PLANNING AND DESIGN OF DIFFERENT SOIL CONSERVATION STRUCTURES AND THEIR PERFORMANCES IN THE MICRO-WATERSHED -a case study

BY

Prativa Kanhar

A THESIS SUBMITTED TO
THE ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY, BHUBANESWAR
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

MASTER OF TECHNOLOGY
(AGRICULTURAL ENGINEERING)
IN
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Department of Soil and Water Conservation Engineering
COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY
Orissa University of Agriculture and Technology
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2002

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CERTIFICATE

This is to certify that the thesis entitled "**PLANNING AND DESIGN OF DIFFERENT SOIL CONSERVATION STRUCTURES AND THEIR PERFORMANCES IN THE MICRO-WATERSHED – a case study** " submitted in partial fulfilment of degree of **MASTER OF TECHNOLOGY (AGRICULTURAL ENGINEERING)** in Soil and Water Conservation Engineering of the Orissa University of Agriculture and Technology, Bhubaneswar is a faithful record of bonafide research work carried out by **MISS PRATIVA KANHAR** under my guidance and supervision. No part of the thesis has been submitted for any other degree or diploma.

The help and information availed during this investigation have been duly acknowledged by her.

Bhubaneswar

Date : 24th September, 2002

24.9.02
(Dr. N. N. Sahu)

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Bhubaneswar

(Prativa Kanhar)

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS AND SYMBOLS

cm	centimeter
cu. m/s	cubic meters per second
ft	feet
ha	hectare
hr	hour
km	kilometer
km^2	square kilometer
m	meter
m^3	cubic meter
sq. cm.	square centimeter
sq. km	square kilometer
AICRP	All India Coordinated Research Project
CRIDA	Central Research Institute for Dry land Agriculture
DDP	Desert Development Programme
DPAP	Draught Prone Area Programme
IWDP	Integrated Watershed Development Programme
NATP	National Agricultural Technology Project
NWDPRA	National Watershed Development Programme for Rainfed Areas

CHAPTER-I

INTRODUCTION

INTRODUCTION

Soil and water are the basic resources essential for survival of human kind on earth. Ironically, very few people realise the importance of conserving and judiciously utilising the soil, the greatest gift of nature. In fact, every kind of farm activity is connected with land and prosperity of a nation depends of the quality of its land resources.

The soil as one of the main resources of the biosphere has been defined by the International soil science society as follows :- "The soil is a limited and irreplaceable resource and the growing degradation and loss of soil means that the expanding population in many parts of the world is pressing this resource to its limit. In its absence the biospheric environment of man will collapse with devasting results for humanity". Soil and land use have become extremely competitive not merely in India but all over the world because of tremendous pressure of growing population in recent years. The problem of soil erosion in India, their extent, severity and nature vary greatly in different parts of the country depending upon climate, topography, soil, land use and also in the pattern of agricultural economy and increasing human and livestock population.

Transformation of rocky earth's crust into the soil by weathering is a very long process. It is estimated that it takes from 400 to 1000 years for formation of just 2.5cm of top soil. Left to nature, the soil is protected by in-born vegetation.

Under undisturbed conditions, geological erosion of 'labrading' and 'aggrading' is well balanced; thus a state of equilibrium is reached between climate, soil, rainfall, land slope and vegetal cover. It is only due to man's interference, the protective shield of land is disturbed and it is torn into pieces by the erosion process – starting from splash erosion to formation of gullies and ravines. As a result, erosion problem has assumed threatening dimensions.

Watershed is a naturally occurring geohydrological unit draining to a common point. Runoff resulting from precipitation flows past a single point into a large stream, a river, a lake or an ocean. A watershed may be of any size but it must be manageable hydrologically. It is a marked by an elevated line that forms a division between two areas drained by separate streams, a system or bodies of water. It is very much 'natural' and it allows planners to focus on all the effects of runoff coming from the hills in a given area and to plan accordingly to control or to store it. Watershed based management has been accepted as the most rational approach today. In this approach, development is not only considered to the agricultural lands, but also covers a wide and diverse area of activities including soil and water conservation, development of degraded and wastelands, afforestation, water harvesting with special reference to rainfed agriculture and also to the generation of employment among the rural poor people. In the long run it preserves the ecosystem, restores the environmental degradation and stabilises and sustains the overall productivity.

A comprehensive definition of watershed management reads as "Rational utilization of land and water resources for optimum and sustained production with minimum hazard to natural resources. It essentially relates 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 water, sediment reduction, and increasing productivity from all land uses" (Tejwani, 1986).

Soil, water and vegetation are the most important natural resources for survival of the mankind. They provide food, fodder, fuel, fibre and other materials to satisfy the need of the people. As the pressure of human and bovine population is becoming a threat to land and water resources for the nation, there is a greater need of conservation and proper management of the natural resources on the sustained basin. Realising this, Govt. has given importance on soil and water conservation through watershed based approach. To achieve them several watershed projects and programmes such as DDP, DPAP, IWDP, NWDPRA, NATP etc. have been launched by the Govt. of India.

The uppermost weathered and disintegrated layer of the earth's crust is referred to as soil. The soil layer is composed of mineral and organic matter and is capable of sustaining plant life. The soil layer is continuously exposed to the actions of atmosphere. Wind and water in motion are two main agencies which act on the soil layer and dislodge the soil particles and transport them. Most of the erosion is caused by water. A watershed is subjected to soil erosion mainly caused by rain water which may be of raindrop / splash erosion, sheet erosion, rill erosion or gully erosion type.

Water occurring as rainfall is responsible for raindrop erosion. Rain drops falling on land surface are responsible for rain drop erosion. Rain drops falling on land surface cause detachment of soil particles and are subsequently transported with the flowing water.

A thin film of soil layer is detached and transported by the rain water flowing on the land surface. This type of erosion is known as sheet erosion, which may not be evident significantly, but land subjected to sheet erosion loose a thin layer of top fertile soil every year.

The second stage of sheet erosion in which finger like rills appear on the landscape is known as rill erosion. These rills are usually smoothened out every year by normal farm operations. But year after year rills slowly increase in their numbers as well as in the shape and size, get wider and deeper and affect crop production.

Gully erosion is an advanced stage of rill erosion. Rills when neglected develop in size and become gullies. Gullies could also be caused by runoff concentrating at a point on the agricultural lands. Gullies when not controlled expand year after year. Ravines are a form of extensive gullies.

In planning for the measures for controlling soil erosion, the factors affecting erosion and the agencies causing erosion need to be understood. The major factors affecting soil erosion are the climate, soil type, vegetation, topography and the cultivation practices.

Climatic factors affecting erosion are precipitation, wind, humidity and solar radiation.

Soil physical properties influence the extent to which soil can be dispersed and transported. The properties which influence erosion include soil structure, texture, organic matter content, moisture content and density.

Topographical features that influence erosion are degree of slope, length of slope, size and shape of the watershed. The velocity of runoff increases with increase in slope. According to law of falling bodies, velocity varies as the square root of the vertical drop.

According to the National Commission on Agriculture (1975) an estimated 150 million ha out of the total geographical area of 328 million ha of the country are subjected to serious water and wind erosion; 69 million ha are at the critical stages of deterioration due to erosion; and 32 million ha are prone to wind erosion. The area affected by gullies and ravines account for about 4 million ha while the area affected by shifting cultivation is about 3 million ha. There is 70 million ha area under rainfed farming in the country. Land degradation has assumed serious dimensions engulfing nearly one third (32.7%) geographical area of the country. Out of 107.43 million ha degraded lands, ravines occupy 2.68 million ha. (Samra *et al.*, 1996). It is estimated that at present 150 million ha (about 45% of the total area of the country) of land under agriculture, forests, grasslands, and other land uses is in need of urgent soil and water conservation.

The problem of erosion and subsequent sediment yield are wide spread and of great concern to hydrologists and water resources engineers. The movement and deposition of sediments in water bodies is of interest to water resources engineers as it influences the downstream hydrology causing sedimentation in reservoirs, lakes, rivers, water quality problem etc. Changes in sediment transport rate on volume can produce changes in the flow condition in the channels, changes in geometry of channels, changes in river regime, degradation and meandering.

The watershed is subjected to soil erosion of varying degrees. Heavy demand of local population for fuel wood, fodder and timber have resulted in large scale denudation of forests and land degradation. The upper areas which consists of forests and common lands are subjected to heavy soil erosion due to high intensity rains on steep denuded slopes and have resulted in the formation of gullies. Erratic, short duration and high intensity rainfall, loose and friable nature of soil, weak geology of alluvium, steep slopes and uneven terrain, faulty agricultural practices, illicit cutting of trees and bushes and overgrazing etc are responsible for the present aggravating situation. Man's activities on or within a watershed can accelerate erosion. Soil and water conservation measures are being practised at upper, middle and lower reaches of watersheds since long through different schemes launched by Government. Afforestation, bunding, terracing, contour cropping, strip cropping, suitable crop rotations, installation of temporary and permanent gully control structures etc are the main soil conservation measures adopted for controlling the soil erosion from watershed area. The working principle of these measures is to make delay in the movement of sediment ladden runoff from the original point of the drainage basin to the reservoir by creating an obstruction in the flow path. Proper planning and design of different conservation structures must be done for achieving the objective of the schemes.

The study area is Sudreju micro-watershed which falls under Sudreju revenue village of Khajuripada block in Kandhamal district of Orissa. The area lies in the Pila-Salki watershed of Mahanadi catchment. Considering the need, the present study has been undertaken with the following objectives.

1. To conduct reconnaissance survey in the micro-watershed for identifying the critical areas for intervention.

2. Planning and design of different soil conservation structures.

3. To study the effectiveness of different conservation structures already constructed in the watershed.

CHAPTER-II
REVIEW OF LITERATURE

REVIEW OF LITERATURE

This chapter deals with the important contribution made by previous research workers in the field of watershed and related aspects such as watershed hydrology, different conservation measures in a watershed, watershed response to conservation measures and watershed management.

2.1 Concept of Watershed

A watershed is a drainage area on earth surface from which runoff resulting from precipitation flow past along a single point in to a larger stream. A watershed may be only few hectares or thousands of square kilometers.

From hydrological point of view, a distinct characteristic of watershed is that the effect of overland flow rather than the effect of channel flow is the dominating factor affecting the runoff production. Consequently a small watershed is sensitive to precipitation of high intensity of short duration and to land use (Tyagi et al 1970)

A watershed may be defined as a hydrological unit which produce water as an end product by interaction of precipitation and the watershed factors. (Balli, 1972).

Verma (1993) has defined the watershed as the manageable hydrological unit.

Samra (2001) has defined the watershed as a naturally occurring geohydrological unit draining to a common point.

2.2 Hydrology in Soil and Water Conservation.

A thorough knowledge of different hydrological phenomena is required in all aspects of soil and water conservation. A knowledge of precipitation is required in estimating runoff, planning erosion control measures and conserving water in low rainfall regions. Knowledge of runoff is required in designing structures and channels that will handle natural flows of water.

2.2.1 Rainfall

Schwab *et al.* (1981) indicated that for design of a structure, the rainfall analysis is done either by the annual series or by the partial duration series. In annual series, only the largest single event for each year is selected for analysis. With partial duration series, all values above a given base are chosen regardless of the number with in a given time period. The annual and partial duration series give essentially identical results for return periods greater than 10 years.

Murty (1985) presented 1 hr and 6 hr duration isohyets for frequencies of 10 years and 25 years. One hr duration isohyetal map for 10 year and 25 year frequencies are presented in Appendix-I. Further determination of rainfall intensity for duration equal to time of concentration based on hourly rainfall data have been developed in graphical form by U.S. Department of Agriculture (Frevert et.al, 1955) and represented in Appendix-II.

Subudhi *et al.* (1996) analysed the rainfall characteristics at Phulbani. On the basis of twenty eight years rainfall data (1968-1995) the average annual rainfall at Phulbani is 1477mm and average number of rainy days is 66. It has been observed that 75 per cent of the annual rainfall is received from July to October. Frequency analysis for maximum annual rainfall data was done by using Weibul technique. Expected maximum annual daily total rainfall for different return period was incorporated frequency analysis for monthly, seasonal and annual rainfall was carried out and values at 70 per cent probability level were estimated. The Kharif season received 839mm rainfall. June, July, August and September received 104.3, 257.2, 242.6 and 143.8mm rainfall, respectively.

2.2.2. Peak Rate of Runoff

The most common formulae used for computation of peak rate of runoff are as follows

2.2.2.1 Dicken's formula

Based on records of peak rate of discharges from various watersheds, Dicken developed a formula relating peak rate of discharge with catchment area. The formula is given as :

$$Q = CA^{3/4} \quad \text{.....................(2.4)}$$

Where

Q = Peak rate of runoff in cu. m /sec.

A = Area of the watershed in sq. km.

C = 11.45 for areas with annual rainfall of 610mm to 1270mm.

= 13.88 to 19.42 for areas in Madhya Pradesh.

This formula is generally applicable in North and Central India. (Murty, 1998)

2.2.2.2 Rational formula

The rational method involves following equation for computing the peak rate of runoff. (Murty, 1998)

$$Q = \frac{1}{360} CIA \text{..........................} (2.1)$$

Where

Q = Peak rate of run off (m^3/s)

C = Runoff coefficient

I = Intensity of rainfall (mm/hr) for a duration equal to the time of concentration and for the given frequency.

A = Area of the catchment (hectares)

Value of 'C' for different slopes and land use conditions, determined from field observations are presented in Appendix-III. (Suresh, 1997). When the catchment consists of varying degrees of slopes, land use and soils, the value of 'C' for the catchment will be weighted average of values of 'C' of each representative portion of land. If C_1, C_2, ... C_n are the values of runoff coefficients and a_1, a_2.......a_n are the areas respectively for representative portion of land, the weighted value is given by

$$C = \frac{C_1 a_1}{A} + \frac{C_2 a_2}{A} + \text{.................} + \frac{C_n a_n}{A} \text{..........} (2.2)$$

The values of rainfall intensity in equation (2.1) is for the period equal to the time of concentration of the catchment and can be found on the basis of article 2.2.1.

The time of concentration of a catchment is defined as the time required for water to flow from the remotest point of the catchment to the outlet. When the duration of rainfall equals the time of concentration, all parts of the catchment will be able to contribute the discharge at the outlet and as such the discharge will be maximum.

Empirical formula available for determining the time of concentration was given by Kirpich as (Murty 1998)

$$T_c=0.0195\ L^{0.77}\ S^{-0.385} \quad \text{.......................} \quad (2.4)$$

Where Tc = Time of concentration, in minutes,

L = Length of channel reach in meters, and

S = Average slope of channel in meter / meter

2.2.2.3 Ryve's formula

Ryve developed the formula for relating peak rate of runoff with catchment area. This formula is mainly applicable in South India, and is given by

$$Q = CA^{2/3} \quad \text{.......................} \quad (2.5)$$

Value of 'C' varies from 6.76 to 40.50 depending on the location of the catchment (Murty, 1998).

Table 2.1 Specifications for materials and location of gully plugs for ravines.

Slope of Gully bed %	Width of Gully bed	Location	Type of gully plug	Vertical interval between two gully plugs (m)
9-5	Upto 4.5	Gully bed	Brushwood	Upto 3
	4.5 to 10.5	Gully bed and side	Earthen gully plug	2.25 to 3
	7.5 to 15	At confluence of two gullies	Sand bag	
	7.5 to 15	At confluence of branches of a compound gully	Brick masonry	
5-10	Upto 4-5	Gully bed	Brushwood check dams	Up to 3
	4.5 to 6	Gully bed and side	Earthen gully plugs	1.5 to 3

Dayal *et al.* (1961) studied on mechanical measures in gully control at Kota and reported that a single diversion or marginal bunds of 2.5 m^2 cross-section with 0.1 to 0.2% grade for safe disposal of runoff has been found to be useful.

Narayan *et al.* (1962) suggested that the check dams constructed by local farmers are either very big or very small than is warranted by the requirement and are not located and designed properly. When the excavated or eroded soil fills upto the top of the brick wall, chekdams are raised progressively practically without any consideration for the stability of the structures.

Murty (1966) considered the drop inlet pipe spillways as an ideal soil conservation structure for erosion control for ravine land.

Haris *et al.* (1987) described a method consisting of shaped grassed waterway equipped with tile drain as a terminating structure and considered structures as an alternate rather than only solution in waterway termination problems.

Annonymous (1987), efficacy of earthen check dam (commonly referred to as gully plug in the ravine regime) that existed for 27 years in deep ravine area under forest was evaluated. The check dams are 1 to 2m high and almost 1m wide at the top with side slope 1:1. This cross section was found adequate as 80% of the structures remained intact.

Dorge *et al.* (1987) studied features of nala bunding works in Maharastra state keeping the main objective to increase the ground water by charging underground aquifer. It is one of the main components of large scale comprehensive watershed development programme being implemented in the state. So far 55600 nos. of such nala bunds have been constructed in the state and as per rapid survey carried out by the Statistics Department of Agriculture. Due to nala bunding, water level in the wells located on the down stream side of nala bund increased by 0.74 metres resulting in increased irrigation potential considerably.

Sastary *et al.* (1987) studied the performance of gully control structures in outer Himalayas of Doon valley and reported that gully control structures that were constructed in the outer Himalayas by several agencies including public works departments, found to be failure due to non-provision of basic components such as spillways, head wall extension etc. in addition to improper selection of site and peak rate of runoff was not considered for their design.

Goel *et al.* (1996), studied the sediment retention by gabion structure in Bunga watershed Eight newly constructed crate wire (gabion) check dams in the catchment of Bunga-II dam in Ambala district of Haryana were selected. Retention capacity of each checkdam at the time of construction and the reduction in capacity due to deposition of sediment after first year and second year monsoon was worked out. The results indicated that within two years, six structures lost nearly 50 percent or more of their capacity due to sedimentation. These structures retained about 23 ha cm sediment in the channel itself which otherwise would have lost valuable water storage capacity of the pond.

2.3.2 Conservation Trenches

Bhardwaj *et al.* (1996) studied on soil working and moisture conservation techniques for establishment of tree seedlings on dry hill slopes. The study was carried out to test the performance of *Acacia catechu* and *Celtis australis* under different intensities of soil working techniques viz. various types of pits, ditches, trenches and gradonies or inward sloping contour terraces. Both species showed higher growth response under different type of trenches, ditches and gradonies than pits. Maximum height, growth at the end of fifth year of growth in both *Acacia catechu* (710.0 cm) and *Celtis australis* (301.5cm) were recorded in plants under half slanting trenches, which was 67 and 43 per cent more over conventional fully filled pits respectively. Throughout the study period, different types of trenches and ditches maintained consistently higher moisture contents than either gradonies or pits, difference being much more pronounced during dry spells.

Dabral (1996) studied the effect of trench irrigation system on tea production. The experiment on trench irrigation was conducted at the Mohurgong and Gulma Tea Estate, Darjeeling district (W.B.). Results showed that trench system is effective in increasing the yield during the dry period and economical when water is applied through gravity flow. Among trench spacing of 2.44, 3.66, 4.88 and 7.32m, 3.66m is recommended as it gave higher made tea yield (753.98 kg ha-1) net return (Rs. 7,628 ha^{-1}) and benefit : cost ratio (1.5:1).

Rath *et al.* (1997) studied an efficacy of planting methods and establishment of *Cassia siamea* in slopy and red lateritic soil belt of Orissa and reported that field studies involving planting methods were made during 1993 to 1995 at Sidingi and Nabaguba village of Phulbani district of Orissa for the establishment of fuel wood species. Continuous contour V-ditch proved most efficient in situ moisture conservation practice and enhanced average soil moisture status by 31.5%, 29.6% and 21.9% in 0-15cm, 15-30cm and 30-45cm layers over normal pit method. It favoured tree growth to the maximum extent and caused maximum increase (75%) in plant height during observation compared to control.

Madhu *et al.* (2001) studied the effect of Contour Staggered Trenching (CST) and cover crop beans in conserving soil and water and its effect of yield plants under half slanting trenches, which was 67 and 43 per cent more over conventional fully filled pits respectively. Throughout the study period, different types of trenches and ditches maintained consistently higher moisture contents than either gradonies or pits, difference being much more pronounced during dry spells.

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Madhu *et al.* (2001) studied the effect of Contour Staggered Trenching (CST) and cover crop beans in conserving soil and water and its effect of yield of green tea leaves in new tea plantations in the Nilgiris. The mean of three years data revealed that, soil and water / moisture conservation efficacy was higher in combination of CST +cover crop of beans and contour staggered trenching. Tea canopy percent, leaf area index and yield of green tea leaves were significantly higher in cover crop of beans and CST+ beans as compared to control and CST alone. Percent increase in yield of green tea leaves over control was 33.6, 30.9 and 11.4 in CST + beans cover crop of beans and CST alone, respectively. Tender pod and green forage yield of cover crop was higher during initial two years of tea planting due to better growth of beans and poor tea canopy cover. Cover crop of beans and CST +beans is new tea plantation showed higher economic viability and environment benefits.

2.4 Watershed Response to Conservation Measures

Systematic studies on watershed hydrology in the country are of recent origin. Around 1960, a beginning was made by the soil conservation research station, ICAR for studying the hydrological behaviour of small watersheds. As the time series data on rainfall, runoff and silt load are now available through network of gauging stations, it is therefore possible to evaluate the effectiveness of conservation measures in watersheds.

Jones (1965) observed that soil conservation practices have affected the rate of sediment discharge from a watershed, although runoff characteristics did not change significantly. The trend was towards decreasing sediment yield but a sharp increase was observed during the period of intense construction of terraces with in the watershed. In the Issaqueena catchment the sediment production rate was reduced from 2400 tonnes/sq. km to1150 tonnes/sq.km by increasing the protected area from 53% to 73% in a period of 8 years. Yet in another case the sediment yield was reduced by 33% as a result of improved watershed management measures in the Lake Waco catchment.

A study conducted in a catchment of Vassad indicated that watershed treated with soil conservation measures reduced not only the sediment yield but also retained large quantity of sediment received from untreated watershed (Tejwani *et al.* 1975).

Land improvement treatments given during 1963 and 1964 in a watershed at Chandigarh reduced soil loss and run off from 80.5 tonnes/ha and 255 mm to 7.4 tonnes/ha and 75 mm respectively in a period of four years after initiation of land treatments (Anonymous, 1976).

Sastry *et al.* (1984) studied on watershed responses to conservation measures. In Doon valley, India, when a natural forest watershed open to grazing is deforested and cultivated, volume and peak rates of runoff were higher by 15% and 72% respectively. When the agricultural watershed is treated with soil and water conservation measures (construction of small field levees or bunds), the peak rate and volume of runoff are reduced by 86% and 62% respectively of the corresponding values when it was a natural forest watershed and the corresponding reduction in soil loss was 94%. When another comparable natural forest watershed is provided with brushwood checkdams at appropriate locations, although no appreciable reduction in peak rate of runoff was observed, soil loss was reduced by 54%.

Hazra *et al.* (1987) in his study on soil and water conservation for efficient crop production on watershed basis at Tejpura (Jhansi), reported that soil conservation works like contour bunding, gully plugging, checkdams etc. constructed across the nallas in Tejpura watershed covering an area of 775.7 hectares. It was observed that the underground recharge was significantly improved and helped in raising water table in the wells by 3 to 7m at different seasons. The crop intensity increased from 83 to 156%. The availability of irrigation water through wells increased from 2-3 hours to 10-14 hours.

Goel *et al.* (1996) studied the impact of soil conservation measures on ground water availability undertaken on 313 ha in an area of 313 ha at Navamata in the Aravalli foot hills. Analysis of water table data collected from 12 open wells located in the watershed reflects average annual rise of 8m in water table due to recharge. Annual rise in water table is highly correlated to annual rainfall. Increase in availability of irrigation water in wells has resulted in 83 per cent increase in rabi cropped area and almost doubled the productivity of rabi and Kharif crops.

Singh *et al.* (1997) studied on soil and water conservation measures in semi arid region of south eastern Rajasthan. Different conservation measures such as graded bunds, gully control structures, contour cultivation, intercropping, use of cover crops in rotation along with other improved package of practices have been found suitable in this region to minimise erosion and maximise production on arable lands. Graded bunds have reduced the runoff from 20 to 4.8 per cent and soil loss from 24 to 4.12 ton ha^{-1} yr^{-1}. Intercropping on contour not only reduced the runoff (2to 3%) and soil loss (5 to 8%) but also resulted in higher yield (48%).

2.5 Watershed Management:

Phadnawis *et al.* (1993) carried out work in Padalsingi watershed, Beed district of Maharastra for resources management in rainfed watershed and concluded that productivity of the traditionally grown crops like Bajra, redgram etc have increased due to resource management in watershed basis. The area under irrigation increased the ground water level was increased due to construction of cement plugs, nala bunds and percolation tanks and per capita income of the farmers increased by a large extent.

Watershed management is based on the sound principles of sustainability, the enhancement in agriculture production as a result of watershed development. Proper orientation of implementing agencies towards adoption of watershed based plans and integrated approach and willingness to involve the local people in the right earnest in the whole process. (Ganeriwala, 1997).

Khatik *et al.* (1997) studied the impact of operational research project on agricultural production through integrated watershed management in Rabni watershed situated in Panchamal, a backward district of Gujarat. Under the integrated watershed management programme the area was treated with different soil and water conservation measures like land leveling, contour bunding, gully plug, check dam etc. The study revealed that integrated watershed management programme increased the ground water recharge de to different soil conservation measures. The cropping intensity also increased, positive impact of operational research project on food grain productivity, fodder availability and animal population etc. in watershed is conspicuous and apparent.

Prasad *et al* (1997) studied the impact of watershed management on runoff, water resource development and productivity of arable lands in Chhajawk watershed of Baran district in Eastern Rajsthan and the results indicate that integrated watershed development treatments such as graded bunds, gully control structures etc. halted the process of land degradation and improved the ground water recharge which could be successfully exploited for increasing productivity of arable lands. The investments made recovered in four years indicating that the programme is economically viable.

CHAPTER-III
METHODS AND MATERIALS

METHODS AND MATERIALS

This chapter deals with the description and socio-economic status of the study area, the methods as well as materials used for carrying out the project work.

3.1 Description of Sudreju Micro-Watershed

3.1.1 Location

The Sudreju micro-watershed lies geographically between 20°30'16" to 20°31'24" N latitude and 84°17'8" to 84°18'14"E longitude at a distance of about 10 kms from the district head quarter Phulbani in the state of Orissa as shown in fig 3.1. The study area lies in the Pila-salki watershed of Mahanadi catchment. It falls under Sudreju revenue village of Khajuripada block of Kandhamal district. As per the report of Soil Conservation Department, Govt. of Orissa, it is a part of watershed ORM 3-9-6-5. As per watershed map classification reported by the Orissa Remote sensing Application Centre, the selected micro-watershed falls under sub-watershed No. 17.07.31-01-01. The micro-watershed under study falls under topo sheet No. 73 D/6 in 1:50000 scale. The study area is located at an altitude of 751m above mean sea level.

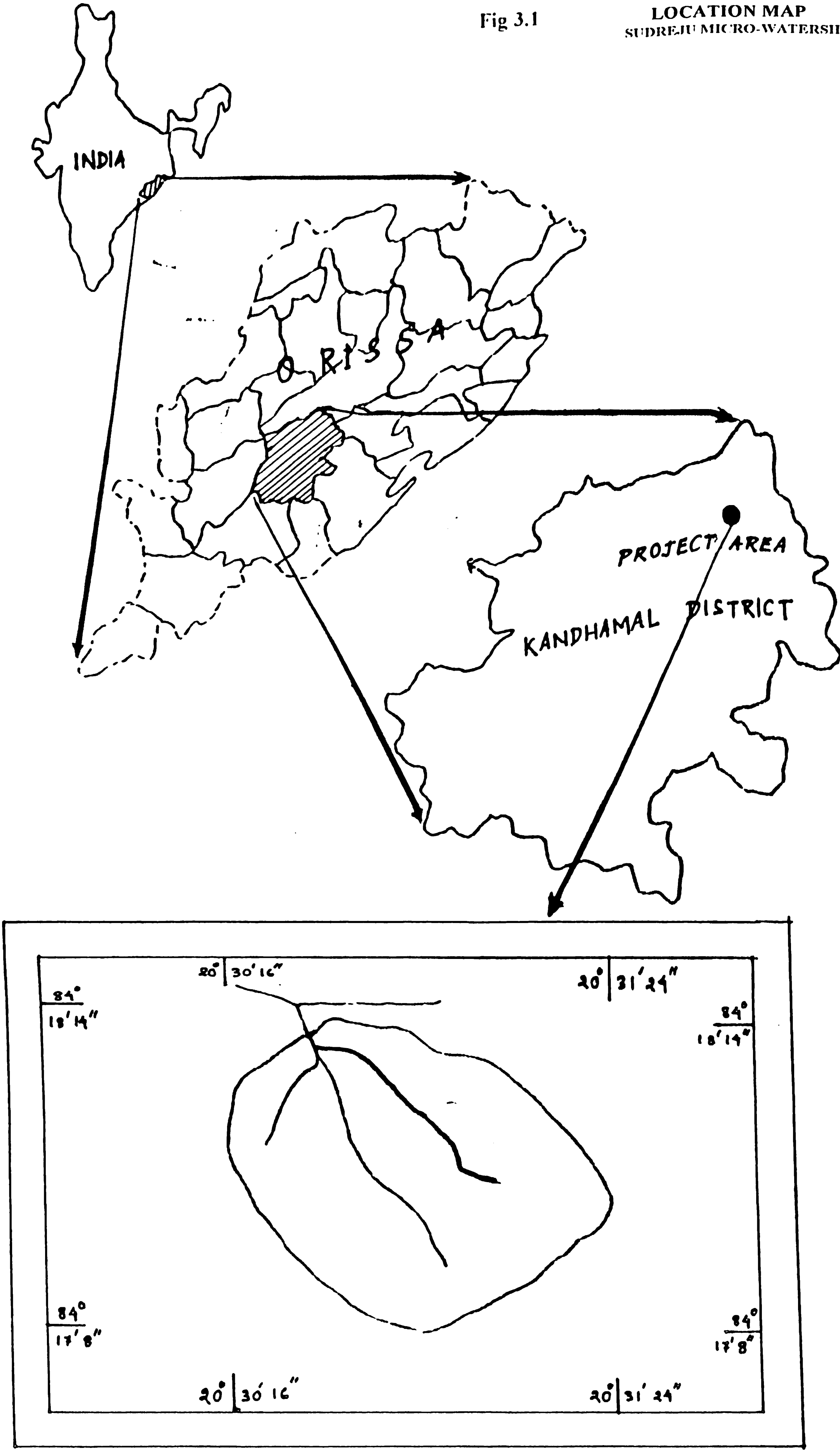
3.1.2 Size and shape

The micro-watershed has an area of 62.5 hectares and is fan shaped watershed with mean length of 1.16 km and average basin width of 0.538 km.

Fig 3.1

LOCATION MAP

SUDREJU MICRO-WATERSHED



3.1.3 Climate

The climate of the study area is of tropical wet sub-humid type. The normal rainfall of Khajuripada block is 1396.15 mm with 67 rainy days. The total annual rainfall for the year 2001 was 1949.7mm with 86 rainy days which was a wet year (Appendix-IV). The rainfall distribution is quite erratic and non-uniform. The month of June and July recorded higher rainfall, where as August and September recorded rainfall lower than normal (Appendix-VI). The daily, weekly and monthly rainfalls for the year 2001 are given in Appendix-IV, V and VI respectively.

The study area is having the mean annual temperature of 21^0C. The month of May is the hottest when the daily maximum temperature is 30°C. The winter is too cold and the temperature sometimes comes down below 2°C in the month of December and January. So, the whole year may be divided in to four seasons such as hot seasons from March to May, monsoon from June to September, the post monsoon months are October and November and the cold season from December to February.

3.1.4 Slopes

The study area has extremely undulating and irregular slopes varying from moderate to steep as the watershed consists of agricultural areas as well as moderate hills. The corrected map was matched with toposheet 73D/6 and contour lines were traced in the map. From this contour lines, the vertical fall of the watershed was calculated by using interpolation technique. Horizontal distance in between the contours was measured from maps by multiplying the map distance with the scale factor. The slope of the watershed ranges from 10 to 15 percent.

3.1.5 Surface Drainage :

The Sudreju micro-watershed has three numbers of drainage lines contributing to the outlet point of the watershed (Fig.1). The nature of flow is seasonal. Total length of the drainage lines is 2.12km and the length of the longest drainage line is 0.75km as determined from the toposheet. The drainage density is found to be 3.39 km/km^2.

3.1.6 Soils

The soil of the study area is red-lateritic type. The texture of the soil varies from loamy to clay loam. The soil analysis report is given in Appendix VII. Soils are very porous with very low water holding capacity.

3.1.7 Land use and cover condition.

The study area can be grouped under three categories on the basis of land use pattern viz, forests, cultivated lands and land under grazing, waste and barren lands. The forest in the watershed is reserve forest. Cultivated lands are slopy and face erosion problem. The grazing and waste lands are eroded and have very poor vegetation cover. Land use pattern of Sudreju micro-watershed is given in Table 3.1.

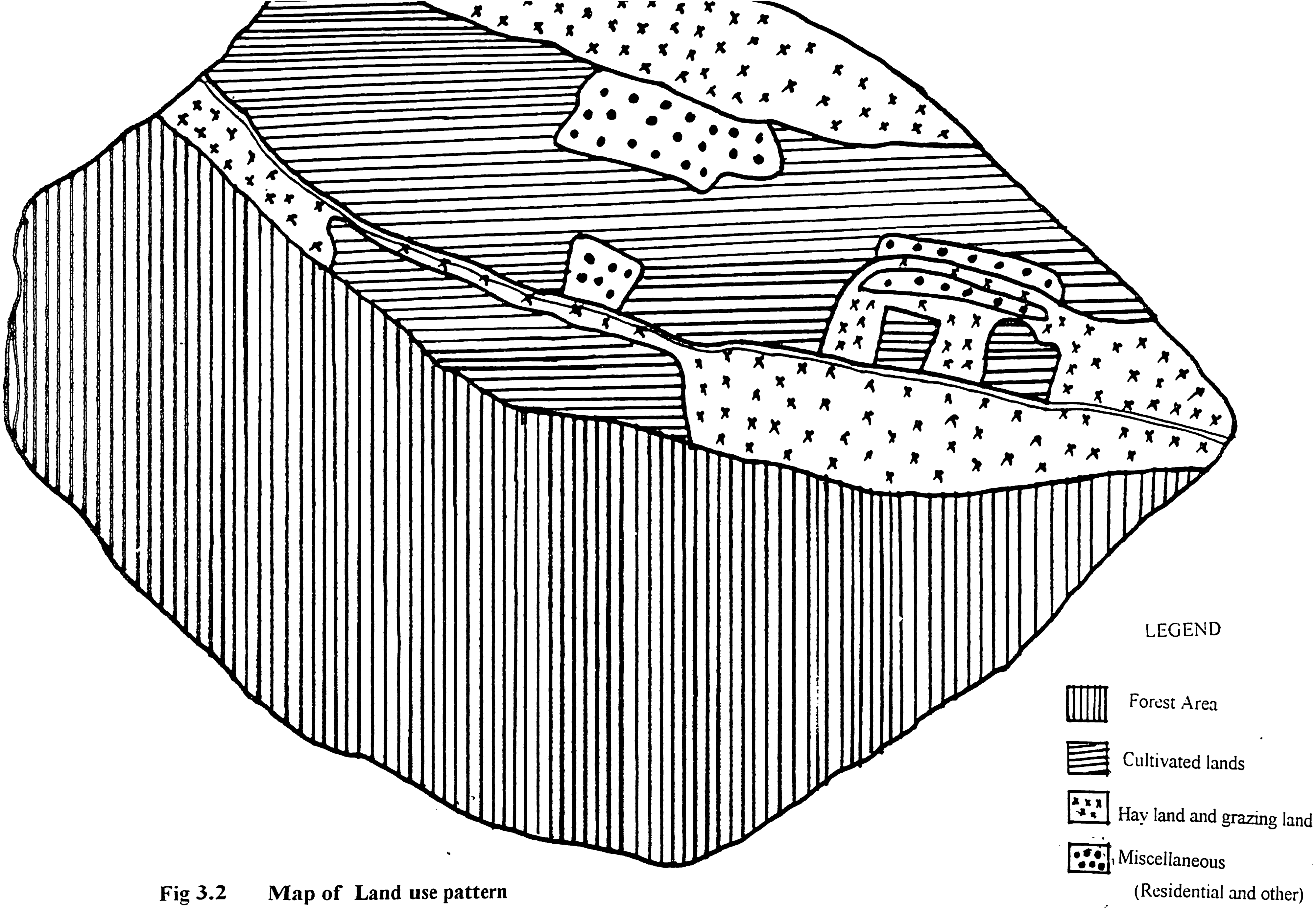


Fig 3.2 Map of Land use pattern

Table 3.1 Land use pattern of Sudreju micro-watershed

Land use pattern	Area, ha	Percent of total area
Cultivated land	13.52	21.632
Hay land and grazing land	12.78	20.448
Reserve forest	33.44	53.504
Miscellaneous (Residential and other areas)	2.76	4.416

The vegetation of the area may be grouped under two categories viz., cultivated and natural. Cultivated vegetation include various field and horticultural crops grown on the fields. Important field and horticultural crops that are grown are paddy, maize, mustard, kulthi, cowpea, niger, potato, mango, turmeric, ginger, bean, cabbage, tomato etc. Natural vegetation includes forest species. Most common forest species in the study area is *sal* (*Sharea robusta*).

3.2 Socio-economic status

The total area of the village Sudreju comes under the watershed boundary. The socio-economic status of the village Sudreju is presented here. The village Sudreju is a tribal village. The population is dominated by schedule tribes. The economic status of the people is not sound. People of village Sudreju are mostly farmers and they lives on farming. They also get some income by selling forest products such as fire woods, honey, *lakha* etc. Females are more engaged than males in this village. Males are engaged in ploughing, thresing and cutting of mulching materials where as females take care of other activities. Both are involved in marketing. Period of maximum workload, cash and fodder availability are June to December. March to May and June to December respectively.

The socio-economic status of the village Sudreju is presented here in the following Tables3.2 and 3.3.

Table 3.2 Population

Sl.No.	Item	Value
1.	No. of house holds	46
2.	Total population	
	a. Total	222
	b. Male	103
	c. Female	119
3.	Schedule Tribe	
	a. Total	80
	b. Male	34
	c. Female	46
4.	Schedule caste	
	a. Total	9
	b. Male	5
	c. Female	4
5.	Literates	
	a. Total	104
	b. Male	78
	c. Female	26

6.	Main workers	
	a. Total	122
	b. Male	55
	c. Female	67
7.	Cultivator	
	a. Total	71
	b. Male	35
	c. Female	36
8.	Agricultural labour	
	a. Total	37
	b. Male	10
	c. Female	27

Table 3.3 Seasonability of work load and cash and fodder availability.

Month	Work load (0-10 scale)	Cash availability (0-10 scale)	Fodder availability (0-10 scale)
May	4	10	0
June	5	9	0
July	10	2	6
August	10	0	10
September	9	2	10
October	5	4	10
November	7	4	7
December	7	6	7
January	4	2	5
February	3	4	2
March	3	3	0
April	4	6	0

3.3 Determination of Morphometric Parameters of the Study Area

The morphometric parameters of the watershed like basin length (L_b), basin width (B). basin perimeter (P). basin area (A), form factor (R_f), circularity ratio (R_c). circularity Index (I_c). compactness coefficient, elongation ratio (R_c).drainage density (D_d) is computed in the following way.

Basin length (L_b)

It is defined as the maximum length of the basin measured from the outlet.

Average basin width (B)

It is calculated as

$$B = \frac{A}{L_b}$$

Where. A = Basin area. km^2

L_b = Basin length. km

Basin shape

The shape of basin affects stream flow hydrographs and peak flow. The important parameters describing the shape of the basin are form factor (R_f), circularity ratio (R_c). circularity Index (I_c). compactness coefficient, elongation (R_e) etc.

Form factor (R_f)

It is defined as the ratio of average width of the basin to the basin length.

$$\text{Form factor, } R_f = \frac{B}{L_b} = \frac{(A / L_b)}{L_b} = \frac{A}{(L_b)^2}$$

Where,

A = Area of the basin, km^2

L_b = Length of the basin, km

The value of form factor should always be less than 0.7854 (for a perfectly circular basin). Smaller the value of form factor more elongated is the basin. The basin with high form factor has high peak flows for shorter duration, where as elongated basin with low form factor will have a flatter peak flow for longer duration. Flood flows of elongated basins are easier to manage than that of the circular basins.

Circularity ratio (R_c)

It is the ratio of circumference of a Circle with same area as that of basin to the basin perimeter.

$$\text{Circularity ratio, } R_c = \frac{P_c}{P} = \frac{2\sqrt{\pi A}}{P}$$

Where,

A = Area of the basin, km^2

P = Basin perimeter, km

P_c = Perimeter of the circle having equal area as that of the drainage basin, km

When the circularity ratio is closer to 1, the basin is more like a circle in shape.

Circularity Index (I_c)

It is the ratio of the drainage basin area (A) to the area of a circle having same perimeter.

$$\text{Circularity Index}, I_c = \frac{A}{A_c} = \frac{4\pi A}{P^2}$$

Where

A = Basin area, km^2

A_c = Area of the circle having equal perimeter as that of the drainage basin, km^2

When I_c is closer to 1, the basin is almost circular in shape.

Compactness coefficient

It is defined as the ratio of the perimeter of the basin to the circumference of a circle whose area equal to the area of the basin.

Elongation ratio (R_e)

It is defined as the ratio of diameter of a circle which has same area as the basin to the basin length, expressed as

$$\text{Elongation ratio}, R_e = \frac{D_c}{L_b} = \frac{2}{L_b} \times \sqrt{A / \pi}$$

Where,

D_c = Diameter of the circle having same area as that of the basin, km

L_b = Basin length, km

A = Basin area, km^2

When R_c value approaches 1, the shape of the basin is nearly circular.

Drainage density (D_d)

Horton (1932) defined drainage density (D_d) as the ratio of total length of all stream segments within a specified basin to the basin area

$$\text{Drainage density, } D_d = \frac{L}{A}$$

Where,

L = Length of all stream segments, km

A = Area of the basin, km^2

The factors controlling drainage density are resistance to weathering and permeability of rock formations apart from the climatic and other factors like vegetation. Low drainage density is observed in regions of highly resistant or permeable soil material under dense vegetation cover and low relief. High drainage density is observed in the regions of weak and impermeable subsurface material and sparse vegetation and mountainous relief. The morphometric parameters has been calculated for the study area and is represented in Table 3.4

Table- 3.4 Morphometric parameters for Sudreju micro-watershed

Sl.No.	Morphometric parameters	Value
1.	Length of basin, km	1.16
2.	Average basin width, km	0.538
3.	Perimeter of the basin, km	3.6
4.	Form factor (R_f)	0.4637
5.	Circularity ratio (R_c)	0.7785
6.	Circularity index (I_c)	0.6061
7.	Compactness coefficient	1.284
8.	Elongation ratio (R_e)	0.768
9.	Drainage density (D_d), km/km^2	3.39

3.4 Determination of Runoff coefficient, Time of concentration, Intensity of rainfall for the duration equal to time of concentration and Peak rate of runoff.

The land use pattern was studied and coefficient of runoff for different land uses were selected from the standard table and the weighted average value of runoff coefficient 'C' was determined. The rainfall intensity ' I ' was also obtained by matching the curves for one hour rainfall intensity with the duration equal to time of concentration . The two factors 'C' and ' I ' were used for calculating peak rate of runoff, which is very important for design purpose.

3.4.1 Runoff coefficient

The weighted runoff coefficient of the watershed is determined by using the equation (2.3). Taking the areas under different land use conditions from Table 3.1 and the appropriate runoff coefficients for the land use conditions, the weighted runoff coefficient was computed.

Table 3.5 Computation of weighted value of runoff coefficient

Land use	Area, ha	Runoff coefficient	Weighted value of runoff coefficient
Cultivated land	13.52	0.50	0.474
Hay land and grazing land	12.78	0.36	
Reserve forest	33.44	0.50	
Residential	2.76	0.55	

3.4.2 Time of Concentration

Empirical formula for determining the time of concentration given by Kirpich (Eqn. 2.4) was used

For this watershed,

Average channel slope, $S = \frac{5}{100}$

Maximum length of channel reach, L = 750m

Time of concentration. $T_c = 0.0195\,(750)^{0.77}\,(5/100)^{-0.385}$

$$= 10.10\text{min} \approx 10 \text{ min.}$$

3.4.3 Intensity of rainfall for the duration equal to time of concentration.

1 hr. rainfall intensity for 10 years frequency at the location from the figure in Appendix-I was found out to be 80mm/hr.

Intensity for 10 minutes rainfall, using the figure given in Appendix-II was found out to be 165mm/hr.

3.4.4 Peak rate of runoff

The maximum rate of runoff that could occur from the Sudreju micro-watershed was determined by using eqn. (2.1) to be

$$Q = \frac{CIA}{360} = \frac{0.474 x 165 x 62.5}{360} = 13.57 m^3 / sec$$

3.5 Identification of Critical Areas in the Watershed for Conservation Treatments

Critical areas in the watershed have the greatest impact. Determining critical areas can be done by looking at the landscape. Goal in determining critical areas is to match resource needs with targeted efforts to get the greatest benefits. A reconnaissance survey of the entire micro-watershed was conducted to have an idea of the relative erosion status of the watershed. Gully erosion is prominent in the watershed. Small and medium gullies are there with drops at some places. Erosion is also taking place from the sloping agricultural fields breaking the field bunds. The gullies and agricultural field bunds needs soil conservation treatments (Fig.3.3).

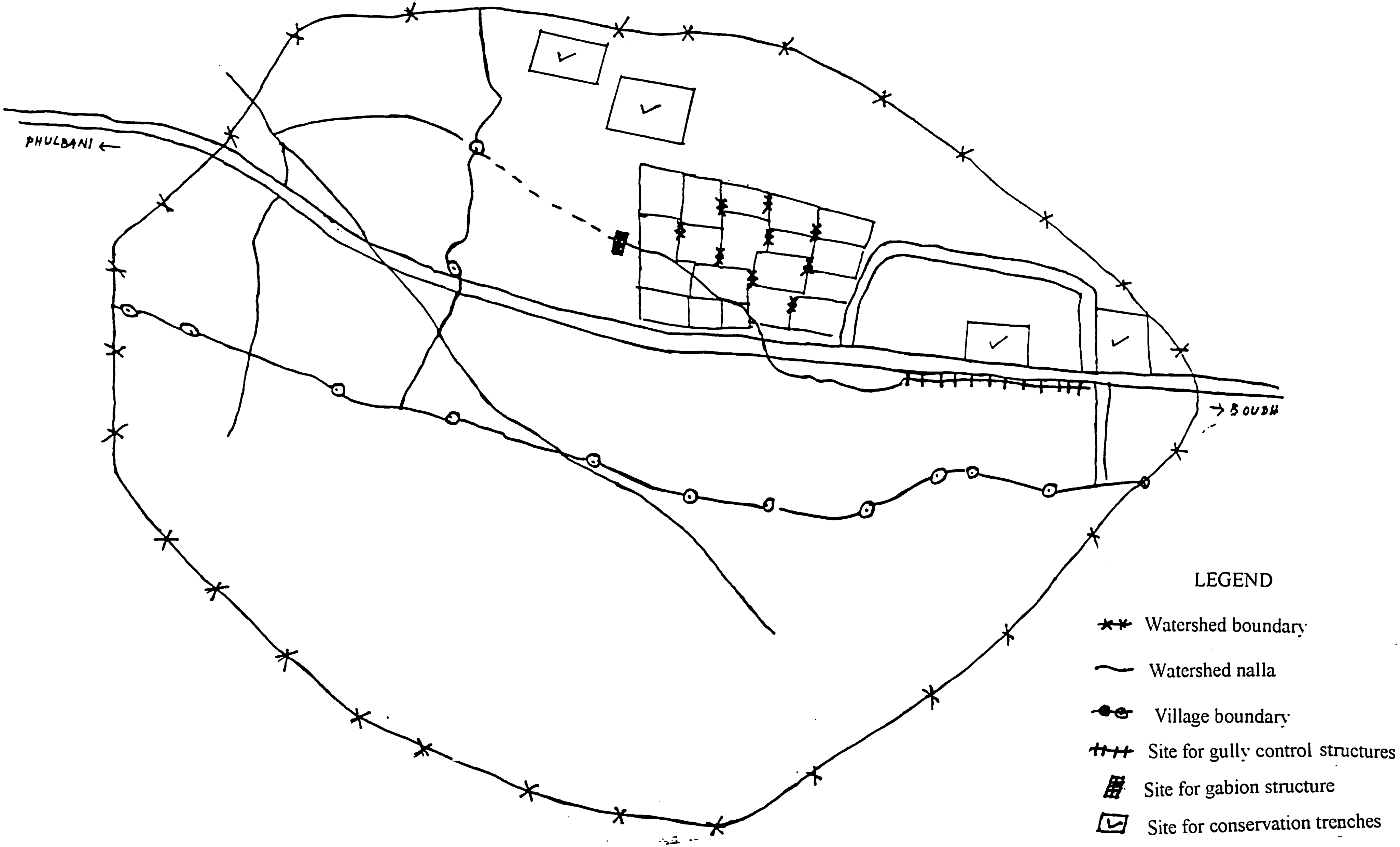


Fig. 3.3 Location of the sites identified for intervention

3.6 Different conservation structures and their Design considerations

The rainfall of the study area is quite erratic and non-uniform. Due to its uneven distribution, heavy downpour of rain at times results in sudden high runoff which ultimately causes substantial soil loss. So, the micro-watershed has been treated with different conservation measures. Different conservation structures that have been constructed in Sudreju micro-watershed are

1. Brushwood checks across gully
2. Loose rock structures across gully
3. Gabion structures across the gully.
4. Loose rock structures on field bunds for bund stabilisation, to check erosion from upstream fields, safe disposal of excess runoff to lower fields and to store water in the field.
5. Brushwood structures on field bunds for the above said objectives.
6. Conservation trenches (V-ditches) to conserve soil and moisture for establishment of plantation crops such as Mango, teak wood etc.

3.6.1 Brushwood structures

Brushwood structures are one of the temporary gully control structures, constructed across the gully. This structures use locally available vegetation cuttings in their construction. Wooden poles are driven deep enough into the ground in rows and vegetation cuttings are given in between them.

Objective:

(i) To reduce peak flow – slow down the velocity of runoff and induce some sedimentation before it leaves for the downstream reach .

(ii) To check soil erosion.

Specific site condition:

Brushwood checks are constructed in places where brushwoods are locally and cheaply available.

Design criteria:

No specific procedure is followed while designing the brushwood structure. Two types of construction are generally followed viz single post row brushwood check dams and double post row check dams. The double post row check dam is used when the expected runoff is in larger quantities. The poles should be driven deep enough to withstand the water force (runoff). It depends on the soil type. Sometimes it is driven up to 1 m deep below the bed. The number of rows, number of poles in a row, pole size (diameter and height), pole to pole spacing, row to row spacing is decided depending upon the expected runoff to be handled, gully width and gully drops. In case of double post row check dams, the poles are arranged in zig zag manner which obstruct the runoff betterly and assures better energy dissipation thus reducing the velocity of runoff and induce some sedimentation before it leaves for the downstream.

Plate No. 1 Brushwood structure across gully

Plate No. 2 Brushwood structure on field bund

Plate No. 3 Silt deposition in the upstream of brushwood structure

3.6.2 Loose rock structures

Loose rock structures are constructed across the gully using variable sizes of stones – is usually a permeable type of temporary/semi-permanent structure.

Objectives:

1. For gully control – to slow down the velocity of runoff and gto induce sedimentation before it leaves for the downstream reach.

2. To stabilise active gullies by encouraging vegetative growth because of favourable moisture condition created by impounding water.

Specific site condition:

Loose rock dams are constructed in places where loose boulders are locally and cheaply available.

Design Consideration:

There is no specific design procedure for loose rock dams. There to be designed keeping in view of the needs and availability of materials in a given situation. However, these structures do have head wall, head wall extension and apron like components of a masonry drop structure which are to be constructed on similar lines as that of masonry drop structure. Keying a check dam into the sides and floor of the gully greatly improves the stability. This involves digging a trench usually 0.6 m deep and wide across the gully . Head wall should be extended in to the banks from the spillway to a length of 1.5 times the effective height of check dam but if it is not possible, at least 0.5 m long wall should be

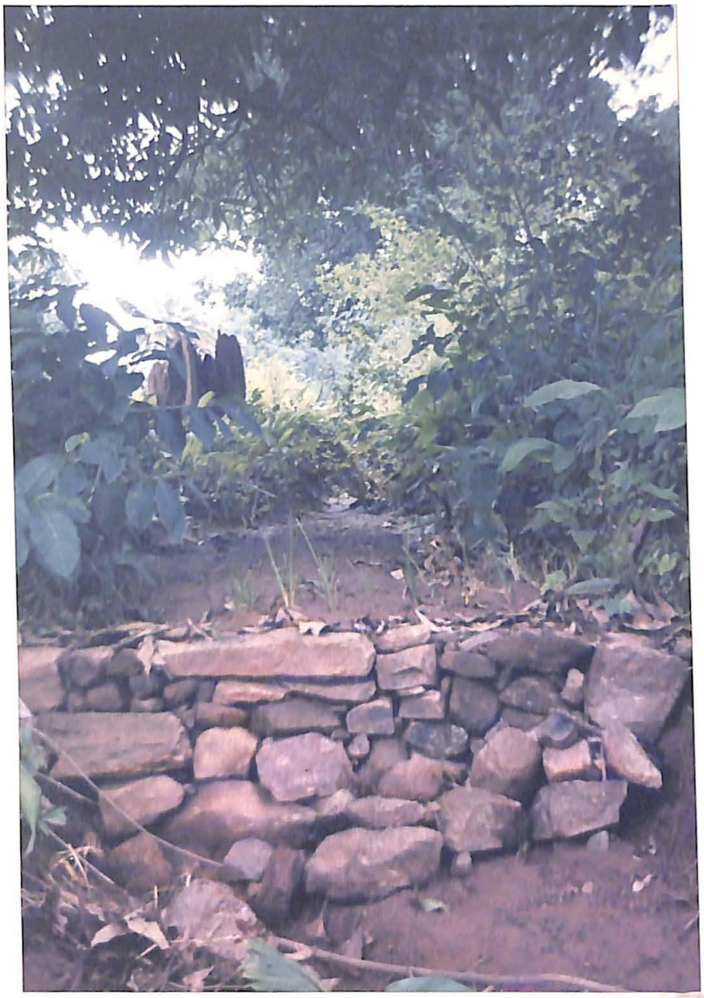


Plate No. 4 Loose rock structure across gully

Plate No. 5 Loose rock structure on field bund

Plate No. 6 Combined structure of loose rock and brushwood on the field bund inserted in to the banks. Apron must be provided on the gully bed on the downstream of check dam to prevent flow from undercutting the structure. Where, the slope of the gully bed is less than 8.5%, the length of apron should be 1.5 times the effective height of the structure. For steeper slopes, it varies from 1.75 times to 2 times the height.

It is recommended that dam section should be provided with a side slope of 2:1 or flatter. It is also safe to provide cut off walls at the upstream. Generally, it should extend a minimum of 20 cm in to the rock surface.

The rock material to be used must be hard and should resist disintegration. The rocks should be dumped and spread in layers. The spreading operation of this kind assure minimum number of large voids and it will provide a compact rock fill.

3.6.3 Gabion Structures

Gabion structures (crate wire check dams) check have been advocated as a suitable semi-permanent structures in controlling gullies. These have also been reported to be successful in silt trapping in the upstream side when constructed across a gully (Goel *et al.* 1996). Gabion structures are constructed across the gully at the places where the velocity and volume of peak runoff is too high for loose rock structures.

Objectives:

(i) To modify the bed gradients in gully so that the run off flow velocities are within non-erosive limits after runoff water leaves the structure at downstream.

(ii) To control gully erosion.

Specific site condition:

Gabion structures are generally adopted for stabilising drops up to 3 m. They are constructed at narrow cross-sections in order to cut down the overall construction cost.

Design:

Design of Gabion structure include the following (Katyal *et al.*, 1995) :

(i) Hydrologic design involving the design runoff rate and flood volume the structure is expected to handle. Rational formula can be used for estimating the peak runoff.

(ii) Hydraulic design is carried out to arrive at the required spillway dimensions to carry the design runoff. The crest length can be determined from the broad crested weir formula.

$$Q = 1.75\, LH^{3/2} \quad \ldots\ldots\ (3.1)$$

Where

Q = discharge, m^3/sec.

L = crest length , m

H = head on spillway, m.

The depth of foundation of the body wall is determined by taking the normal scour depth and maximum scour depth in to account. The normal scour depth is given as

Normal scour depth,

$$d_n = 0.473\left(\frac{Q}{f}\right)^{1/3} \quad \text{..........(3.2)}$$

Where, Q =discharge, ft^3/sec.

f = silt factor which is taken as 1.0 in view of steep bed slopes on upper as well as below the structure.

The maximum scour depth is given as

Maximum scour depth, d_m = 1.5 dn.

The foundation depth 'D' is determined as, $D=1.33d_m$

The length of solid apron 'X' in ft. is determined as, $X = 6\sqrt{H}$

The thickness of solid apron 'T_a' is determined as, $T_a = \frac{h+H}{5}$

Where, h = height of the body wall, m.

H = head on spillway, m.

3.6.4 Conservation Trenches with Diversion Drain

Conservation trenches are constructed both on hill slopes as well as on degraded and bare waste lands for soil and moisture conservation and afforestation purposes. These trenches break the slope lengths, reduce the velocity of surface runoff and consequently retard its scouring action and carrying capacity. The water retained in the trenches helps in conserving the moisture and provide advantageous sites for sowing and planting.

Specification of Trenches:

Conservation trenches may be continuous or interrupted. The interrupted trenches may be constructed in series or in staggered manner.

The size of the trenches depends upon the soil depth available at the site. Normally sizes between 1000 sq. cm to 2500 sq.cm in cross section are adopted. Knowing the amount of rainfall to be retained in an unit area, it is possible to calculate the size and the number of trenches required. As far as length of the trenches are concerned, shorter length viz 3.5 or 7 m lengths are generally adopted for convenience of layout and construction. Generally a standard design of conservation trenches is used. (Murty, 1998)

Diversion drain:

Diversion drains are constructed at upstream side of the plantation plots with conservation trenches, for the purpose of intercepting the surface runoff as well as preventing the outside water entering into the field and conveying the same to a safe outlet.

There is no specific design procedure for this type of diversion drains. Generally a depth of 30 cm, bed width of 100 cm with side slopes 1:1 or 1 ½ :1 or more is taken. The spoil bank is constructed with the volume of excavated soil.

Different treatments of conservation trenches undertaken on experimental basis in this watershed are as given below:-

T_1 - No treatment

Plate No. 7 V-ditch constructed in the farmers field.

Plate No. 8 Diversion drain for intercepting run

T_2 - Continuous V- ditches at 10 m horizontal interval

T_3 - Continuous V-ditches at 20m horizontal interval

T_4 - V-ditches staggered at 5 m horizontal interval

T_5 - V-ditches staggered at 10 m horizontal interval.

3.7 Observation

3.7.1 Measurement of silt deposition

The silt deposition under each structure is observed. Deposited sediment measurements are taken under each structure. The silt deposition is measured by simply measuring the depth, width and length of the sediment deposited at the upstream of the structure with the measuring tape.

In case of loose rock structure, the silt deposits at the upstream side. Maximum of silt deposits at the near of the structure in upstream side and gradually it reduces to zero at certain length. The length is measured, width is the width of the structure and the depth of silt deposition is taken as average so divided by two or half of the depth is taken and volume of the silt deposited is calculated by multiplying the length, width and depth.

In case of brush wood structure, the silt is deposited at the up stream as well as in between the rows. So, the depth of silt deposited is measured in between the rows and at the upstream of the structure. In between the rows, the width is the width of structure, length is the row to row spacing and depth is the depth of the silt deposited. The volume is calculated by simply multiplying the length, width and depth. The volume of silt deposited at the upstream is calculated as in the case of loose rock structure. Then the volume of silt deposited is calculated by adding the volume of silt deposited in between the rows and at the up stream of the structure.

3.7.2 Measurement of plant height

Different treatments of conservation trenches (as said before) have been experimented in the fields of three farmers F_1, F_2 and F_3. The height of the plants (Mango) was measured in each treatment in each of the farmer's field to study the performance and effectiveness of conservation trenches in moisture conservation to help better growth of plant.

CHAPTER-IV
RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The present chapter deals with the designs of different soil conservation structures and discussions on their performances in the micro-watershed.

4.1 Design of Brushwood Structure

The design of brushwood structure (Fig. 4.1) consists in determination of the size of the structure i.e. the number of rows, number of brushwoods in a row, row to row spacing and line to line spacing as per the the article 3.6.1.

As the rate of runoff to be handled is more, double post row check dams are recommended here. Number of brushwood poles in a row depends upon the width of the structure which is bit less than the width of gully. The number of poles in a row ranges from 4 to 7 in the structures constructed across gully and 3 to 6 in the structures constructed on field bunds. Pole to pole spacing is taken as roughly, which ranges from 25-40cm across gully and 20 to 30cm on the field bunds. Row to row spacing is also taken as roughly which ranges from 40-75cm across gully and 50-63cm on field bunds. The brushwood poles are the locally available *Dhupa* (in local language) poles which are quite strong to withstand the runoff and water pressure. The poles are driven deep enough upto 1m. The details of brushwood checks across gully and on field bunds are given in the Table 4.1.

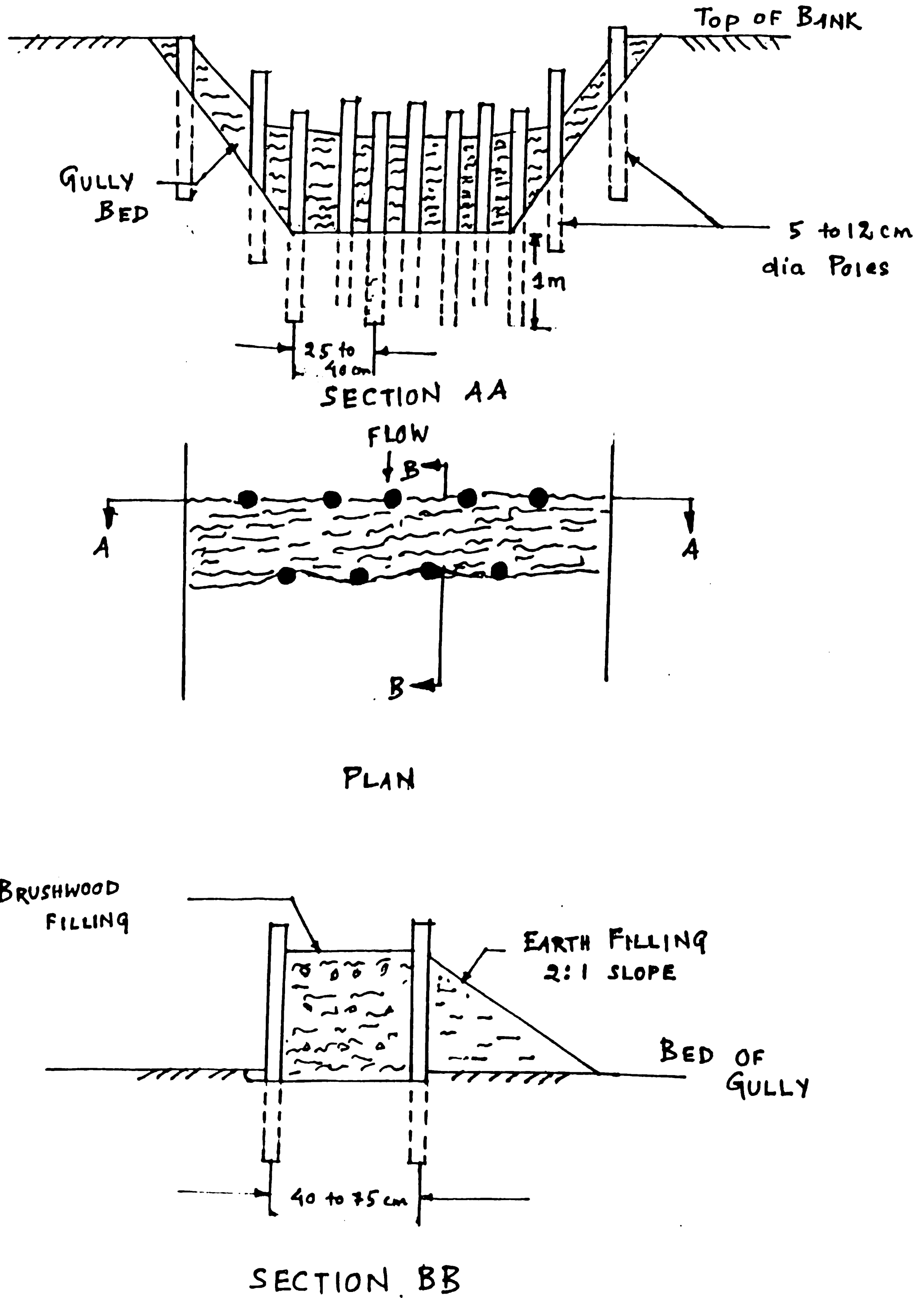


Fig. 4.1 Brushwood check dam

Table 4.1 Details of brushwood structures across gully.

Replications	No. of rows	No. of poles		Row to row spacing, cm	Pole to pole spacing, cm	Size of brushwoods (pole dia), cm
		First row	Second row			
Across gully						
R_1	2	7	7	75	28	5.10-9.55
R_2	2	5	4	40	25	5.40-10.80
R_3	2	8	6	50	26	5.10-10.20
R_4	2	6	5	60	25	5.70-10.80
R_5	2	4	4	60	30	5.70-10.20
R_6	2	7	6	60	40	6.30-9.50
On field bunds						
R_1	2	3	3	63	20	5.70-9.80
R_2	2	4	3	60	30	6.30-10.20
R_3	2	3	3	50	25	6.30-9.50
R_4	2	5	4	60	26	5.10-8.9
R_5	2	4	3	50	27	5.70-10.20
R_6	2	5	6	50	25	5.7-10.80
R_7	2	6	6	50	24	7.64-12.10

Brushwood structures (6 Nos.) were constructed across the gully at 10m intervals as the width of gully is not uniform, somewhere it is narrow and somewhere it is wide, the width of the structure, numbers of poles in the rows and pole to pole spacing varies in each structure. More the gully width, more is the numbers of poles in the rows and more is the pole to pole spacing and vice versa. Minimum three poles should be given in a row, accordingly numbers of poles in a row and pole to pole spacing were decided.

4.2 Design of loose rock structure

The loose rock structure (Fig. 4.2) have been designed taking the design considerations stated in article 3.6.2 into account.

The gullies are small gullies having a depth range of 45-190cm and width range of 170-230cm. The dimension of the structure comprises of top width, bottom width and height, which were decided by looking at the gully dimension, and availability of loose rocks. The dimensions of different replications are given in Table 4.2. The depth of foundation is 30cm.

The loose rock structure constructed on field bunds (Fig. 4.3) is similar to drop structure. The dimension of the structures comprises of crest length, height above the crest, head wall extension. The dimensions were decided as per the situation. The dimensions of different replications of the structure constructed on field bunds are given in Table 4.3. The depth of foundation is taken as 30cm. The toe wall is taken as 30cm.

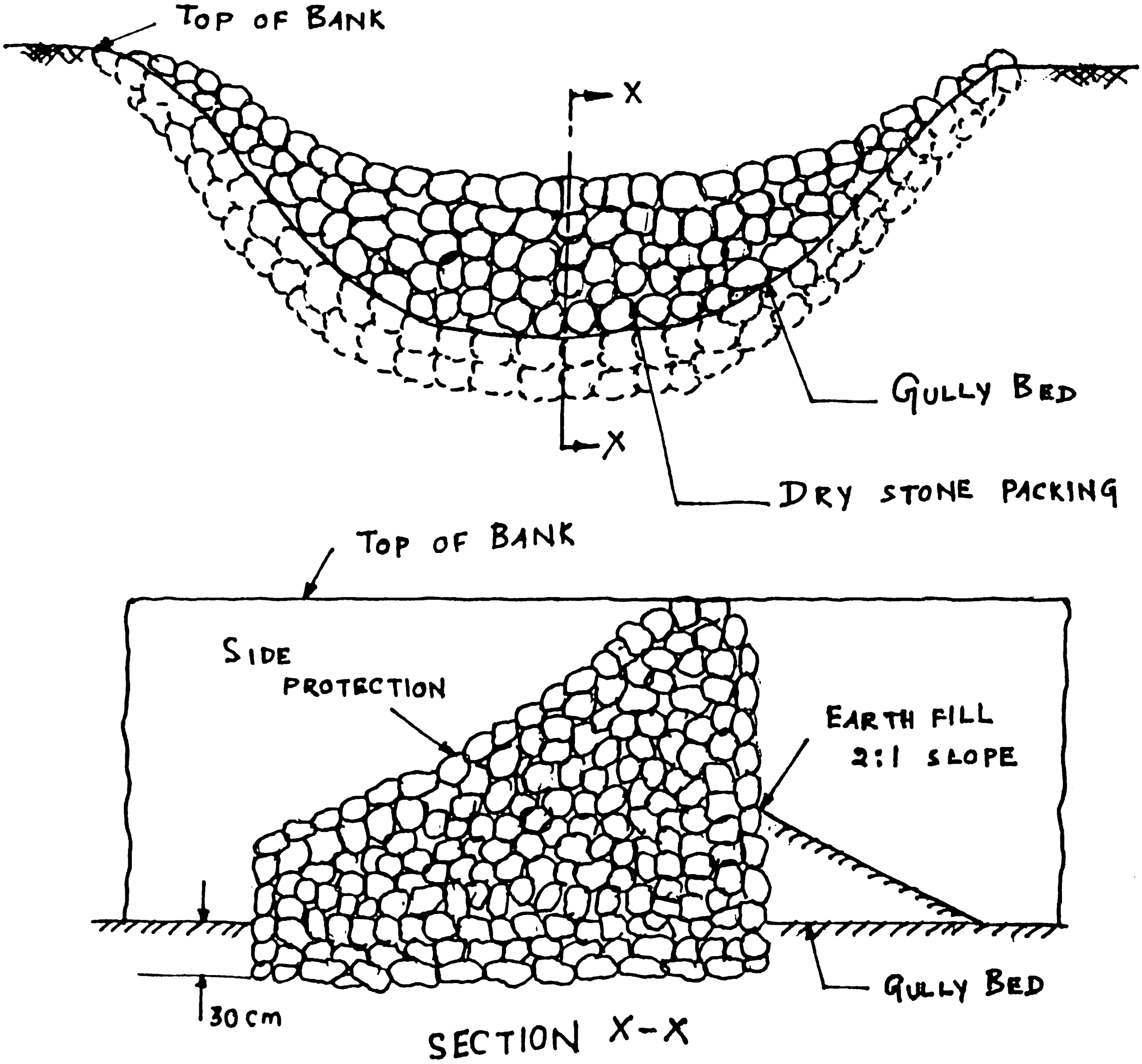


Fig. 4.2 Loose rock structure across gully

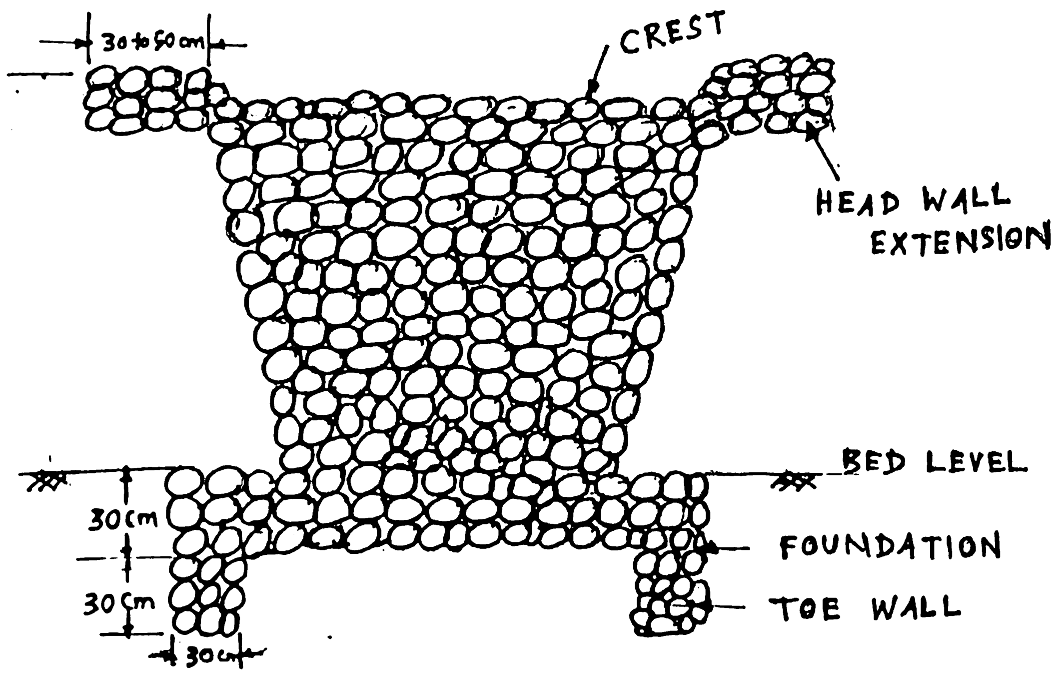


Fig. 4.3 Cross-section of loose rock structural on field bunds

Table 4.2 **Detail dimensions of loose rock structures across gully.**

Replications	Gully dimension, cm			Structure dimension, cm		
	Top width	Bottom width	Depth	Top width	Bottom width	Depth
R_1	180	90	90	90	60	55
R_2	100	60	80	80	60	45
R_3	120	60	70	80	60	50
R_4	170	90	80	90	60	50
R_5	190	80	80	120	80	60
R_6	180	70	70	80	60	50
R_7	170	100	45	100	60	45
R_8	190	100	85	90	70	55
R_9	180	100	100	90	60	60
R_{10}	230	120	100	100	70	60
R_{11}	160	70	100	60	40	35
R_{12}	160	110	190	70	40	60

Loose rock structures (12 nos.) were constructed across the gully at 10m intervals with varying dimensions which were resulted due to the varying dimensions of the gully at different places. Looking at the gully dimensions given in Table 4.2, the size variability of the gully is cleared. As these structures are temporary structures, emphasis is not given on exact dimensions of the structures. It is taken in ranges, depending upon the gully condition and availability of loose rocks. So, after construction of the structure, the top width, bottom width and depth of the structures were measured, and is as represented in the table given above.

Table 4.3 Dimensions of loose rock structures on field bunds

Replications	Depth of fall, cm	Crest length, cm	Height above crest, cm	Head wall extension on each side, cm
R_1	110	50	15	30
R_2	70	55	20	35
R_3	150	70	20	50
R_4	140	55	25	40
R_5	50	60	15	40
R_6	30	50	20	35
R_7	60	60	18	50

Seven numbers of loose rock structures were constructed on the field bunds for bund stabilisation as well as safe disposal of runoff to lower fields. The crest length were decided by looking at the width of the broken field bunds. Height above the crest and head wall extension were decided by looking at the crest length, in the range of 15-25cm respectively.

4.3 Design of gabion structure

Estimate of peak rate of runoff to be handled by the structure, as per article (2.2).

Having the data on land use pattern of the contributing catchment.

Land use	Area, ha	Runoff coefficient
Residential area	0.976	0.55
Cultivated area	2.5232	0.50
Pasture land	0.4863	0.36
Forest	0.7936	0.50

Weighted value of runoff coefficient ,

$$C = \frac{C_1 a_1 + C_2 a_2 + C_3 a_3 + C_4 a_4}{A} = 0.483$$

Length of channel reach, L = 340m

Average slope of channel, S = 0.05

Time of concentration, $T_c = 0.0195\ L^{077}\ S^{-0.385} = 5.50$min.

1 hr rainfall intensity for 10 year frequency at the location of the watershed = 80mm/hr.

Then, the intensity of rainfall for a duration of 5.5 min., I = 164mm/hr.

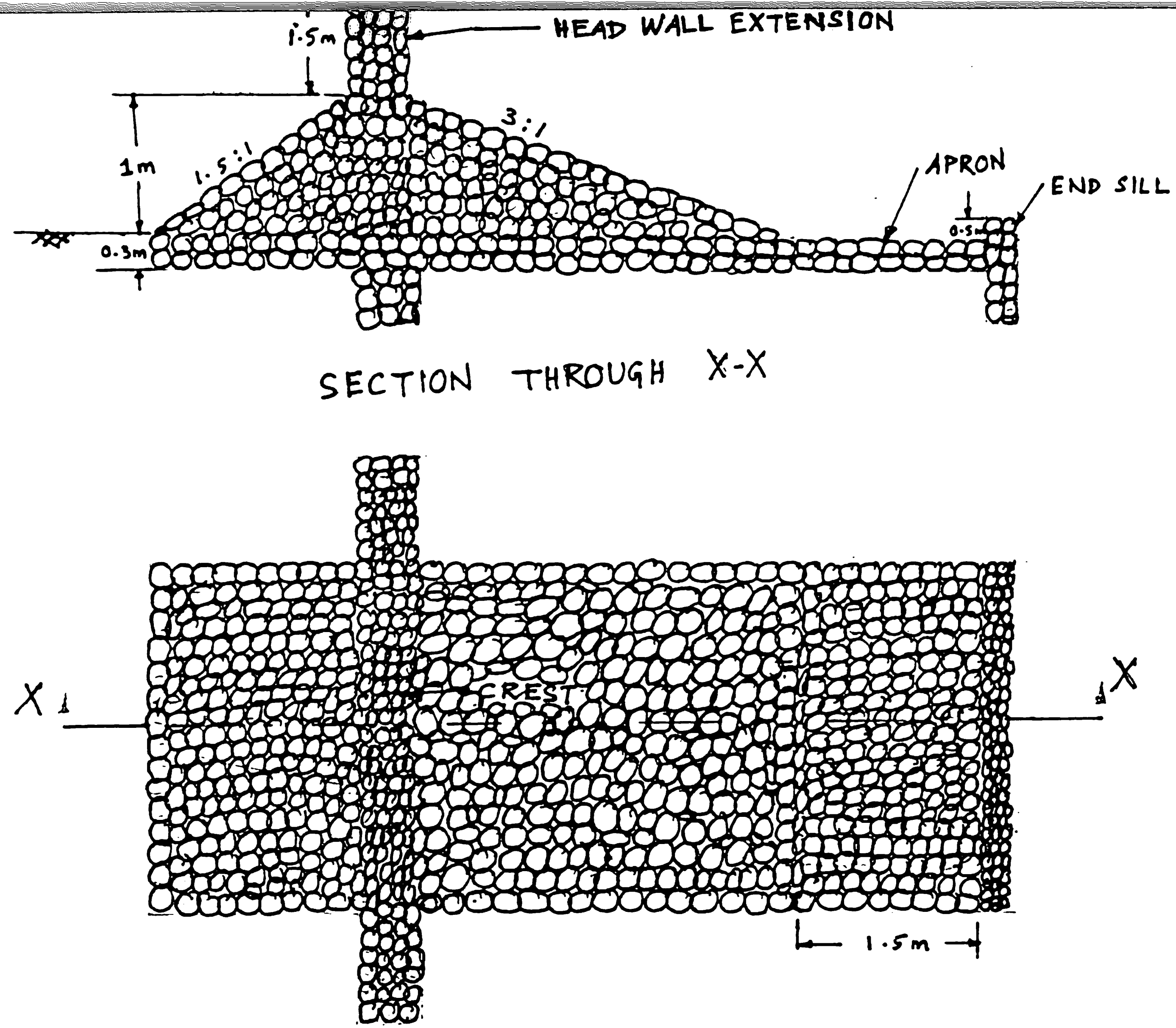


Fig. 4.4 Gabion structure

Peak rate of runoff,

$$Q = \frac{CIA}{360} = 0.86\, {m^3}/{s}$$

Assuming, Length of weir, L = 1.5m

Height of body wall, h=1.0m

Depth of flow over the crest, $H = \left[\frac{Q}{1.75L}\right]^{2/3} = 0.47m \approx 0.5m$

Depth of foundation of body wall :

Normal scour depth, $d_n = 0.473\left(\frac{Q}{f}\right)^{1/3} = 1.47' = 0.44m$

Maximum scour depth, $d_m = 1.5d_n = 0.66m$.

Foundation depth $D = 1.33d_m = 0.87m \approx 0.9m$

Minimum top width, t = 0.50m (Assumed)

Considering u/s side slope as 1.5:1and d/s side slope as 3:1

bottom width, T = 5m

Length of d/s solid apron (ft), $X = 6\sqrt{H} = 4.2ft. = 1.27m$; say 1.5m

Thickness of solid apron, $T_a = \frac{h + H}{5} = 0.3m$

Length of Head wall extension on each side = 1.5m.

4.4 Design of Conservation trenches (V-ditch) with diversion drains.

As the area is under rainfed agro-ecosystem, receiving an annual rainfall of around 1400mm, moisture conservation treatments were undertaken in this

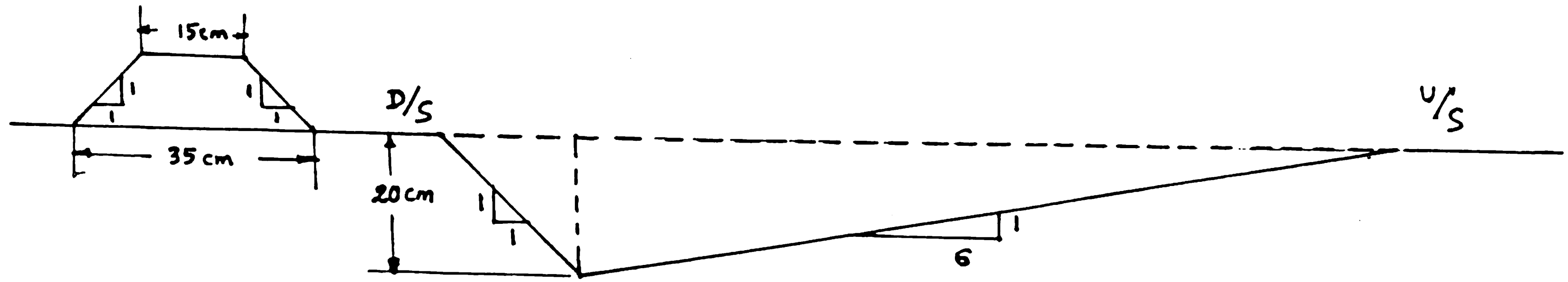


Fig. 4.5 Cross-section of V-ditch

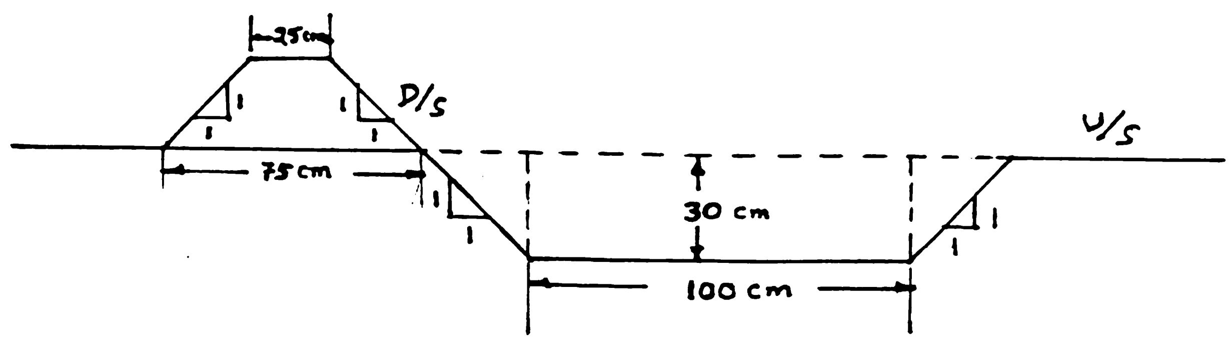
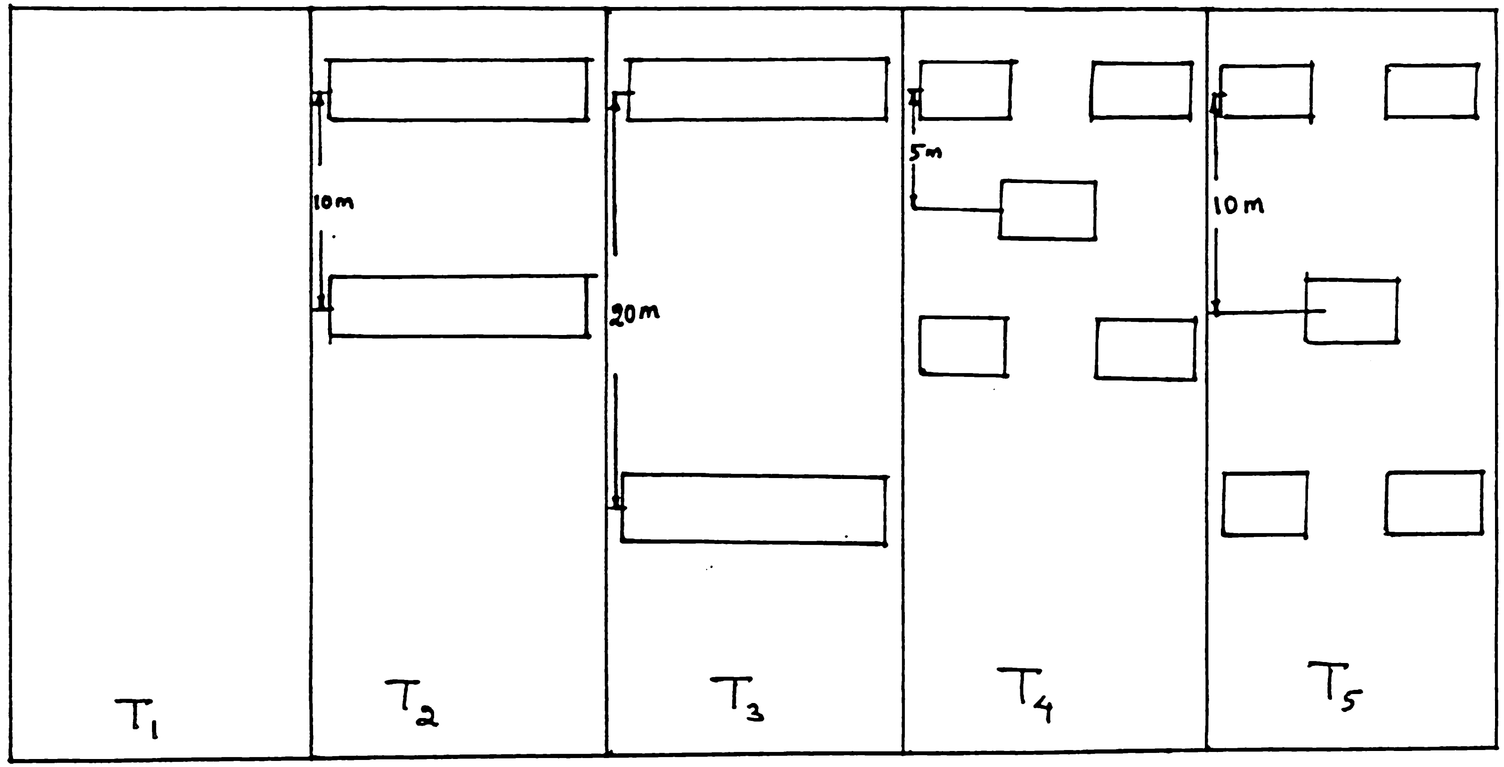


Fig. 4.6 Cross-section of Diversion drain



T_1 - No treatment

T_2 - Continuous V- ditches at 10 m horizontal interval

T_3 - Continuous V-ditches at 20m horizontal interval

T_4 - V-ditches staggered at 5 m horizontal interval

T_5 - V-ditches staggered at 10 m horizontal interval.

Fig. 4.7 Layout of different treatments of V-ditches

watershed. V-ditches were constructed to conserve soil as well as moisture to help the establishment of plantation crop. Diversion drains were constructed at the upstream of V-ditches to intercept the runoff and preventing the entry of surface water into the field from upstream hence provide advantageous site for plantation crops and helps to increase the longevity of the V-ditches.

A standard cross section of V-ditch has been taken here (Fig. 4.5). The V-ditch is having a depth of 20cm with slopes 6:1 in u/s and 1:1 in d/s. The dimension of spoil bank has been determined by equalising the volume of earthwork excavated and volume of the spoil bank of trapezoidal cross section.

The diversion drain having a depth of 30cm and bed width of 100cm with side slopes 1:1 both in u/s and D/s have been constructed. The cross section of the diversion drain is shown in Fig. 4.6.

4.5 Performances of the structures

The performances of the different conservation structures that have been constructed in the Sudreju micro-watershed has been discussed in the following articles.

4.5.1 Performance of Brushwood structure

The brushwood structures were found to be quite effective in obstructing the flowing runoff, reducing the runoff velocity and inducing sedimentation in the upstream and in between the rows of the structure. Deposition of silt under each structure was noticed. Measuring the depth, width and length of silt deposition at the upstream and in between the rows, the volume of silt deposition has been calculated and is represented in Table 4.4.

Table 4.4 Silt deposition in the brushwood structures across gully.

Replications	Upstream side				In between the rows				Total volume m^3	Average m^3
	Depth m	Width m	Length m	Volume m^3	Depth m	Width m	Length m	Volume m^3		
R_1	0.23	1.15	4.25	0.562	0.23	1.15	0.75	0.198	0.760	
R_2	0.42	0.85	3.10	0.553	0.42	0.85	0.40	0.143	0.696	
R_3	0.18	0.95	2.50	0.214	0.18	0.95	0.50	0.085	0.299	0.474
R_4	0.33	1.25	2.00	0.430	0.33	1.25	0.60	0.248	0.661	
R_5	0.18	1.30	1.35	0.158	0.18	1.30	0.60	0.140	0.298	
R_6	0.09	1.20	1.25	0.0675	0.09	1.20	0.60	0.065	0.133	
Total									2.844	

The average volume of silt deposition was found to be $0.474m^3$. No considerable amount of silt were deposited in case of the structures constructed on the field bunds due to higher velocity of flow caused by falls. It is concluded that brushwood structure is a good, low cost, temporary gully control structure.

4.5.2 Performance of loose rock structures

Observing the silt deposition at the upstream of the loose rock structure, it is concluded that this structures are very effective in entrapping silts, flowing from the upstream gullies and controlling gully erosion

Measuring the depth, width and length of silt deposition at the upstream side of the structure, the volume of silt deposition under each structure has been calculated and is represented in Table 4.5.

Table 4.5 Silt deposition in the u/s of loose rock structures

Replications	Depth, m	Width, m	Length, m	Volume, m^3	Avg. vol., m^3
Across the gully					
R_1	0.55	1.35	6.40	2.376	
R_2	0.45	0.80	2.80	0.504	
R_3	0.50	0.90	2.90	0.652	
R_4	0.50	1.30	4.20	1.365	
R_5	0.60	1.35	3.10	1.255	
R_6	0.50	1.25	1.80	0.563	0.862
R_7	0.45	1.35	1.20	0.364	
R_8	0.55	1.45	2.50	4.996	
R_9	0.60	1.40	0.80	0.336	
R_{10}	0.60	1.75	1.8	0.945	
R_{11}	0.35	1.15	3.50	0.704	
R_{12}	0.60	1.35	0.70	0.283	
Total				10.338	
On the field bund					
R_1	0.020	0.63	0.84	0.0050	
R_2	0.012	0.88	0.63	0.0030	
R_3	0.008	0.59	0.44	0.0009	0.0017
R_4	0.004	0.53	0.13	0.0001	
R_5	0.007	0.64	0.29	0.0006	
R_6	0.009	0.63	0.38	0.0010	
Total				0.0106	

The average volume of silt deposition under the structure across gully was found to be 0.862m^3. The total volume of silt deposited was found to be

$10.338m^3$. The average volume of silt of deposition under the loose rock structure constructed on the field bund was found to be $0.0017m^3$. Loose rock structures on the field bunds were constructed with the main objective of safe disposal of runoff to lower fields bund stabilisation and help retention of water in the paddy fields. A very little silt deposition (avg. vol. of $0.0017m^3$) was observed under these structures which comes with the runoff and settle down at the u/s of the structure.

4.5.3 Performance of V-ditches

V-ditches were constructed with the main objective of moisture conservation for establishment of plantation crop. Their performance is studied by observing the growth of plants that have been planted in the different treatments of V-ditches. The five moisture conservation treatment were experimented in the field of three farmers F_1, F_2 and F_3 with Mango as the plantation crop. The plant height observation was taken. It was noticed that the plant height increased continuously with variable rate of growth caused by the treatment variables as represented in the Table 4.6. Control plot (no moisture conservation treatment) recorded the minimum monthly growth rate of plants. All the moisture conservation practices recorded higher monthly growth rate than control. The maximum growth rate was recorded in continuous contour V-ditches at 10m horizontal interval closely followed by 5m staggered V-ditch.

Table 4.6 Plant height and monthly rate of growth of Mango plants in the farmers fields.

Farmers / Treatments	Farmer F_1			Farmer F_2			Farmer F_3		
	Ht. in July' '01,cm	Ht. in March' 02, cm	Rate of growth, cm/ month	Ht. in July'01, cm	Ht. in March' 02, cm	Rate of growth, cm/month	Ht. in July'02, cm	Ht. in March' 02, cm	Rate of growth, cm /month
T_1 Control	38.0	48.6	1.32	36.9	43.0	0.77	54.0	62.3	1.04
T_2 CCVD at 10m horizontal interval	29.0	41.0	1.50	16.8	29.	1.54	29.0	43.0	1.75
T_3 CCVD at 20m horizontal interval	43.0	54.0	1.38	24.2	32.0	0.98	49.7	60.0	1.29
T_4 VD staggered at 5m interval	57.5	69.0	1.44	42.3	54.0	1.47	39.0	52.0	1.63
T5 VD staggered at 10m interval	40.0	51.3	1.41	24.6	34.0	1.17	37.6	49.0	1.42
Average	41.5	52.8	1.41	29.0	38.4	1.19	41.9	53.3	1.43

The rate at growth of the plants in the plants of the three farmers F_1, F_2, and F_3 were found to be 1.5cm/month. 1.54cm/month and 1.75 cm/month respectively in the treatment T2 of continuous contour V-ditches at 10m horizontal interval. The higher rate of growths of plants indicate better conservation capacity of the treatment. Hence continuous contour V-ditches at 10m horizontal interval were found to be more efficient than other treatments.

CHAPTER-V
SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSIONS

The present study entitled "PLANNING AND DESIGN OF DIFFERENT SOIL CONSERVATION STRUCTURES AND THEIR PERFORMANCES IN THE MICRO-WATERSHED - a case study" was undertaken with the following objectives.

1. To conduct reconnaissance survey in the micro-watershed for identifying the critical areas for intervention.

2. Planning and design of different soil conservation structures.

3. To study the effectiveness of different conservation structures already constructed in the watershed.

The Sudreju micro-watershed is a part of watershed ORM 3-9-6-5 and falls under sub-watershed No. 17-07-31-01-01and topo sheet No. 73D/6. Different morphometric parameters of the watershed like basin length, basin width, from factor, circularity index, circularity ratio, elongation ratio, drainage density were determined from the toposheet. The details of different watershed characteristics like climate, soil type, topography, surface drainage, land use and cover condition of the study area were collected. Runoff coefficient, time of concentration, Intensity of rainfall for the duration equal to time of concentration and peak rate of runoff of the watershed were determined. Reconnaissance survey was conducted in the watershed for identifying the critical areas for intervention. Soil erosion was prominent in gullies and sloping agricultural fields hence these areas were prioritised for intervention. Looking into easily and cheaply availability of materials such as brushwoods and loose rocks in the area different low cost, temporary and semi permanent structures such as brushwood structures, loose rock structures, gabion structures conservation trenches (V-ditches) were planned and designed. This micro-watershed has been treated with these conservation structures and numbers of these structures have been constructed at proper locations. Their performances was studied by observing the silt deposition under the structures and growth rate of plant that has been planted in the conservation trenches. An average volume of silt deposition under each brushwood structure was found to be $0.474 m^3$ and under each loose rock structure to be $0.862 m^3$, across gully. Continuous contour V-ditches at 10m horizontal interval recorded maximum rate of growth of plant in comparison to other treatments, hence proved better in moisture conservation. Loose rock structures were found to be better in entrapping silt as well as from stability point of view.

5.1 Conclusion

The following conclusions were drawn from the present study :

1. The general texture of soil of the area ranges from loamy to clay loam with very low water holding capacity. The land of the area is subjected to severe erosion in hilly slope and upland areas.

2. Watershed characteristic such as form factor, circularity ratio, elongation ratio were found to be 0.4637, 0.7785 and 0.768 respectively. These values indicated that the watershed is fan shaped, hence produces higher peak rate of runoff in shorter duration.

3. Drainage density of the micro-watershed was found to be 3.39 km/km^2 which implies runoff yield is relatively more.

4. Rainfall intensity for the duration equal to time of concentration and weighted runoff coefficient for the area were found to be 165 mm/hr and 0.474 respectively. The time of concentration was found to be 10 minutes which is very low and indicates that the water remains in the watershed area for a small time thereby allowing a very little ground water recharge through infiltration.

5. Gullies and sloping agricultural fields are the critical areas in the micro watershed which needs conservation treatments, as concluded from reconnaissance survey conducted in the watershed.

6. Loose rocks and brushwoods are easily and cheaply available in the area so temporary and semi permanent gully control structures were planned.

7. As the study area is under rainfed agro-ecosystem, conservation trenches (v-ditches) were planned to conserve soil as well as moisture to help establishment of plantation crop.

8. Brushwood structures, loose rock structures, gabion structures and V-ditches with diversion drains were designed.

9. Performances of the structures in the watershed was studied by observing the silt deposition under the structures. The average volume of silt deposited under brushwood structures and loose rock structure were found to be 0.474m^3 and 0.862 m^3 respectively that have been constructed

across gully. Deposition of silt is more in loose rock structures due to its higher dimensions.

10. Due to construction of loose rock and brushwood structure across field bunds a water level of 5-10 cm were maintained in the fields. A considerable amount of silt (avg. volume 0.0017 m^3) deposited in the upstream of loose rock structure but the same were not deposited in the case of brushwood structure due to higher velocity of flow caused by falls. In both cases, velocity of runoff was reduced to a great extent and controlled the damage of field in downstream due to siltation. Loose rock structures proved to be better as far as stability is concerned.

11. Continuous contour V-ditches at 10m horizontal interval was found to be better than other treatments in moisture conservation which was concluded by observing the rate of growth of plants that have been planted in the conservation trenches.

CHAPTER-VI

SUGGESTIONS FOR FUTURE WORK

SUGGESTIONS FOR FUTURE WORK

The following are the suggestions for future work for the development of watershed project.

1. Planning and design of different soil and water conservation structures has been done for Sudreju micro-watershed by taking the design considerations in to account . The work may be extended for planning and design of different conservation structures for other watersheds of the district.

2. Temporary gully control structures like loose rock structures, brush wood structures gabion structures have been constructed in the watershed. Permanent gully control structure like drop spillway may be designed and constructed in this watershed.

3. Sometimes sand bags are used for gully plugging which is a low cost, temporary gully control measure. Sand bags may be put across the gully for conserving soil as well as moisture and controlling gully erosion.

4. Grass waterways maybe planned and designed and constructed in the watershed with the objective to convert gullies in to stable channels by providing vegetal protection to soil surface for effecting drainage as well

as channelising and regulating runoff flows for water harvesting purposes.

5. The heavy downpour of rain at times results in sudden high runoff and flows through the channels. So, impounding type of water harvesting structure, where an embankment is constructed across the channel may be designed and constructed in this watershed.

6. The benefit- cost analysis may be made.

Before implementation of a programme in the watershed, people's participation and views of the public is of utmost importance. They are to be explained in details and their views are to be incorporated for successful planning of the project.

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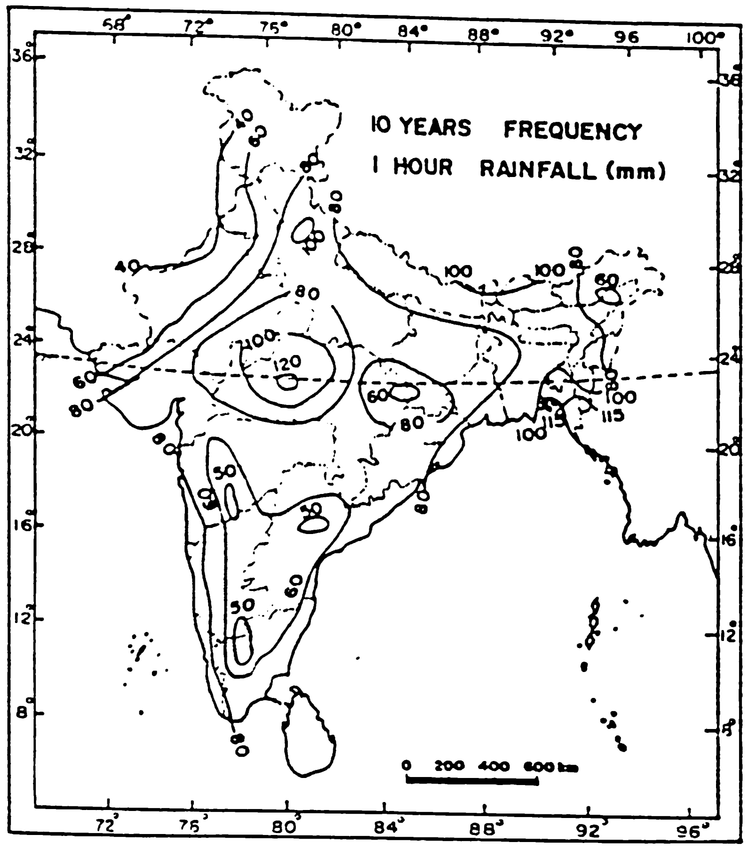
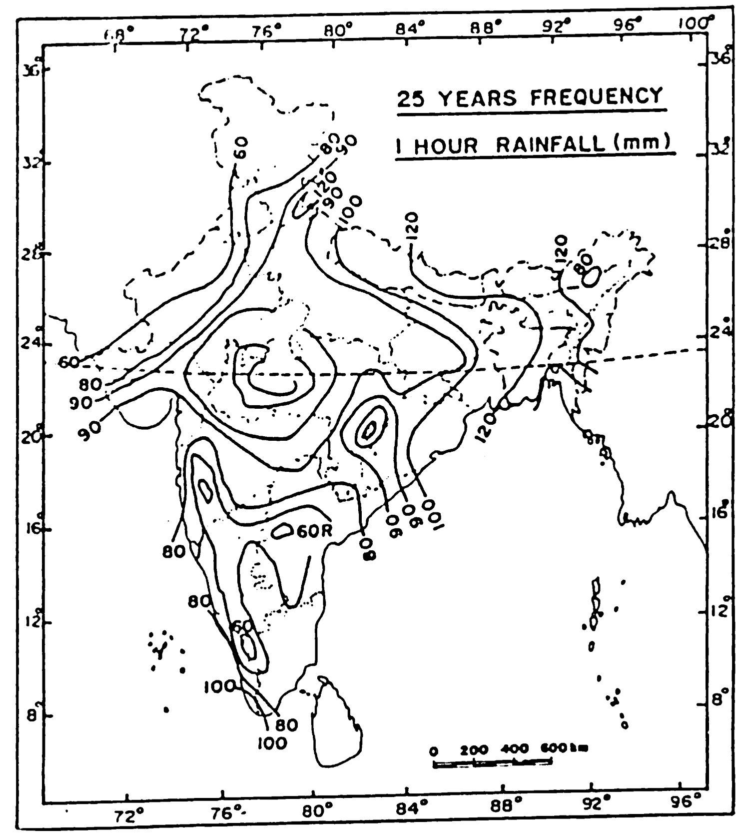
APPENDICES

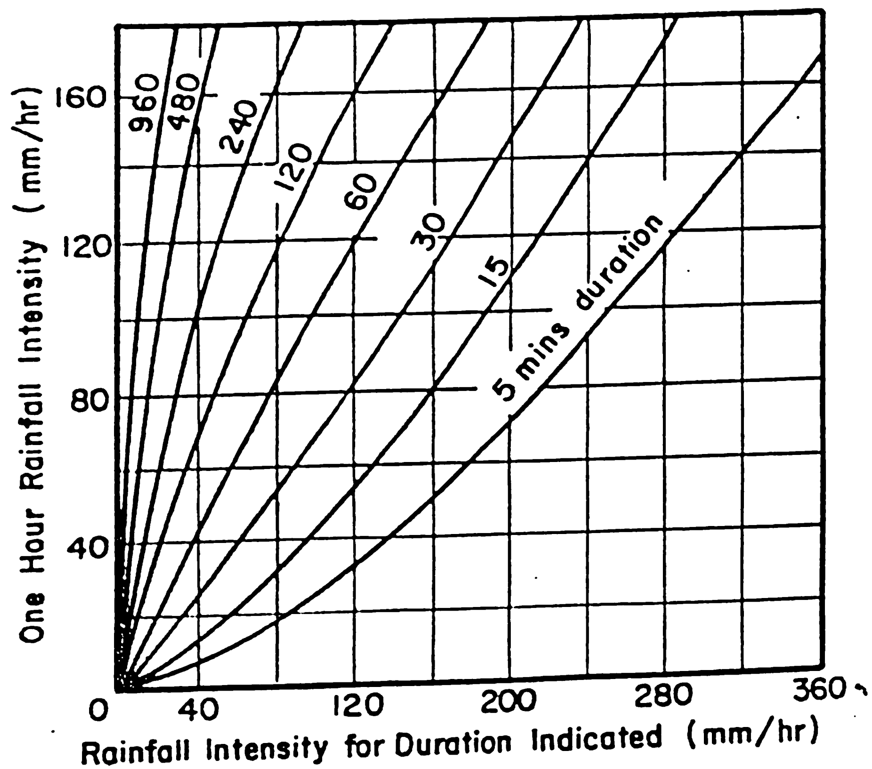
APPENDIX-I

Maps showing rainfall characteristics for runoff calculations





APPENDIX-II



Relation to convert one hour rainfall to intensities for other durations

APPENDIX-III

Value of 'C' for use in Rational formula

Sl. No.	Land use and Topography	Soil Types		
		Sandy loam	Clay and silt loam	Tight clay
1.	Cultivated land			
	i) Flat	0.30	0.50	0.60
	ii) Rolling	0.40	0.60	0.70
	iii) Hilling	0.52	0.70	0.82
2.	Pasture land			
	i) Flat	0.10	0.30	0.40
	ii) Rolling	0.16	0.36	0.55
	iii) Hilling	0.22	0.42	0.60
3.	Forest land			
	i) Flat	0.10	0.30	0.40
	ii) Hilling	0.30	0.50	0.50
4.	Populated land			
	i) Flat	0.40	0.55	0.65
	ii) Rolling	0.50	0.65	0.80

APPENDIX-III

Value of 'C' for use in Rational formula

Sl. No.	Land use and Topography	Soil Types		
		Sandy loam	Clay and silt loam	Tight clay
1.	Cultivated land			
	i) Flat	0.30	0.50	0.60
	ii) Rolling	0.40	0.60	0.70
	iii) Hilling	0.52	0.70	0.82
2.	Pasture land			
	i) Flat	0.10	0.30	0.40
	ii) Rolling	0.16	0.36	0.55
	iii) Hilling	0.22	0.42	0.60
3.	Forest land			
	i) Flat	0.10	0.30	0.40
	ii) Hilling	0.30	0.50	0.50
4.	Populated land			
	i) Flat	0.40	0.55	0.65
	ii) Rolling	0.50	0.65	0.80

APPENDIX – IV

DAILY RAINFALL DATA (mm) AT PHULBANI DURING 2001.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1.	-	-	-	-	-		4.9	24	2	-	-	-
2.	-	-	-	-	-			5	-	-	-	-
3.	-	-	-	-	-	20	79.2	29	-	-	-	-
4.	-	-	-	-	-	3	86	4	4.3	-	-	-
5.	-	-	-	-	-	6	51	5	1.2	-	-	-
6.	-	-	-	-	-		19	8	-	33	-	-
7.	-	-	-	-	20	38	111	-	-	-	-	-
8.	-	-	-	-	-		83	2	-	7.5	-	-
9.	-	-	-	-	-	8	13	6	-	-	-	-
10.	-	-	-	-	-		6	36	-	5.0	1.9	-
11.	-	-	-	-	-	7	39	2	2	-		-
12.	-	-	-	-	-	66	11	12	2	-	4.0	-
13.	-	-	-	-	-	117		4.5	1.2	-		-
14.	-	-	-	-	10	32	10	11	-	-		-
15.	-	-	-	-	-	10	15	-	-	-	1.0	-
16.	-	-	-	-	-	3	85	-		-	-	-
17.	-	-	-	-	-		62	3	64	-	-	-
18.	-	-	-	-	-		43	1.1	-	-	-	-
19.	-	-	-	-	-		10	6	-	66	-	-
20.	-	-	-	-	-	7	4	20	-	-	-	-
21.	-	-	-	-	-	-	7	11	-	-	-	-
22.	-	-	-	-	-	-	13	-	-	-	-	-
23.	-	-	-	-	-	4	17	2.2	-	-	-	-
24.	-	-	-	-	-	61	21.5	-	-	-	-	-
25.	-	-	-	-	-	38.5	2.0	-	-	-	-	-
26.	-	-	-	-	-	10.9	-	-	-	-	-	-
27.	-	-	-	-	18	-	-	-	-	-	-	-
28.	-	-	-	-	-	5	5.0	26.3	-	-	-	-
29.	-	-	-	-	-	42	-	7	-	-	-	-
30.	-	-	45	-	-	26.5	-	23	48	-	-	-
31.	-	-	11	-	-	-	-	52	-	-	-	-
Total	Nil	Nil	56	Nil	48	504.9	797.6	300.1	124.7	111.5	6.9	Nil
Cum. Total	Nil	Nil	56	56	104	608.9	1406.5	1706.6	1831.3	1942.8	1949.7	1949.7

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1.	-	-	-	-	-		4.9	24	2	-	-	-
2.	-	-	-	-	-			5	-	-	-	-
3.	-	-	-	-	-	20	79.2	29	-	-	-	-
4.	-	-	-	-	-	3	86	4	4.3	-	-	-
5.	-	-	-	-	-	6	51	5	1.2	-	-	-
6.	-	-	-	-	-		19	8	-	33	-	-
7.	-	-	-	-	20	38	111	-	-	-	-	-
8.	-	-	-	-	-		83	2	-	7.5	-	-
9.	-	-	-	-	-	8	13	6	-	-	-	-
10.	-	-	-	-	-		6	36	-	5.0	1.9	-
11.	-	-	-	-	-	7	39	2	2	-		-
12.	-	-	-	-	-	66	11	12	2	-	4.0	-
13.	-	-	-	-	-	117		4.5	1.2	-		-
14.	-	-	-	-	10	32	10	11	-	-		-
15.	-	-	-	-	-	10	15	-	-	-	1.0	-
16.	-	-	-	-	-	3	85	-		-	-	-
17.	-	-	-	-	-		62	3	64	-	-	-
18.	-	-	-	-	-		43	1.1	-	-	-	-
19.	-	-	-	-	-		10	6	-	66	-	-
20.	-	-	-	-	-	7	4	20	-	-	-	-
21.	-	-	-	-	-	-	7	11	-	-	-	-
22.	-	-	-	-	-	-	13	-	-	-	-	-
23.	-	-	-	-	-	4	17	2.2	-	-	-	-
24.	-	-	-	-	-	61	21.5	-	-	-	-	-
25.	-	-	-	-	-	38.5	2.0	-	-	-	-	-
26.	-	-	-	-	-	10.9	-	-	-	-	-	-
27.	-	-	-	-	18	-	-	-	-	-	-	-
28.	-	-	-	-	-	5	5.0	26.3	-	-	-	-
29.	-	-	-	-	-	42	-	7	-	-	-	-
30.	-	-	45	-	-	26.5	-	23	48	-	-	-
31.	-	-	11	-	-	-	-	52	-	-	-	-
Total	Nil	Nil	56	Nil	48	504.9	797.6	300.1	124.7	111.5	6.9	Nil
Cum. Total	Nil	Nil	56	56	104	608.9	1406.5	1706.6	1831.3	1942.8	1949.7	1949.7

Standard week	Period	Rainfall (mm)		No. of rainy days	
		Normal	2001	Normal	2001
1.	1-7 Jan.	1.43	-	0.15	-
2.	8-14	4.45	-	0.24	-
3.	15-21	2.58	-	0.25	-
4.	22-28	0.74	-	0.07	-
5.	29-4 Feb	0.59	-	0.08	-
6.	5-11	4.99	-	0.38	-
7.	12-18	6.45	-	0.59	-
8.	19-25	0.88	-	0.16	-
9.	26-4 Mar	5.87	-	0.37	-
10.	5-11	3.44	-	0.35	-
11.	12-18	3.37	-	0.33	-
12.	19-25	4.20	-	0.38	-
13.	26- 1 Apr	5.96	56	0.25	2
14.	2-8	10.59	-	0.79	-
15.	9-15	3.3	-	0.25	-
16.	16-22	9.25	-	0.80	-
17.	23-29	5.72	-	0.50	-
18.	30-6 May	9.25	-	0.69	-
19.	7-13	18.95	20	1.07	1
20.	14-20	15.10	10	0.72	1
21.	21-27	8.60	18	0.68	1
22.	28-3 June	9.96	20	0.80	1
23.	4-10	15.85	55	0.98	4
24.	11-17	61.41	235	2.60	6
25.	18-24	52.99	72	2.75	3
26.	25-1 Jul	58.83	127.8	2.91	6
27.	2-8	90.08	429.2	3.27	6
28.	9-15	71.0	94	3.69	6
29.	16-22	71.14	224	3.92	7
30.	23-29	85.22	45.5	3.19	4
31.	30-5 Aug	84.98	67	3.69	5
32.	6-12	83.96	66	3.75	6
33.	13-19	94.46	25.6	3.55	5
34.	20-26	64.62	33.2	2.53	3
35.	27-2 Sep	93.96	110.3	3.72	5
36.	3-9	49.12	5.5	2.82	2
37.	10-16	73.01	5.2	3.19	3
38.	17-23	50.74	64	1.88	1
39.	24-30	35.09	48	2.12	1

40.	1-7 Oct	30.76	33	1.67	1
41.	8-14	20.87	12.5	1.22	2
42.	15-21	26.41	66	1.13	1
43.	22-28	10.95	-	0.26	-
44.	29-4 Nov	7.20	-	0.58	-
45.	5-11	13.59	1.9	0.61	1
46.	12-18	2.57	5.0	0.40	2
47.	19-25	5.70	-	0.20	-
48.	26-2 Dec	1.46	-	0.10	-
49.	3-9	0.06	-	-	-
50.	10-16	2.28	-	0.60	-
51.	17-23	0.03	-	-	-
52.	24-31	2.14	-	0.15	-
Total		1396.15	1949.7	66.84	86

APPENDIX -VI

MONTHLY RAINFALL (mm) AT PHULBANI DURING 2001.

Sl.No.	Month	Monthly normal	Actual in 2001
1	January	9.18	-
2	February	14.07	-
3	March	21.70	56.0
4	April	30.40	-
5	May	57.48	48.0
6	June	191.62	504.9
7	July	353.62	797.6
8	August	378.65	300.1
9	September	218.57	124.7
10	October	88.93	111.5
11	November	27.48	6.9
12	December	4.45	-
Total		1396.15	1949.7

APPENDIX –VII

Soil testing report of different farmers.

Sl.No	Name of farmers	% sand	% silt	% clay	Texture	WHC (%)	pH	EC (dSm^{-1})	O.C (%)	Av.N (kg/ha)	Av.P_2O_5 (Kg/ha)	Av. K_2O (Kg/ha)
1.	Dasaratha Pradhan	55	14.4	31.6	Clay loam	36.1	5.84	0.040	0.30	214.8	27.9	492
2.	Kishore Ch. Pradhan	74	12.4	13.6	Loam	30.0	5.60	0.033	0.311	175.5	41.4	280
3.	Agasti Mallick	82	10.4	7.6	Loamy sand	30.4	5.02	0.045	0.42	150.0	36.75	505