robusta) watersheds	0.52

Source: Gurmel Singh et al (1999)

Table 4.8 Soil Losses Of Chevella Watershed, India

Land Use	Slope Class in %	Area (ha)	R	K	LS	C	P	Annual Soil Loss Ton/ Year	Annual Soil Loss Ton/ha/ Year
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1978									
1) Kharif cropping (Sorghum, greengram, Pigeonpea, Chilli	5 – 8	504.00	42.42	0.37	1.38	1.00	0.60	6,550	13.00
2) Kharif fallow and rabi cropping (Sorghum, Coriander)	3 – 5	121.00	42.42	0.37	0.70	1.00	0.50	665	5.49
		625.00						*7,215*	*11.54*
1979									
1) Kharif cropping (Sorghum, greengram, Pigeonpea, Chilli	5 – 8	504.00	40.29	0.37	1.38	1.00	0.60	6,221	12.34
2) Kharif fallow and rabi cropping (Sorghum, Coriander)	3 – 5	121.00	40.29	0.37	0.70	1.00	0.50	631	5.22
		625.00						*6,852*	*10.96*
1980									
1) Kharif cropping (Sorghum, greengram, Pigeonpea, Chilli	5 – 8	504.00	41.02	0.37	1.38	1.00	0.60	6,334	12.57
2) Kharif fallow and rabi cropping (Sorghum, Coriander)	3 – 5	121.00	41.02	0.37	0.70	1.00	0.50	643	5.31
		625.00						*6,976*	*11.16*

Land Use	Slope Class in %	Area (ha)	R	K	LS	C	P	Annual Soil Loss Ton/ Year	Annual Soil Loss Ton/ha/ Year
1981									
1) Kharif cropping (Sorghum, greengram, Pigeonpea, Chilli	5 - 8	504.00	41.30	0.37	1.38	1.00	0.60	6,377	12.65
2) Kharif fallow and rabi cropping (Sorghum, Coriander)	3 - 5	121.00	41.30	0.37	0.70	1.00	0.50	647	5.35
		625.00						*7,024*	*11.24*
1982									
1) Kharif cropping (Sorghum, greengram, Pigeonpea, Chilli	5 - 8	504.00	41.44	0.37	1.38	1.00	0.60	6,399	12.70
2) Kharif fallow and rabi cropping (Sorghum, Coriander)	3 - 5	121.00	41.44	0.37	0.70	1.00	0.50	649	5.37
		625.00						*7,048*	*11.28*
AVERAGE ANNUAL SOIL LOSS									**11.23**

Calculations:

Column 4, R=12.1+8.9log I, (Table 4.4)
Column 5, K (Table 2.4)
Column 6, LS (Slope Factor, Table 4.2)
Column 7, C (Table 4.5)
Column 8, P (Table 2.6)

4.3.3 Mount Balatukan Range Natural Park, Philippines

Table 4.9 Annual Rainfall and Calculated Runoff Erosivity Index at 30-min. maximum rainfall intensity (Mt. Balatukan Range Natural Park Watershed, Philippines),1988-1996

Year	**Annual (mm)**	Runoff Erosivity Index, R*
(1)	(2)	(3)
1988	1835	43.83
1989	1425	42.85
1990	1246	42.33
1991	2014	44.19
1992	2399	44.86
1993	1328	42.58
1994	1864	43.89
1995	1434	42.87
1996	1396	42.77
Ave.	1661.6	43.44

*Column 3, $R=12.1+8.9 \log I$,
Where:
R=rainfall and runoff erosivity index
I= intensity of rainfall, mm/hr.

Table 4.10 Soil Losses Of Mount Balatukan Range Natural Park, Philippines (Using Universal Soil Loss Equation)

Land Use	Slope class in %	Area	R	K	LS	C	P	Annual Soil Loss Ton/ Year	Annual Soil Loss Ton/ha/ Year
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1988									
1) Lowland Dipterocarp forest	>45	9,346.40	43.83	0.21	19.80	0.40	0.45	306,600	32.80
2) Mossy or montane forest	30-45	1,752.45	43.83	0.21	10.40	0.40	0.45	30,196	17.23
3) Cogonal grass	0-30	584.15	43.83	0.21	4.16	0.40	0.40	3,579	6.13
		11,683.00						*340,375*	*29.13*
1989									
1) Lowland Dipterocarp forest	>45	9,346.40	42.85	0.21	19.80	0.40	0.45	299,745	32.07
2) Mossy or montane forest	30-45	1,752.45	42.85	0.21	10.40	0.40	0.45	29,520	16.85
3) Cogonal grass	0-30	584.15	42.85	0.21	4.16	0.40	0.40	3,499	5.99
		11,683.00						*332,764*	*28.48*
1990									
1) Lowland Dipterocarp forest	>45	9,346.40	42.33	0.21	19.80	0.40	0.45	296,108	31.68
2) Mossy or montane forest	30-45	1,752.45	42.33	0.21	10.40	0.40	0.45	29,162	16.64
3) Cogonal grass	0-30	584.15	42.33	0.21	4.16	0.40	0.40	3,456	5.92
		11,683.00						*328,726*	*28.14*
1991									
1) Lowland Dipterocarp forest	>45	9,346.40	44.19	0.21	19.80	0.40	0.45	309,119	33.07
2) Mossy or montane forest	30-45	1,752.45	44.19	0.21	10.40	0.40	0.45	30,444	17.37
3) Cogonal grass	0-30	584.15	44.19	0.21	4.16	0.40	0.40	3,608	6.18
		11,683.00						*343,170*	*29.37*
1992									
1) Lowland Dipterocarp forest	>45	9,346.40	44.86	0.21	19.80	0.40	0.45	313,806	33.58
2) Mossy or montane forest	30-45	1,752.45	44.86	0.21	10.40	0.40	0.45	30,905	17.64
3) Cogonal grass	0-30	584.15	44.86	0.21	4.16	0.40	0.40	3,663	6.27
		11,683.00						*348,373*	*29.82*

Land Use	Slope class in %	Area	R	K	LS	C	P	Annual Soil Loss Ton/ Year	Annual Soil Loss Ton/ha/ Year
1993									
1) Lowland Dipterocarp forest	>45	9,346.40	42.58	0.21	19.80	0.40	0.45	297,856	31.87
2) Mossy or montane forest	30-45	1,752.45	42.58	0.21	10.40	0.40	0.45	29,334	16.74
3) Cogonal grass	0-30	584.15	42.58	0.21	4.16	0.40	0.40	3,477	5.95
		11,683.00						*330,667*	*28.30*
1994									
1) Lowland Dipterocarp forest	>45	9,346.40	43.89	0.21	19.80	0.40	0.45	307,020	32.85
2) Mossy or montane forest	30-45	1,752.45	43.89	0.21	10.40	0.40	0.45	30,237	17.25
3) Cogonal grass	0-30	584.15	43.89	0.21	4.16	0.40	0.40	3,584	6.13
		11,683.00						*340,841*	*29.17*
1995									
1) Lowland Dipterocarp forest	>45	9,346.40	42.87	0.21	19.80	0.40	0.45	300,585	32.16
2) Mossy or montane forest	30-45	1,752.45	42.87	0.21	10.40	0.40	0.45	29,603	16.89
3) Cogonal grass	0-30	584.15	42.87	0.21	4.16	0.40	0.40	3,509	6.01
		11,683.00						*333,696*	*28.56*
1996									
1) Lowland Dipterocarp forest	>45	9,346.40	42.77	0.21	19.80	0.40	0.45	299,186	32.01
2) Mossy or montane forest	30-45	1,752.45	42.77	0.21	10.40	0.40	0.45	29,465	16.81
3) Cogonal grass	0-30	584.15	42.77	0.21	4.16	0.40	0.40	3,492	5.98
		11,683.00						*332,143*	*28.43*
AVERAGE ANNUAL SOIL LOSS									**28.82**

Calculations:

Column 4, R=12.1+8.9log I, (Table 4.9)
Column 5, K (Table 2.4)
Column 6, LS (Slope Factor, Table 4.2)
Column 7, C (Table 2.5)
Column 8, P (Table 2.6)

CHARACTERISTICS AND TREATMENTS OF A FEW SELECTED WATERSHEDS IN INDIA AND PHILIPPINES

5.1 WATERSHED CHARACTERISTICS

5.1.1 General characteristics of the two selected watersheds in India

One of the common problem of Navamota and Chevella watershed is the over-exploitation and improper management of natural resources which causes serious concerns to environmental degradation especially to watershed area that don't have any technical assistance granted by the government.

Government of India has taken very bold steps to make use of science and technology to modernize itself. The country has, however, yet to pay serious attention to the very intense use of its natural resources-soils, land, water, forests, minerals etc. It is a well known fact that these resources are already over exploited and ravaged due to very intense increase in human population, rapid industrialization and with the consequent improvement in standard of living. Thus in India, as time passes, there will be greater need for conservation and better management of soil and water resources.

Soil erosion and degradation are among the most severe watershed and environmental problems in India. Soil degradation, especially in the semi-arid region. Apart from the on-farm impacts like decline in the productivity and shift to low value crops, it creates off-farm problems like sedimentation of reservoirs, and deterioration of water quality. Considering the importance of the problem the government initiated a series of soil and water conservation programs through watershed approach. Despite the huge investments made, very little empirical analyses has been carried out on the economics of soil conservation in India mainly because of non-availability of data, conceptual issues and methodological problems.

5.1.2 Mount Balatukan Range Natural Park Watershed Characteristics

In broad-spectrum, watershed degradation in Mount Balatukan Range Natural Park Watershed, Philippines poses a threat to the country's economy and the livelihoods of the many rural households that depend on using the natural resources within individual watersheds for their farming and/or forestry activities. As the rural population continues to grow in number, pressure on the country's natural resources will increase leading to an expansion in the number of watershed areas affected by deforestation, soil erosion, declining soil productivity and deterioration in water quality and quantity. However, watershed degradation does not have to be an inevitable consequence of using land for agricultural and/or forestry purposes. It is possible to gain economic benefit from employing the natural resources found in the country's watershed while at the same time preserving the water resource for future generations.

In general, watershed in Philippines are government lands. Despite the policy and laws enacted by the government prohibiting the use of the watershed areas reserved for these specific purpose, people are still encroaching and illegally utilizing these areas for production purposes for subsistence and eventual survival and to feed their families. Illegal cutting of trees are rampant resulting in the denudation of the watershed. These are the jobs assigned to number of forest security guards to implement the restriction imposed by the government but because of large coverage areas and also government do not have enough funds, still nowadays the problem continue to exist and happening.

It is the desire of the government to adopt the full comprehensive land use, plan to save the continuous degradation of the watershed areas, however due to constraint of funding only few soil conservation technologies and approaches had been implemented. Construction of soil conservation structures is not adopted due to lack of funds of the government.

5.1.3 Treatments

5.1.3.1 Treatments adopted by the few selected watersheds in India and Philippines towards watershed management

Government of India invested a huge amount in order to solve the massive problems on soil erosion and land degradation.

Generally Indian watershed management adopted comprehensive land use plan which included development programmes related to agriculture, afforestation, grassland development and horticulture. This also shows the engineering measures like contour bunded area , land levelling, gully stabilization measures and water storage structures etc. All these practices were implemented in the areas where Government of India assisted the watershed projects.

On the part of the Philippine government, commonly watershed development concentrated on reforestation projects for its soil and water conservation. No engineering structures had been adopted due to fund constraints of the government.

5.1.3.1.1 Treatments adopted in Navamota Watershed of Sabarkantha district in Gujarat state, India

Navamota Watershed adopted the following treatments for the integrated development of the watershed:

i. In-Situ moisture conservation

Contour cultivation, contour bunding and minor levelling, ridge and furrow system, soil working and planking, addition of organic matter and green manure to improve soil structure and conserve more moisture.

ii. Soil conservation structures

Construction of composite check and masonry dams whichever is convenient and applicable in the area with gauging device. Also construction of boulder check dams and gully plugs had been adopted.

iii. Optimal utilization of water resources

Since India is a semi arid region where rainfall is not quiet adequate, construction of small check dam is widely used at the sites where water could be impounded for life saving irrigation in the rabi season.

iv. Crop improvement in arable land

Balanced fertilizer, certified seed, timely sowing, maintaining optimum plant population, soil working, weeding, control of pest and diseases, harvesting at right stage, field demonstration, contour cultivation, introduction of cover crops and other conservation agronomy practices.

v. **Horticulture development**

Better management and maintenance of existing fruit plants like lemon, ber, mango. Pruning and budding with improved varieties.

vi. **Forestry, Grassland and Agroforestry Development**

Planting of area along foothills with Eucalyptus tereticornis, grasses and bamboo in and around the gullies. Planting of Neem and Acacia Nilotica, Acacia tortilis on hilly and degraded lands, live-hedge fencing of Thor (Euphorbia neriifolia), Prosopis juliflora etc. around plantations. Planting of grass slips on all old and new earthen structures like bunds, terrace risers and check dams etc. in the watershed. Also, introduction and promotion of hybrid napier grass and para grass in areas where sufficient moisture is available.

vii. **Instrumentation for monitoring of hydrological changes**

Monitoring rainfall intensity, runoff outflow and water loss from the watershed was done by an instrument installed in the watershed area.

Table 5.1 Land treatment works imposed in Navamota Watershed

S.NO.	Item of Work	Achievement
Arable Land		
1	Contour bunding and land levelling (ha)	197
2	Gully plugs (No.)	37
3	Masonry check dams with gauging structures (No.)	2
4	Loose boulder check dams (No.)	17
Non-arable land		
1	Trenches (m)	5,007
2	Stone wall (m)	1,057
3	Gabbions (m)	16,325
4	Loose boulder check dams (No)	17

Source: Kurothe et al (1997)

5.1.3.1.2 Treatments adopted in Chevella Watershed, Medak District of Andhra Pradesh

Significant achievements of Chevella Watershed :

1. **Resources created for Soil and Water Conservation**

The various measures that were taken up for soil and water conservation is grouped into following categories:

i) **Community works**

Safe disposal of excess runoff is among the most crucial requirement in black soils. In achieving this objective the following measures were taken:

a) Diversion drains

In the watershed , an area of about 95 ha was covered with hilly ridges. The runoff from these lands traversed over the cultivated fields lying on the lower side. On its way, it damaged both the land and the crops. Therefore a diversion drain was constructed to protect these cultivated fields from the ravages of rill erosion and water logging. This drain, 810 m in length, was aligned to serve as a feeder channel for the community tank in Chevella village. Stone revetment was provided for this diversion drain for a length of 24 m.

b) Rock fill dams

In the Chevella watershed there existed two major nallahs 2-3 m deep, which were badly eroded. In order to stabilized, 92 rock-fill check dams were constructed at suitable intervals along the entire length of the nallahs. These structures were also expected to help in recharging of the ground water.

c) Community tank

An existing community tank near Chevella village was found non-functional. It was renovated with the objective of recharging ground water and for meeting the requirement of drinking water for animals during summer season.

d) Water harvesting pond

Water resource development is one of the most important component of a watershed development programme. In pursuance of this objective a pucca masonry check dam-cum-water harvesting pond with a storage capacity of 1200 m^3 was constructed in a perennial nallah. With the construction of this structure it became possible to raise irrigated crops, viz., rice, wheat, onion and ground nut in an area of about 2.0 ha both during kharif and rabi seasons. Also, the structure has the potential for providing supplemental or protective irrigation to kharif and rabi crops for 5 – 10 ha to cover moisture stress periods.

ii) Major land treatments in cultivated fields

a) Conservation drains

In situations where a field has been divided into a number of sub-plots or where holding size is small (i.e. less than 2.0 ha), the farmers do not prefer to have the graded bunds which further divide their fields into small parcels. In such cases, farmers have preference for conservation drains. This drains is running across the major slope between two holdings. The spoil of drain is used in such a way that field bunds are made on each side of the drain. The bund on the upper side of the drain would be useful for trapping the silt in the field itself before the runoff water enters the drain. The bund on the lower side would avoid breaching of drain so that runoff water could be diverted safely towards the minor slope of the watershed rather than going downwards in an uncontrolled manner. Suitable waste weirs are also provided at the lowest point of the upper field, so that runoff water enter into the drains without causing any gully formation.

A total of 250 ha was covered with conservation drains. These drains were covered with grass to minimize bed erosion.. Siltation of these drains would take place inspite of provision of protective bunds and waste weirs.

b) Graded bunds

Wherever holding size is large (i.e > 2 ha) graded bunds laid at suitable vertical interval should be preferred. Graded bunds were constructed after obtaining consent of individual farmers. However, the alignment of the bunds is adjusted that, as far as possible, it coincided with the land holding boundaries. A total area of 200 ha was covered with graded bunds.

c) Waste weirs

During implementation of the bunding programme, erosion was observed at the outlet points due to compromise made in the alignment of bunds (to accommodate property lines) and also because of the elevation between the fields and the waterways. At such places stone waste weirs were erected to check the erosion. A total of 114 waste weirs were constructed.

d) Waterways

The excess runoff diverted by graded bunds or conservation drains was required to pass through major waterways before it merged with the community drains. Suitably designed waterways measuring a total of about 9,555 m length were constructed. Some of these waterways were reinforced with stone checks to cut down velocities on steeper slopes in addition to vegetative protection provided by proper grass covers.

2. Crop Production Programme and Impact on Crops

a) Improved crop management

Out of the 338 farm families in the watershed, 215 were covered under the improved cropping programme. The important improved management practices followed were i) use of high yielding varieties of seed ; ii) use of fertilizer at recommended doses; iii) placement of fertilizer using different types of implements according to farmer's choice and iv) use of need based pesticides.

b) Silvipasture

An area of 9.5 ha had been covered with silvi-pastoral systems (5 ha of Government land and 4.5 ha of private land). However, only 5 ha of fodder crop involving Stylosanthes hamata and Leucaena leucocephala could be raised. These species suffered huge mortality due to severe drought during the year of planting.

c) Social forestry

An area of 5 ha was covered under social forestry in 1984-85 and 4 ha in 1985-86. Due to severe drought during these years, survival percentage was very poor (only 5%). Further plantation was pursued on an area of 34.4 ha including the 9 ha covered during 1984-86. In all 60,000 seedlings of Eucalyptus hybrids were planted. This plantation was also affected severely by drought of 1986-87.

d) Farm implements

Farm implements like Akkadias (182), pora tubes (97), gorru attachments (2) and funnels (338) were distributed to the farmers on 75% subsidy to enable the farmers to place the seed and fertilizer simultaneously with speed and precision. In addition, rocker sprayers (40) and hand compression sprayers were distributed to small and marginal farmers to protect crop against insect/pest attacks.

Table 5.2 Land treatment works carried out in Chevella Watershed

S. No.	Item of Work	Achievement
1	Bunding (ha)	450
2	Waterways (m)	9,555
3	Check dams in gullies (No.)	92
4	Waste weirs (No.)	114
5	Stone checks in waterways (No.)	31
6	Stone revetment for diversion drain (m)	24
7	Community ponds (No.)	1
8	Feeder channel for pond (m)	810
9	Deep (tractor) tillage (ha)	249
10	Control of perennial weeds by weedicide (ha)	22
11	Bed and furrow (ha)	1
12	Water harvesting pond (No.)	1

Source: Katyal et al (1995)

5.1.3.1.3 Treatments adopted in Mount Balatukan Range Natural Park Watershed, Philippines

A number of the activities adopted for the integrated development of the Mount Balatukan Range Natural Park Watershed, Philippines:

i. Soil and water conservation

Planting of fast growing trees in the identified watershed is a must to keep away from the following environmental losses:

a) Water conservation

- To increase the ground water recharge due to increased infiltration
- Minimize incidence of floods and droughts
- To minimize contamination and depletion of ground water resource
- To avoid siltation of rivers and lakes
- To keep away from destruction of wildlife habitat
- To protect the endangered and threatened wildlife

b) Soil conservation

- To avoid excessive surface soil erosion
- To minimize loss of soil fertility
- To decrease carbon emission to atmosphere and to increase the oxygen generation due to increase in plant cover.
- Rainfall/humidity enhancement
- Plant photosynthesis releasing oxygen to the atmosphere

ii. Crop improvement in arable land

Balanced fertilizer, certified seed, timely sowing, maintaining optimum plant population, soil working, weeding, control of pest and diseases, harvesting at right stage, field demonstration, contour farming known commonly in Philippines as Sloping Agricultural Land Technology

(SALT Project) introduced and implemented by the Department of Agriculture particularly in hilly and mountainous areas.

iii. Biodiversity preservation or wildlife protection

- Preservation of endangered flora and fauna species
- Preservation of ecosystems
- Preservation of the natural and agricultural gene pool

Table 5.3 Selected agricultural land treatments adopted in Mount Balatukan Range Natural Park Watershed, Philippines

S. No.	Treatments	Remarks
1	Contour plowing	Common soil-conserving technologies adopted in Mount Balatukan Range Range Natural Park. Watershed. No Engineering or agronomic structures had been constructed due to fund constraint of the government.
2	Integrated Pest Mgt (IPM)	
3	Contour strips/ hedgerows	
4	Plant trees or grasses on border	
5	Regular fallowing	
6	Regular crop rotation	

Source: Mt. Balatukan Range Natural Park Initial Protected area Plan (2002)

RESULTS AND DISCUSSION

6.1 RESULTS

In this study an effort has been made to analyze the different aspects of watershed management by undertaking a thorough study with all the available data of the few selected watersheds in India and Philippines to be able to compare and determine the major approaches and technologies adopted by both countries. Typical engineering measures are identified and planning and design aspects of various agronomic structures and other soil and water conservation technologies for the prevention of erosion are discussed with example and corresponding type of designs. Soil loss calculation has been conducted and analysed for the three selected watersheds using the commonly wide accepted Universal Soil Loss Equation (USLE) to determine the various factors affecting soil erosion. Furthermore, the characteristics of the selected watersheds and treatments being implemented had been studied and identified.

6.1.1 Annual Soil Loss Estimates and Average Annual Rainfall for the three selected watersheds using Universal Soil Loss Equation (USLE)

Table 6.1 Average Annual Soil Loss Estimates and Average Annual Rainfall

Particulars	Selected Watersheds		
	India		Philippines
	Navamota, Gujarat India	Chevella, Andhra Pradesh	Mt. Balatukan Range Natural Park, Misamis Oriental, Philippines
Average Annual Soil Loss (ton/ha)	1.43	11.23	28.82
Average Annual Rainfall (mm)	665.1	969.0	1661.6

Table 6.2 Treatments adopted and implemented in the selected Few watersheds in India and Philippines

S.NO.	Item of Work	Achievement
(Navamota Watershed, Gujarat India)		
Arable Land		
1	Contour bunding and land levelling (ha)	197
2	Gully plugs (No.)	37
3	Masonry check dams with gauging structures (No.)	2
4	Loose boulder check dams (No.)	17
Non-arable land		
1	Trenches (m)	5,007
2	Stone wall (m)	1,057
3	Gabbions (m)	16,325
4	Loose boulder check dams (No)	17
(Chevella Watershed, Andhra Pradesh, India)		
1	Bunding (ha)	450
2	Waterways (m)	9,555
3	Check dams in gullies (No.)	92
4	Waste weirs (No.)	114
5	Stone checks in waterways (No.)	31
6	Stone revetment for diversion drain (m)	24
7	Community ponds (No.)	1
8	Feeder channel for pond (m)	810
9	Deep (tractor) tillage (ha)	249
10	Control of perennial weeds by weedicide (ha)	22
11	Bed and furrow (ha)	1
12	Water harvesting pond (No.)	1
(Mount Balatukan Range Natural Park Watershed, Philippines)		
1	Contour plowing	No Engineering or agronomic structures had been adopted and constructed due to fund constraint of the government.
2	Integrated Pest Mgt (IPM)	
3	Contour strips/ hedgerows	
4	Plant trees or grasses on border	
5	Regular fallowing	
6	Regular crop rotation	

6.2 DISCUSSIONS

6.2.1 Navamota Watershed

Navamota watershed is located in Khedbrahmma taluka of Sabarkantha district in Gujarat State at 23^0 13' N latitude and 73^0 01' E longitude, at a height of 203.91 m above mean sea level. The total area of the watershed is 313 ha. The watershed drains into Sabarmati river.

The climate is subtropical and semi-arid. The Rainfall in the area is irregular and erratic accompanied by gusty winds. The average annual rainfall is 665 mm (Table 6.1). This wide variation highlighted the uncertainty of the rainfall in the area.

Major, medium or minor irrigation projects were non-existent in the watershed at the beginning of the project. The tract had very little ground water resources and therefore, deep tube wells were not successful. Kuchcha shallow wells and pucca wells were the main source for drinking water with little possibility of irrigation.

The semi-arid, sub-tropical climate of the area supported dry deciduous type of vegetation. The floristic composition can be generally classified as an associate formation of mixed deciduous species. The 52 ha forest land and 43 ha Government /Panchayat land was devoid of trees and grasses due to over exploitation of vegetation.

Based on the study, It has been observed through monitoring of runoff outflow and water loss from the watershed was done by a Stage Level Recorder installed in the masonry check dam. Year-wise rainfall, runoff and soil loss are summarized in Table 4.3.

It is estimated that from highly undulating topography of the watershed and denuded slopes prior to the project about 25% runoff occurred from the watershed. This was now reduced to only 3.7 percent by in situ soaking and storage behind dams. Now only part of runoff produced from storms is lost from the watershed. This is the welcome effect of conservation practices and structures adopted and implemented. Less runoff and more rainwater retained within the watershed recharges the ground water. Likewise, the soil loss was observed at 1.43 ton/ha which is quiet very low as compared to the other selected watersheds (Table 6.1)

6.2.2 Chevella Watershed

Chevella watershed is located in Chevella and Pothulaboguda village in Medak district of Andhra Pradesh. It has an area of 673 ha. The project was implemented by

CRIDA for development in collaboration with State Department of Agriculture, Government of Andhra Pradesh. The watershed is located in sub-tropical climate and receives about 969 mm rainfall per annum which occurs mostly through the South-West monsoon (Table 6.1). The watershed area is located in black soil (Vertisol) region of Medak district. The surface texture varies from sandy clay loam to clay loam. Clay content is usually higher in the subsurface layers. There is very little natural vegetation in the watershed area due to the intense biotic interference. The overgrazed area is left with few trees and shrubs.

With the implementation of the watershed management project, it was calculated that an average annual soil loss of 11.23 ton/ha was observed which is still quiet very low as compared to the selected watershed in Philippines (Table 6.1). This was attributed mainly by the adoption of suitable soil and water conservation technologies and engineering or agronomic structures built in the watershed area. This showed that the modern technologies adopted by Indian watershed played a very significant role resulting to the enormous effect in the soil and water conservation.

6.2.3 Mount Balatukan Range Natural Park Watershed

The Mount Balatukan Range Natural Park is a mountain range located southwest of Gingoog City. Mt. Balatukan Range Natural Park plays an important role toward economic and environmental well being of Northeastern part of the province of Misamis Oriental. It serves as watershed area of several rivers that are vital to the province of Misamis Oriental.

The socio-economic survey indicates that one indigenous community resides in the area. Tenured migrants from the province of Misamis Oriental are also present. These occupants mostly engaged in farming, and are now encroaching on the forested portion of the proposed protected area. Surveys conducted within the occupied areas also shows that some of these areas are not suitable for intensive cultivation. These areas have steep slopes ranging from 30 to greater than 50 % and are highly prone to erosion.

Mt. Balatukan Park covers an area of Eleven Thousand Six Hundred Eighty Three (11,683) hectares, of which virgin forests covers about 6,500 hectares.

Its seasons are not very pronounced but relatively dry from November to April and wet during the rest of the year. Rainfall is evenly distributed throughout the year.

Generally, Mt. Balatukan Range has a very rugged terrain made up by numerous mountain peaks and deep ravines with its slope gradient ranging from 8 % to above 45 %.

It has been observed in the study that Mount Balatukan Range Natural Park selected from one of the Philippine watershed has a very high average annual soil loss which reached to 28.82 ton/ha as compared to the selected watershed in India due to fact that the project is not adopting any engineering or agronomic structures for the prevention of soil erosion (Table 6.1 & 6.2). Further, the huge soil loss is also attributed with the unsustainable cultivation practices by the farmers encroaching the protected forested area in the highly sloping land and also the illegal cutting of trees resulting to continuous problems on soil erosion and land degradation.

Based on the results of the study, all information regarding land cover, land uses, soil types, climate and rainfall plays a significant task in watershed management study. Evidently, suitable soil and water conservation technologies and engineering and agronomic structures plays a very significant role in the watershed managements aspects.

CHAPTER 7

SUMMARY AND CONCLUSION

7.1 SUMMARY

Watershed Management plays a very significant role in the arid and semi-arid regions which have concentration of eroded and degraded natural resources especially along highlands areas. Loss of vegetative cover followed by soil degradation through various forms of erosion have resulted into lands which are thirsty in terms of water as well as hungry in terms of soil nutrients. To obtain the maximum and optimum production of vegetation, all the three resources have to be managed efficiently. For their efficient management, one has to look for a suitable units of management so that these resources are handled and managed effectively, collectively and simultaneously. The watershed is considered the ideal unit for managing these vital resources of soil, water and vegetation.

In order to maximize advantages in developing these watershed areas, all developmental activities viz. soil and water conservation technologies and suitable engineering or agronomic structures should be undertaken and adopted through the assistance of the government with full participation by the farmers in an integrated and comprehensive arrangement.

Based on the study made, it has been found out that modern technologies along watershed management adopted by the two selected watersheds of India showed a very worthy and significant welcome effect in reducing soil erosion as well as conservation of rainwater in the watershed.

On the other hand, it has been observed in the study that Mt. Balatukan Range Natural Park Watershed selected from among the Philippine watershed project considerably experienced the continuing problem of soil erosion because it is not adopting any engineering or agronomic structures so as to prevent soil erosion and land degradation. Moreover, unsustainable cultivation practices is extensively practiced by the small farmers resulting in to continuous denudation of the watershed which ultimately resulted to frequent flooding, lowering of soil productivity, sediment problems, deterioration of water quality and eventually environmental problems.

7.2 CONCLUSION

India		Philippines
Navamota Watershed	*Chevella Watershed*	*Mt. Balatukan Range Natural Park*
1. Uncertainty of rainfall in the area is prevalent. It is irregular and erratic with only 665 mm average annual rainfall was observed.	1. Rainfall in the area is undependable and erratic which adversely affect the yield potential of long duration crops. It has only 969 mm of average annual rainfall.	1. The average annual rainfall is 1661 mm and it is distributed uniformly throughout the year.
2. Adoption of watershed management is found to be very effective and promising. Based on the results of the study, it has been observed that the average annual soil loss is quiet low with only 1.43 ton/ha. This is the welcome effect of conservation practices and engineering structures implemented in the area.	2. With the adoption of suitable soil and water conservation technologies and engineering or agronomic structures only an 11.23 ton/ha soil loss was observed in the watershed area. This showed that the modern technologies adopted by Indian watershed played a very significant role in soil and water conservation.	2. It has been observed that the project had resulted a very high average annual soil loss that reached to 28.82 ton/ha for the main reason that it is not implementing any engineering or agronomic structures so as to prevent soil erosion. The huge loss is also attributed by the unsustainable cultivation practices by the farmers in the area.

India		Philippines
Navamota Watershed	Chevella Watershed	Mt. Balatukan Range Natural Park
3. Suitable technology had been adopted in the area so as to prevent soil erosion and land degradation. Construction and development of structures such as contour bunding and land leveling, gully plugs, masonry check dams, loose boulder check dams, trenches, stone walls and gabbion at various quantities had been implemented which significantly reduced the soil erosion.	3. The project had implemented appropriate soil and water technologies for preventing the soil erosion and land conservation. Development of bunding, waterways, check dams in gullies, waste weirs, stone check in waterways, stone revetment for diversion drain, community ponds, feeder channel for pond, Deep (tractor) tillage, control perennial weeds by weedicide, bed furrow and water harvesting pond were observed that shows a very significant effect in the project area.	3. The project concentrated on the reforestation of the declared watershed. Planting of various species of trees is observed and implemented in the project. It is not implementing any engineering or agronomic structures in preventing the soil erosion due to fund constraint of the government. Common soil conservation technologies adopted in the project are contour plowing, contour strips/hedgerows, regular fallowing, regular crop rotation and planting of trees or grasses on borders.

India		Philippines
Navamota Watershed	Chevella Watershed	Mt. Balatukan Range Natural Park
4. Government of India made a huge investments towards watershed project because soil erosion and land degradation are among the most severe watershed and environmental problems.		4. The Philippine government allocate only a nominal amount to watershed projects and its not given a priority concern project.
5. Declared watershed areas are mostly owned by farmers.		5. Majority of the declared watershed areas are government lands.
6. The government provides technical assistance and related funds to watershed projects to conserved the watershed area and similarly enforce the law strictly.		6. It was found out that due to failure of the government to enforce existing forestry laws resulted to watershed degradation.
7. The farmers are adopting sustainable cultivation practices in spite of the hefty increase in population.		7. High pressure of cultivation in declared watershed areas and extensively adopting the unsustainable cultivation practices due to increased industrial and domestic demand of a growing population resulting to severe damage of the watershed area.

Based on the present study following observation and conclusions can be drawn:

i. Watershed Management is very essential and significant in the implementation and selection of the appropriate soil and water conservation technologies and suitable engineering or agronomic structures in the preservation and management of the natural resources in the watershed.

ii. The judicious and capability based management of natural resources, namely, soil, water, plant and animal on watershed basis is the key for maximizing production on sustained basis by preservation of environment.

iii. Watershed management should be a long-term policy for mitigating drought and flood and conservation of natural wealth.

iv. Involvement of farmers, technicians, development agencies and different line departments is very essential at planning as well as at the developmental stage of watershed.

v. Water storage acts as a catalyst to win the hearts of farmers for the active and effective involvement for manifold increase in crop production and decrease in erosion hazards.

vi. The government should allocate the necessary funds, inputs and technology and may be made available at the proper time and place.

vii. The involvement of all government agencies working in the environment and irrigation department is very essential and should work hand in hand and collaborate each other for the effective and efficient management of the watershed.

viii. Strict implementation of environmental regulation plays a vital role in managing the watershed. Similarly Comprehensive Land Use plan should be strictly enforced.

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