Planning and Designing of Conservation Measures for Kanore Micro-Watershed Using Remote Sensing and GIS

सुदूर संवेदन और भौगोलिक सुचना प्रणाली का उपयोग कर के कानोड़ सुक्ष्म -जलग्रहण के संरक्षण उपायों की योजना और अभिकल्पना

Gaurav Kumar

Thesis

Master of Technology in Agricultural Engineering

(Soil and Water Conservation Engineering)

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Department of Soil and Water Engineering

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Maharana Pratap University of Agriculture &Technology, Udaipur

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Gaurav Kumar

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COLLEGE OF TECHNOLOGY AND ENGINEERING, UDAIPUR

Date: 11 / 06/2018

CERTIFICATE - I

This is to certify that **Gaurav Kumar** has successfully completed the comprehensive examination held on 19/02/2018 as required under the regulations for Master of Technology in Soil and Water Engineering.

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CERTIFICATE-II

This is to certify that this thesis entitled **''Planning and Designing of Conservation Measures for Kanor Micro-Watershed Using Remote Sensing and GIS''** submitted for the degree of **Master of Technology** in Agricultural Engineering in the subject of **Soil and Water Engineering** embodies bonafide research work carried out by **Mr. Gaurav Kumar** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of the thesis was also approved by the advisory committee on / /2018.

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This is to certify that **Mr. Gaurav Kumar** student of **Master of Technology in Agriculture Engineering** in the subject of **Soil and Water Conservation Engineering**, Department of Soil and Water Engineering has made all corrections/modifications in the thesis entitled **"Planning and Designing of Conservation Measures for Kanore Micro Watershed Using Remote Sensing and GIS"** which were suggested by the external examiner and the advisory committee in the oral examination held on 11/06/2018. The final copies of the thesis duly bound and corrected were submitted on 12/06/2018.

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Place: Udaipur

Date: / 06 / 2018 **(Gaurav Kumar)**

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVATIONS

ASAE	:	American Society of Agriculture Engineering
BSR	:	Basic Schedule of Rates
CTAE	:	College of Technology And Engineering
DEM	:	Digital Elevation Model
DES	:	Directorate of Economics and Statistics
ESRI	:	Environmental System Research Institute
FCC	:	False Colour Composite
Fig.	:	Figure
FL	:	Fine Loam
GIS	:	Geographical Information System
ha	:	Hectare
ha-m	:	Hectare meter
HI	:	Horizontal Interval
IRS	:	Indian Remote Sensing
ISAE	:	Indian Society of Agricultural Engineers
LISS	:	Linear Imaging Self Scanning Sensor
LSCD	:	Loose Stone Check Dam
LSK	:	Loamy Skeleton
M. Tech	:	Master of Technology
MPUAT	:	Maharana Pratap University of Agriculture and Technology
NBSS & LUP	:	National Bureau of Soil Survey and Land Use Planning
PRT	:	Puerto Rico Terrace
SWCE	:	Soil and Water Conservation Engineering
SWT	:	Stone Wall Terrace
TIN	:	Triangulated Irregular Network
VI	:	Vertical Interval
WHS		Water Harvesting structure
M-ha	:	Million Hectare

LIST OF SYMBOLS

Symbol	Description
%	Per cent
A	Area
Avg.	Average
C	Constant of channel maintenance
^0C	Degree Celsius
D_d	Drainage density
e.g.	Example
F	Stream frequency
H	Maximum watershed relief
i.e.	That is
J.	Journal
Km	Kilometer
L_b	Basin length
L_u	Stream length of order u
m	Meter
N_u	Number of stream of order u
R_b	Bifurcation ratio
R_c	Circulatory ratio
R_e	Elongation ratio
R_f	Form factor
R_N	Ruggedness number
S_g	Ground slope
T_c	Time of concentration
Viz.	Namely

CHAPTER-I

INTRODUCTION

1.1 General

Soil and water are most precious gift of the nature. Due to scarcity of water and cultivable land and increase rate of population it has become essential to make optimum use of these available resources. More than 2000 years ago, Plato (427-347 BC) recognized that human actions might degrade natural resources enough to limit productivity. In spite of such an early insight, accelerated erosion and associated downstream effects impoverished many great civilizations. For successful agriculture, proper utilization of these resources is essential which is vital for economic growth and development of rural areas especially while addressing the concern of poverty and backwardness, which is relevant to any country in the world. Due to scarcity of water and cultivable land and increased rate of population it has become essential to make optimum use of available resources. Land and Water Management Engineering broadly implies the application of engineering principles to the solution of land and water management problems.

For the purpose of study of the engineering problems involved in land and water management or soil and water conservation, we may divide the subject into different topics. These are: soil erosion control, moisture conservation, land development, irrigation, groundwater development and wells, agricultural drainage and watershed management. Soil erosion control refers to the protection of soil from erosive action of natural agencies like water and wind. Moisture conservation practices are needed to conserve rainfall for crop production. Watershed management is the study of the relevant characteristics of a watershed aimed at the sustainable distribution of its resources and the process of creating and implementing plans, programs, and projects to sustain and enhance watershed functions that affect the plant, animal, and human communities within the watershed boundary. Features of a watershed that agencies seek to manage include water supply, water quality, drainage, storm water runoff, water rights, and the overall planning and utilization of watersheds. Landowners, land use agencies, storm water management experts, environmental specialists, water use surveyors and communities all play an integral part in watershed management.

Rainfall is the principal phenomenon driving many hydrological extremes such as floods, droughts, landslides, debris and mud-flows; its analysis and modeling are typical problems in applied hydrometeorology. Rainfall exhibits a strong variability in time and space across the globe. Hence, its stochastic modeling is necessary for the prevention of natural disaster. Understanding the rainfall distribution is equally necessary for future planning. The distribution pattern of rainfall rather than the total amount of rainfall within the entire period of time is more important for studying the pattern of rainfall occurrence.

The land is subjected to soil erosion and land degradation problem due to flood, wind and faulty cultivation practices resulting in loss of topsoil and there by all soil nutrients are lost. This leads to poor yields, uneconomic returns, reservoir sedimentation, and reduction in storage capacity and shutdown of hydel power stations, ecological imbalance, environmental pollution, droughts and floods. Hence, the conservation, development and management of the land resources which ensures the physical, chemical and biological health of soil profile are of prime importance.

1.2 Watershed Development and Management

Watershed as an approach to development was first adopted in United States in Tennessee Valley for reducing soil erosion in the valley areas during early 1920s. The term catchment instead of watershed is more familiar to irrigation engineers and geo-hydrologists. Till 1950, the approach was confined to problem specific areas particularly the soil erosion (Kumar, 2000).

The concept of integrated watershed assessment, development is that the development and management of the resources in the watershed should be taken up such as to achieve higher production that can be sustained without causing any deterioration in the resource base or causing no ecological imbalances. Therefore, accurate and reliable data base generation and management is extremely important for devising ways for optimal planning and managements of watersheds.

Watershed Management (WSM) has emerged as a new paradigm for planning, development and management of land, water and biomass resources with a focus on social and institutional aspects apart from bio-physical aspects following a participatory approach. The basic objective of watershed is “holistic development seeking sustainable livelihood security system for all life forms in the area”.

1.3 Remote Sensing and GIS

Remote sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation. Remote sensing is largely concerned with the measurement of electromagnetic energy from the sun which is reflected, scattered or emitted by the objects on the surface of the earth. Different objects on the earth surface reflect different amounts of energy in different wavelengths of the electromagnetic spectrum. Satellite remote sensing provides multispectral, multi-spatial and multi-temporal data useful for resources inventory, monitoring and their management by both visual interpretation and digital (computer) analysis.

Geographical Information System (GIS) integrates geographically referenced spatial and non-spatial data required at different scales and times, and in different formats. GIS provides a digital representation of the watershed characterization used in the hydrologic modeling. During the systematic survey of watershed, factors like physiography soils, vegetation, land use, slope, drainage pattern etc. are considered simultaneously and huge amount of attribute data are required to be collected. One of the major advantages of GIS is its capability to overlay multi-thematic data, which could be used in hydrological models or in integrated watershed management planning. The results thus obtained are much more realistic, comprehensive and less time consuming.

1.4 Digital Delineation of Watershed

For giving practical shape to the systematic, scientific and rational approach of watershed as a unit of planning and development, a proper delineation of a watershed is a pre-requisite. In general, a watershed can be delineated either through conventional manual methods or through modern GIS based digital method. All India Soil and Land Use Survey (AISLUS) have taken the responsibility of delineating watershed at the national level. The task of delineating watershed of size larger than about 20,000 ha has already been completed.

1.5 Land Capability Classification

The land use capability classification is a systematic arrangement of different kinds of land according to their properties that determine the ability of land to produce on virtually permanent basis. It is based on the intensity of hazards and limitation of use. Land is the sole source of sustenance of mankind supporting the plants and animals on it providing the food, fiber and shelter. Land capability is the suitability of land for use without damage. In soil and water conservation planning, land capability classification is very important aspect because all the soil and water conservation measures are recommended on the basis of the land use capability classification.

1.6 Soil and Water Conservation Measures

Adoption of soil and water conservation measures depends upon the site and needs of the ultimate users. The watershed area has got a high level of production potential provided that suitable soil and water conservation measures are adopted and the new packages of practices are followed. Rainwater harvesting is the only source in the Southern Rajasthan to meet the demand and supply gap. Ministry of Agriculture, National Commission on Farmers, Fifth Report, 4 October 2006, assessed that it is impossible to provide irrigation more than 40 per cent of cultural area in India even with utilization of all available water resources in the form of major and medium irrigation projects / schemes. The remaining 60 per cent of land area shall remain dependent on available monsoon rains as a source of water for crops. Recent studies have shown that the crop production can be increased substantially by providing one or two life-saving irrigations during dry spells to crops by harvesting surplus water flowing as runoff during monsoon periods. This necessitates for the development of water harvesting techniques, which could be applied in small watersheds (Kumar, 2000).

1.7 Geomorphology and Drainage Basin

If we defined geomorphology in terms of three Greeks roots from which the word was derived, it would mean “a discourse on earth forms”. Geomorphology has been characterized as the earth shape science. It deals with the study and interpretation of land from and the processes that produce them. A drainage basin is the entire area providing runoff to, and sustaining part or all of the stream flow, of the main stream and its tributaries. Geomorphological analysis is the systematic description of watershed’s geometry and its stream channel system to measure the linear aspects of drainage network, aerial aspects of drainage basin and relief aspects of channel network.

1.8 Justification

Planning, assessment, management and utilization of natural resources, especially land and water at local level, assume prime importance. Owing to the synergistic effect of land and water resources within a watershed, the watershed approach is more rationally being employed in various developmental programs of the country. For giving practical shape to the systematic, scientific and rational approach of watershed as a unit of planning and development, a proper delineation of a watershed is a pre-requisite. A digital watershed delineation procedure provides flexibility of delineating watershed of various sizes by interactive choosing outlets along stream links on either mainstream or its branches. Further, it can lead to a more accurate and less subjective shape and size of a watershed than a conventional (manual) AISLUS approach based on a single drainage input data.

The geomorphological parameters directly or indirectly reflect almost the entire watershed based causative factors affecting runoff and sediment loss. For timely seedbed preparation, selection of crop varieties and choice of cropping pattern, it is necessary to estimate the probable period of onset of monsoon, amount of rainfall and its distribution over the cropping season. Therefore, timely data on land use / land cover is of prime importance. The use of remote sensing and GIS can better organize and integrate scientific data, address spatial and temporal variability, model soil-landscape using quantitative and statistical methods to define relationships, advance knowledge and manage landscape as ecosystem. Use of GIS and computers can reduce the time and money invested while increasing the accuracy of results from the classification and rating process. Using the satellite remote sensing imagery and toposheet of the watershed required information like land classification, contour map, drainage network, soil map, land slope map etc. can be gathered and the appropriate engineering measures can be suggested.

Due to erratic distribution of rainfall, sandy nature of soil, barren hills and non-availability of ground water in sufficient quantity crop yield is low that affect the overall economy of the area. Land capability classification gives the suitability of land for engineering measures. The interventions such as Puerto-rico terrace, stone wall terrace, contour vegetative bund and contour bund on arable land; V-ditches, contour trenches and staggered trenches on non-arable land are most popularly used soil and water conservation measures. Many Government and Non-Government Organizations are constructing these measures, but the selection of measures and its dimension should be the location specific. Therefore, for the selection of soil and water conservation measures, geomorphological characteristics, land capability classification, drainage pattern, contour map, soil map, land slope etc. will be studied and analyzed for the present study. Benefits and cost will be summarized and compared to determine economic feasibility of a micro-watershed. Benefit cost ratios will also be discounted for time producing internal rate of returns. Looking to the need of proper planning and designing of soil and water conservation measures on watershed approach and also it determines cost of measures the present study was undertaken using remote sensing and GIS with following objectives.

Keeping all these aspects in mind, the present study was undertaken with the following objectives.

Objectives

1. To delineation of micro-watershed and analysis of geomorphological characteristics using Remote Sensing and GIS.
2. To analyze the rainfall characteristics of watershed using probability analysis.
3. To plan and design suitable soil and water conservation measures based on rainfall and watershed characteristics.
4. To evaluate the cost effectiveness of different soil and water conservation measures to assess their economic feasibility.

CHAPTER - II

REVIEW OF LITERATURE

Many scientists have attempted to plan and design the watershed through different approaches. To gain some knowledge from the previous work, the review of literature was collected which has been cited under following five sub heads:

1. Digital delineation of watershed
2. Analysis of geomorphological parameters of watershed
3. Probability analysis of rainfall
4. Land use/land cover
5. Soil and water conservation measures

2.1 Digital Delineation of Watershed

Watershed delineation is one of the most commonly performed activities in hydrologic and environmental analysis. Digital Elevation Model (DEM) provides good terrain representation from which the watersheds can be derived automatically using GIS technology. The techniques for automated delineation have been implemented in various GIS system and custom applications.

Baker *et al.* (2006) compared manual delineations with those derived from ten automated delineations of 420 watersheds in four physiographic provinces of the Chesapeake basin. Automated delineation included enhanced methods and Un-enhanced methods. Un-enhanced methods resulted in individual watershed boundaries with some gross discrepancies in watershed size relative to manual delineations (error > 25 per cent difference compared to manual). Analysis of cropland area showed a significant difference between manual estimates and un-enhanced estimates that was corrected using enhanced algorithms. Subsequent analysis of per cent cropland revealed that measurements of land cover proportions were not always affected by delineation errors. They found that enhanced automated watershed delineation within the Chesapeake basin can be an effective augmentation of existing stream burning and reconditioning procedures.

Hollenhorst *et al.* (2007) delineated thousands of Great Lakes watersheds using new watershed delineation techniques. All delineation techniques proved useful, but each had applications for which they were most appropriate. A set of watershed delineations and stressor summaries was developed for sampling site identification, providing relatively coarse strata for selecting sites along the U.S. Great Lakes coastline. Subsequent watershed delineations were used for high-resolution site characterization of specific sites and characterizing the full coastal stressor gradient. For these delineations they used three general approaches: (1) segmentation of the shoreline at point's midway between adjacent streams and delineation of a watershed for each segment; (2) specific watershed delineations for sampled sites; and (3) a Great Lakes basin-wide. They found that third approach was unique in that and provides a nested framework based on hierarchies of catchments with associated stressor data. This hierarchical framework was used to derive additional watershed delineations, and their associated stressor summaries.

Tetzlaff *et al.* (2009) studied that intensive agriculture in lowland river catchments is unthinkable without artificial drainage, but drainage installations also represent an important pathway for diffuse nutrient inputs to surface water. This lead to the development of an approach, how artificially drained lands can be identified by interpreting aerial photographs, and how these findings can be extrapolated by combining land use and soil information in GIS. The approach results in a map of artificially drained areas, which is presented here for the River Ems basin (12,940 km^2), located in north-western Germany. This map provides the basis for distributed modelling of drainage runoff and diffuses phosphorus inputs. From the model results, it was found that about 69 per cent of all *P*-inputs into surface waters are discharged via artificial drainages.

Luo *et al.* (2011) studied that watershed delineation based on digital elevation models (DEMs) was the prerequisite to set up SWAT model. With topography and hydrologic processes different from the mountainous area, the watershed delineation in low-lying plain areas faces three problems: (1) the sub basins and reaches delineated from the DEM do not agree well with the realistic ones (2) the braided streams cannot be identified by SWAT model; (3) routing processes are affected by the water-control projects seriously. In the first method, "Burn-in" and drawing reach and sub basin boundary manually were applied. First, the digital channel network (DCN) was imported using the "Burn-in" function, and the streams and sub- basins were delineated based on DEM and DCN. Then the "watershed" and "reach" layers were edited in Arc GIS, where the location, range, and hydrologic connection could be adjusted. In the second method, streams and sub basins could be drawn manually or re-edited. They found that the watershed delineation results using both methods agreed well with the realistic hydrologic processes in low-lying plain area and could meet the demands of the following model setup.

Bose *et al.* (2012) delineated the Kaddam watershed of Middle Godavari sub basin (G-5) of Godavari river basin into mini watersheds using GIS. Kaddam watershed was divided into two sub watersheds 4E3C4 and 4E3C5 in watershed atlas of India. 4E3C4 sub watershed was further delineated in GIS environment into eleven mini watersheds namely 4E3C4a to 4E3C4k and 4E3C5 sub watershed was delineated into seven mini watersheds namely 4E3C5a to 4E3C5g. The mini watershed 4E3C5a (Kaddam River) was found to be of longest basin length with 44.46 km and 4E3C4g (Batkamma Vagu) mini watershed was found to be with lowest basin length of 8.54 km. It was observed from the above analysis that the mini watershed 4E3C5a (Kaddam River) represented highest perimeter, area and basin length. The total length of all streams for the entire watershed was thus found to be 4691.23 km representing a dense drainage network. It was observed that the study area i.e., Kaddam watershed was well drained and the drainage was in a well-integrated pattern. They demonstrated that GIS is found to be flexible and is relatively easy to apply on large areas enabling gathering of all data and information in a common data base for watershed delineation and stream network analysis.

Mehra (2012) delineated sub-watershed and micro-watersheds in Mahendergarh district of Haryana. Data has been generated from Survey of India toposheet on 1:25,000 scale and multi-spectral satellite data of IRS P6. Watershed boundary has been delineated using ArcGIS 9.3 software. By using Arc-hydro tools, 40 micro-watersheds have been delineated. These can be used more conveniently in assessing ground water resources and execution of development programme at micro-level. After delineating micro-watershed, an attempt has also been made to study the land use pattern of these micro watersheds. Monitoring of micro-watersheds through the knowledge of land use pattern helps in management or in sustainable development of natural resources in that area in scientific manner.

Ilorme and Griffis (2013) used regional flood frequency techniques to estimate flood quantiles when flow data is unavailable for the basin or the record length is insufficient for reliable analyses. Data from nearby gauged sites are pooled to compensate for the lack of at-site data. This required the delineation of hydrologically homogeneous regions in which the flood regime is sufficiently similar to allow the spatial transfer of information. It is generally accepted that hydrologic similarity results from similarity among basins physiographic characteristics and thus these characteristics can be used to delineate regions and classify ungauged sites. However, as currently practiced, the delineation is highly subjective and dependent on the similarity measures and classification techniques employed. The novel approach for region delineation is shown to produce regions which are more homogeneous and more efficient for quantile estimation at ungauged sites than those delineated using alternative physically-based procedures typically employed in practice. In addition, the identified physical attributes can be used to infer the flood regime and estimate quantiles at sites outside the extent of the area used for model development.

Khan *et al.* (2014) considered automated and supervised delineation in the Upper Indus Basin (UIB), Pakistan. Automatic delineation defined a basin area of 440,000 km^2 for the UIB, but included a large area of internal drainage in the western Tibetan Plateau. It showed that discrepancies between different estimates reflect differences in the initial extent of the DEM used for watershed delineation, and the unchecked effect of iterative pit-filling of the DEM. For the UIB they identified critical points where spurious addition of catchment area has arisen, and use Google Earth to examine the geomorphology adjacent to these points, and also examine the basin boundary data provided by the Hydro SHEDS database. They showed some other areas in the western Tibetan plateau are not part of the UIB but are areas of internal drainage. Their best estimate of the area of the Upper Indus Basin is 164,867 km^2 based on the SRTM DEM, and 164,853km^2 using the ASTER DEM. An important lesson from this investigation is that one should not rely on automated delineation, as iterative pit-filling can produce spurious drainage networks and basins, when there are areas of internal drainage nearby.

Freitas *et al.* (2016) studied Triangulated Irregular Networks (TIN) efficiently define terrain models from which drainage networks and watersheds can be extracted with important applications in hydrology. The TIN model is represented by a constrained Delaunay triangulation obtained from contour lines and sampled points. Paths of steepest descent calculated from the TIN are connected by processing the triangles according to an associated priority, then forming a drainage graph structure proposed to generate drainage networks from accumulated flows. Major problems such as flat areas and pits that create inconsistencies in the terrain model and discontinuities in flows are removed with procedures that interpolate the elevation values of particular points on the TIN. Drainage networks are defined by arbitrary threshold values, and their associated watersheds and sub watersheds are then delineated. TIN results are qualitatively and quantitatively compared to an available reference drainage network, and also to regular grid results generated with the TerraHidro system. The drainage networks automatically obtained from the drainage graph highly agree to the main courses of water on the terrain, indicating that the TIN is an attractive alternative terrain model for hydrological purposes, and that the proposed drainage graph can be used for the automatic extraction of drainage networks that are consistent with real-world hydrological patterns.

Bohner and Bechtel (2017) analyzed "GIS in Climatology and Meteorology" introduces basic sources of ground-based and remotely sensed climate and weather observations and provides an overview of principles, methods and techniques for the GIS based analysis, estimations and spatial modeling of continuous climate surfaces from point source data. The chapter covers the main concepts of deterministic and geostatistical interpolation as well as multivariate statistical specialization technique, and highlights the specific requirements, advantages and limitations of different spatialization approaches; these are demonstrated using example data sets. Basic principles of GIS based terrain and surface parameterization techniques are introduced with respect to their application in statistical climate modeling and downscaling of limited resolution climate model data

Savita *et al.* (2018) analyzed the demand and needs of the population towards water is growing the value of water is felt in all sectors. At the same time, surface water resources are becoming insufficient to fulfill the water demand. So that systematic planning of groundwater improvement using modern technique is fundamental for the proper management and utilization of this precious resource. But still groundwater resources have not yet been properly exploited, keeping this in view, the present study has been undertaken to demarcate the groundwater potential zones in Kanakanala Reservoir Sub-watershed, Karnataka by using RS and GIS approach. Thematic maps of geology, geomorphology, soil, slope, Land Use/Land Cover (LULC) and drainage density were used and groundwater potential zones were demarcated by Weighted

Index Overlay Analysis (WIOA) in Arc GIS 10.1 software. During overlay analysis the ranking has been given for each individual parameter of each thematic map and weights were assigned according to the influence towards groundwater. Finally, four groundwater potential zones were delineated viz., very good, good, moderate and poor. From the study it was concluded that, demarcation of groundwater potential zones helpful for effective recognition of suitable locations for its extraction and better planning and management.

2.2 Analysis of Geomorphological Parameters of Watershed

Measurement and quantitative expression of the drainage basin perhaps began with the ideas of James Hutton, whose law of Accordant Tributary Junction was expressed by Play fair in 1802. During the nineteenth century quantitative measures were proposed for specific areas or for the particular problems, but by the early twentieth century methods of stream ordering were being conceived. A great step forward was made by R.E. Horton in 1932 when he crystallized previous work, added new measures and proposed general methods for the description of drainage basin characteristics. Such characteristics according to Horton, included morphologic, soil, geologic or structural and vegetation factors. Horton proposed the way in which examples of each factor could be expressed in a way relevant to the functions of the drainage basin. These parameters have been used in various studies of geomorphology and surface-water hydrology, such as flood characteristics, sediment yield and evolution of basin morphology.

Gowd (2004) analyzed morphometric and relative parameters for the Peddavanka basin, Anantpur district, Andhra Pradesh. He showed that the basin is of 6^{th} order with dendritic drainage pattern, having slope range of 0 to 17º 27’. The basin length decreases as the order of stream increases and it is lowest in case of the highest stream orders. The elongation ratio of Peddavanka basin was 0.45 showing extremely elongated nature. The drainage density revealed that the nature of subsurface strata is permeable. The mean bifurcation ratio lies between 3 and 5 indicating the homogeneous character and geologic structure with mature topography.

Nookaratnam *et al.* (2005) made an attempt for check dam positioning by prioritization of micro-watersheds using SYI model and morphometric analysis using remote sensing and GIS. Morphometric parameters such as bifurcation ratio, drainage density, texture ratio, length of overland flow, stream frequency, compactness coefficient, circulatory ratio, elongation ratio, shape factor and form factor were computed. Automated demarcation of prioritization of micro-watershed was done by using GIS overlaying technique by assigning weight factors to all the identified features in each thematic map and ranks were assigned to the morphometric parameters. Five categories of priority viz. very high, high, medium, low and very low were given to all the watersheds. Sixty-two micro-watersheds using SYI method and twenty-three micro-watershed using morphometric data were prioritized under very high priority. Twenty-four suitable sites were identified for check dam construction in 21 highly prioritized watersheds.

Narendra and Rao (2006) determined the drainage characteristics of the six sub watersheds (M-I, M-II, M-III, M-IV, N-I and NB-I). The ranking of streams was carried out based on the method proposed by Strahler (1964). Out of six sub-watersheds, M-IV was the trunk stream of 6^{th} order and M-III, NB-I were of 5^{th} order, while remaining sub-watersheds: M-I, M-II, N-I were of 4^{th} order. The mean bifurcation ratio values range between 2.93- 4.93 for six sub-watersheds indicates that the geological structures were not disturbing the drainage pattern. The total length of stream segments was maximum in first order streams and decreases as the stream order increases. The drainage density (D_d) of the area varies between 1.77 to 2.70 km/km^2 indicating low drainage density. It was suggested that the low drainage density indicates the watershed is having highly permeable subsoil and thick vegetative cover. The values of stream frequency (F_s) for six sub watersheds exhibits positive correlation with the drainage density values of the area indicating the increase in stream population with respect to increase in drainage density. The form factor (R_f) values range between 0.27 to 0.48 for six sub-watersheds indicate lower values of form factor and thus represent elongated in shape. The elongated basin with low form factor indicates that the watershed will have a flatter peak of flow for longer duration. An elongation ratio and form factor value shows that watershed possesses elongated shape that indicates the low runoff and flatter peak of flow.

Thakkar and Dhiman (2007**)** studied morphometric analysis and prioritization of the eight mini-watersheds of Mohr watershed, in Gujarat, India using Remote Sensing and GIS techniques. The morphometric parameters considered for analysis are stream length, bifurcation ratio, drainage density, stream frequency, texture ratio, form factor, circularity ratio, elongation ratio and compactness ratio. The Mohr watershed has a dendritic drainage pattern. The highest bifurcation ratio among all the mini-watersheds is 9.5 which indicates a strong structural control on the drainage. The form factor values are in range of 0.29 to 0.34 which indicates that the Mohr watershed has moderately high peak flow for shorter duration. The compound parameter values are calculated and prioritization rating of eight mini-watersheds in Mohr watershed is carried out. The mini-watershed with the lowest compound parameter value is given the highest priority. The mini-watershed 5F2B5b2 has a minimum compound parameter value of 3.12 is likely to be subjected to maximum soil erosion hence it should be provided with immediate soil conservation measures.

Rudraiah *et al.* (2008) analyzed morphometric characteristic of the area, which is a part of Kagna river basin in the Gulburga district of Karnataka, India. The morphometric parameters were computed using Arc Info and ArcView GIS software. The drainage pattern of the study area was dendritic to sub-dendritic with stream orders ranging from IV to VII orders. Drainage density ranges from 1.40 to 1.86 km/km^2 suggesting coarse to moderate drainage texture. The change in values of stream length ratio indicates their late youth stage of geomorphic development. The values of bifurcation ratio ranging from 2.00 to 4.71, which indicates that all the sub-basins falls under normal basin category. The values of form factor and circulatory ratio, suggest that the Kurkunta sub basin was elongated and the remaining sub-basins were more or less circular in shape. Elongation ratio indicates that the Wadi sub-basin is a region of very low relief whereas the other sub-basins were associated with moderate to high relief and steep ground slopes. It was concluded that Remote Sensing and GIS have been proved efficient tools in drainage delineation.

Shreedevi *et al.* (2009) studied drainage morphometry and its influence on hydrology of Wailapalli watershed, India. They used Shuttle Radar Topographic Mission (SRTM) data for preparing Digital Elevation Model (DEM), aspect grid and slope maps, Geographical information system(GIS) was used in elevation of linear, areal and relief aspect of morphometric parameters. The lower order streams are mostly dominating the basin. The development of stream segments in the basin area is more or less affected by rainfall. Relief ratio indicates that the discharge capability of these watersheds is very high and the groundwater potential is meager.

Mishra and Nagarajan (2010) analyzed morphometric characteristics of the watersheds of Tel river, in Bhawanipatna area of Kalahandi district, Orissa. The entire study area was further divided into 12 sub watersheds named SWS1 to SWS12, taken up for prioritization based on morphometric analysis using GIS and Remote Sensing techniques. The drainage density of sub watersheds varies between 1.09 to 3.36 km/km^2 and low drainage density values of sub watershed SWS11 indicates that it was highly resistant, impermeable subsoil material with dense vegetative cover and low relief. The elongation ratio varies from 0.6 - 0.8 which indicates high relief and steep ground slope. The high value of circulatory ratio for SWS11 sub watershed (0.8) indicates the late maturity stage of topography. This anomaly is due to diversity of slope, relief and structural conditions prevailing in this sub watershed. The compound parameter values were calculated and the sub watershed with the lowest compound parameter was given the highest priority. The sub watershed SWS1 was a minimum compound parameter value of 4 is likely to be subjected to maximum soil erosion and susceptible to natural hazards. Hence, it should be provided with immediate soil conservation measures.

Rao *et al.* (2010) adopted GIS and image processing techniques for the identification of morphological features and analyzing their properties of the Lower Gostani River Basin (LGRB) area in Andhra Pradesh. The basin morphometric parameters such as linear and areal aspects of the river basin were determined and It was observed that the drainage density value is low which indicates the basin is having highly permeable subsoil and thick vegetative cover. The circulatory ratio value reveals that the basin was strongly elongated and highly permeable homogenous geologic materials.

Javed *et al.* (2011) studied Jaggar watershed which is a constituent of the Gambhir river basin, in eastern Rajasthan and covers an area of 352.82 km^2, representing arid climate. They found that drainage network is dendritic to sub-dendritic pattern however parallel to sub-parallel. The Jaggar watershed has been divided into fourteen sub-watersheds, designated as SW1 to SW14, for prioritization purpose. The prioritization of the sub-watersheds has been done on the basis of morphometric analysis and land use/land cover categories. Based on morphometric and land use/land cover analysis and their ranks, the sub watersheds have been classified into four categories as very high, high, medium and low in terms of priority for conservation and management of natural resources. The prioritization results based on morphometry revealed that only SW7 and SW10 fall under very high priority, whereas SW6, SW11 and SW13 fall under very high priority on the basis of land use/land cover analysis. However, on the integration of morphometry and land use/land cover only SW14 show common priority whereas rest have little or no correlation.

Kanth and Hassan (2012) studied the quantitative analysis of morphometric parameters which is found to be of immense utility in watershed prioritization for soil and water conservation and natural resources management at micro level. The present work is an attempt to carry out a detailed study of linear and shape morphometric parameters in nineteen watersheds of Wular catchment and their prioritization for soil and water resource management. Following Strahler's stream ordering scheme, it has been found that in Wular catchment the total number of streams is 2708 belonging to different stream orders with the highest order of 6. The study has shown that the Wular catchment is in conformity with the Horton's law of stream numbers and stream lengths.

Sinha (2012) made use of GIS for geomorphological analysis and prioritization of Wakal river basin which is a seventh order basin. The total drainage area of Wakal river basin is divided into seven sub-basins for the analysis. The various geomorphological characteristics including area and perimeter, stream number (order wise), stream length, basin length, stream frequency, bifurcation ratio, stream length ratio, form factor, circulatory ratio, elongation ratio, drainage density, constant of channel maintenance, length of overland flow, relief ratio, relative relief and ruggedness number were determined. The prioritization of the basin was carried out on the basis of the geomorphological parameters and based on this the first priority is given to sub-basin-3 for soil and water conservation measures.

Rao *et al.* (2013) studied Mahi River to characterize the morphology of different order streams and to measure the alteration in cross section and bank of different order streams. Field monitoring of stream bank morphological parameters and alterations in cross sections and banks of different order streams was carried out at different sections of 6 categorized streams which are Mahi River, adjoining lower order streams directly draining into Mahi, 1 order streams, 2 order streams, 3 order streams, and 4 order streams. The stream bank morphological conditions such as soil texture, bank angles, bank shapes and alterations in stream banks and channel cross sections of different category streams in different locations were collected and analyzed. They found that concave banks of all the category streams and straight banks of adjoining streams directly draining into Mahi and 1 order streams are the vulnerable locations which need immediate attention for controlling bank erosion or flood havoc.

Nayar and Natarajan (2013) studied the morphometric and surface drainage characteristics of Kosasthalaiyar sub basin with an area of 2835.06 km^2. SRTM data and Arc GIS 10, spatial analyst tools along with arc hydro tools were used for morphometric analysis of the sub basin to derive linear, relief, and aerial aspects. They found that the elongated sub basin is reasonably homogeneous in geology without structural disturbances with low relief and moderate to gentle slope in all the constituent sub-watersheds. The low drainage density is because of the highly permeable subsoil, with good permeability of sub-surface material and dense vegetative cover with low relief. The overland flow is significantly affected by infiltration and percolation through the soil, both varying in time and space. They also found that structural interventions are needed to improve the surface storage and land use modifications for better water management.

Bhuriya and Dev (2014) analyzed quantitative morphometric of the Pat river basin in Meghnagar area located in Jhabua district of Madhya Pradesh, India. The study area is mainly drained by three tributaries of the Pat river such as the Hatyadeli, Jhonsali and Jiwari covering an area of 97.38 km^2. The drainage basin has been divided into six sub-basins A, B, C, D, E and F. They determined the linear, areal and relief parameters indicate a fairly good variation ranges and their significance. The hypsometric analysis of Pat river basin of Meghnagar area revealed that the sub basin E belongs to Young stage and sub basins A and D represent mature stage and sub basin C belongs to monadnock stage of River drainage development. The morphometric analysis indicates the presence of dendritic drainage pattern pointing out favorable conditions in selecting the groundwater potential sites at Gura chhota, Shivgarh, Mahura and Sutreti Villages.

Aher *et al.* (2014) recognized hydrological behavior of the basin for carrying out management strategies. Previous prioritization methods suffer from cavities in which uncertainties were associated with morphometric variables of watershed ecosystem. Keeping this in view, geospatial–statistical techniques were used for identifying critical and priority sub-watersheds in water scarce region of India. A novel

Weighted Sum Analysis (WSA) technique was developed for ranking of each hydrological unit concerning the weightages obtained from morphometric parameters. Considering WSA approach, sub-watersheds were alienated into very high, high, medium, low and poor priority zones. The results illustrate that 51.66% of sub-watersheds are in the moderately to highly susceptible zones, which shows potential areas for preferential conservation works planning.

Singh *et al.* (2014) carried out a detailed study of linear and shape morphometric parameters in Chanavada micro-watershed of Udaipur district of Rajasthan covering an area of 1475 ha. Topographic map of Survey of India on 1:50000 scale were utilized to delineate the drainage system, to identify precisely water divides using Geographic Information System (GIS). It has been found that Chanavada micro-watershed 81 streams are belonging to different stream order with highest order existing 4. The study has shown that the Chanavada micro-watershed is in conformity with the Horton's law of stream number and stream length.

Norini *et al.* (2016) studied that alluvial fans are prominent depositional geomorphic features present in nearly all global climates on Earth, and also found on Mars. In this study, we present a Geographic Information System (GIS) algorithm designed for the semi-automated detection of alluvial fans that are connected to their contributing upstream drainage network, from the analysis of Digital Elevation Models (DEMs). Through a combination of spatial analysis procedures, the GIS algorithm generates maps of alluvial fans and their upstream source drainage and watersheds. Tests of the algorithm in areas with well-known alluvial fans indicate that this new GIS procedure is capable of high-accuracy mapping of the fan apexes and correct delineation of fan deposits, in both arid and humid climates. Possible future applications of the GIS algorithm presented in this study include the systematic survey of alluvial fans at the local, regional and planetary scales, important for geologic hazard assessment, studies on the evolution of climate, analysis of continental sedimentary environments, understanding of the interplay between the endogenous dynamics and exogenous processes, and the evaluation of natural resources.

Ikbal and Ali (2017) studied Remote sensing and GIS is very valuable and time saving techniques for drainage analysis. The purpose of the study is to locate the area susceptible to soil erosion and to mitigate the hazards by improving soil conservation.

Drainage channel and Watershed boundary were demarcated by using topographic map, SRTM DEM of 1 arc resolution and satellite data (Landsat 2008 and Google earth image) under GIS environment. Linear, shape and relief parameter has been computed for each sub-watershed using arc map 10.2 and assigned rank based on the relationship with erodibility so as to arrive at a compound value for the final rankings of each sub-watershed. Value of compound parameter and priority for soil conservation are inversely proportional to each other. On the basis of compound value, the Ahar watershed has been classified into three classes (high, medium and low) in terms of priority for soil conservation and management.

Choudhary *et al.* (2018) studied that morphometric analysis gives a quantitative description of drainage basin. The main aim of the present study is to identify the morphometric parameters of a watershed of Mula River basin, Pune district of state Maharashtra, India, and to prioritize the sub-basin. The work outlines the significance of digital elevation model for assessment of drainage pattern and extraction of relative parameters. Basin has been divided into 5 sub-watersheds namely SW1 to SW5. The stream order of watershed ranges from first to sixth order and have dendritic drainage pattern means homogeneity in texture and lack of structural control. Further, each parameter has been assigned their ranks according to their value. The basin with lowest parameter value is ranked as first. It was considered as high priority for adopting conservation measure as well. The suitable locations for conservation measure structures in highly prioritized sub-watersheds were also identified for the appropriate land and water management plane. The relevance of work shows the appropriate measure structure locations for preventing the soil from getting eroded from the highly prioritized sub-watershed.

2.3 Probability Analysis of Rainfall

The interpretation of hydrological events to forecast the probability of occurrence and frequency of an event is based on methods of statics and probability. Statics deals with the computation of recorded data and probability deals with the measure of chance. The runoff volume from one or more storms is of interest where flood control reservoirs or other structures are to be designed. Most methods of estimating storm volume use rainfall, from which infiltration, interception, surface storage and other losses are subtracted to obtain the runoff.

Bansal (2004) analyzed 25 years' rain fall data of Pantnagar by using Markov-Chain model to predict the sequences of wet and dry days. He concluded that weekly probability of a particular day in the week being wet or dry showed that wheat planted in the first week of December has a 50 to 70 per cent chance of getting rain at crown root initiation and flowering stages and a sure chance of rain at jointing and milk stages.

Shoji and Kitaura (2006) analyzed precipitation data statistically and geo-statistically in order to obtain fundamental information for assessing water resources and predicting natural hazards caused by heavy rains in the mountainous Chubu and plain Kanto districts of central Japan. For the statistical distribution of hourly, daily and annual precipitations, lognormal distributions were fitted well in both districts, but exponential distribution was more suited for monthly precipitations. Spatial variations of annual precipitations showed that the station density is sufficient for assessing water resource. Temporal variations of hourly precipitations showed severe floods attacked in Kanto if it rains heavy in a wide area on a series of rainfall. Ranges of variations increase with increasing accumulation time and became constant as 120–150 km over 3-5 h. This range value is two or three times of the average station distance, and the accumulation time is three to five times of the measuring intervals. They concluded that the station density and the measuring interval are insufficient for predicting natural hazards.

Patle (2008) analyzed the daily rainfall data of 25 years (1974–1998) to ascertain one to four consecutive days' maximum rainfall of Akola (MS). The observed values were estimated by Weibull's plotting position and expected values were estimated by three well known probability distribution functions viz, Gumbel, Lognormal and Log Pearson type -III. The expected values calculated out by three' probability distributions were compared with observed values worked out by Weibull's method and goodness of fit were determined by Chi-square (X^2) test. The frequency analysis indicates that Lognormal distribution gives the closest fit to the observed data to forecast 1-day annual maximum rainfall. Study further revealed that incase of two, three and four consecutive days' annual maximum rainfall for different return periods, Lognormal distribution gave the closest fit to the observed data.

Kothari *et al.* (2009) studied critical dry spell and availability of surplus water required for crop planning. For this they analyzed 45 years' weekly rainfall data of

Bhilwara district in Rajasthan. Conventionally, probabilities of dry spells are computed for different standard meteorological weeks without consideration of the onset of monsoon in each year and information for crop growth period is based on normal week of onset of monsoon. This approach has been compared with a rational approach called "Onset of monsoon approach" wherein the weekly rainfall data are arranged by considering onset of monsoon as datum in each year. Considerable difference has been observed in the initial and conditional probability of intervening dry spells due to these two approaches but the new approach has been found more rational as compared to conventional approach. Therefore, it has been adopted for analysis of dry spells and availability of surplus water at tehsil level in the district for rainwater management practices, crop planning at micro (Tehsil) level and efficient utilization of rainfall.

Dhanya and Kumar (2010) studied the significance of treating rainfall as a chaotic system instead of a stochastic system for a better understanding. An attempt was made to identify chaos using various techniques. Daily rainfall data of three regions with contrasting characteristics were used for the study. A comparison of results of the three regions indicates that although they are chaotic in nature, the spatial averaging over a large area can increase the dimension and improve the predictability, thus destroying the chaotic nature.

Praveen *et al.* (2011) studied probability analysis of rainfall characteristics of Semiliguda in Koraput, Orissa to estimate the probable period of onset of monsoon, amount of rainfall and its distribution over the cropping season because it is important for timely seedbed preparation, selection of crop varieties and choice of cropping pattern. They found that the onset of monsoon is on 11th June and the occurrence of 75 per cent probable rainfall in Kharif, summer and Rabi season are 1095.5 mm, 91.4 mm and 83 mm respectively, whereas 1274.5 mm is the annual rainfall. It was forecasted that the occurrence of rainy days (>2.5 mm rainfall per day) is 70 days per annum.

Subudhi *et al.* (2012) analyzed 42 years' rainfall data for probability analysis of annual, seasonal and monthly rainfall data for crop planning in Kandhamal district of Orissa. They observed that rainfall during June to September is more than 100 mm and cropping pattern like paddy (110 days), mustard is suitable to the region. The analysis shows that less than 12.5 mm may be looked into at 75 per cent probability level and different steps may be taken to irrigate during that period from pond or irrigation canal.

The availability of rain water for crop is assured at 75 per cent probability levels. Excess runoff should be collected in some storage structures so as to use it for irrigating post-monsoon crops.

Sharma and Dubey (2013) analyzed the rainfall under changing climatic scenario for better planning of farming practices in semi-arid region of Uttar Pradesh. They found that there was a decreasing trend of rainfall as well as rainy days during last decade (2000-2010). Occurrence of frequent long dry spell of 10-15 was recorded during the period, indicated the need of construction of water harvesting structures for life saving irrigation for the survival of crops. Probability analysis showed that occurrence of probable rainfall was of 440.0 mm, 26.5 mm, 11.9 mm and 508.0 mm respectively for the kharif, rabi, summer season and annual at 76 per cent confidence level, the occurrence of rainy days was found to be 30, 21, 2 and 1 days for the annual, kharif, rabi and summer season, respectively. Probability analysis of rainfall revealed that selection of less water demanding crops such as green gram, pearl millet, and guar in kharif season. For rabi crops, early sowing or pre-sowing irrigation through water harvesting in ponds and recycling is very good strategy for proper germination of rabi crops like mustard, lentil and barley.

Van and Truong (2015) supported tool for statistical modeling of extreme rainfall processes (SMExRain) was therefore developed to identify the most suitable distribution that could provide accurate extreme rainfall estimates. The proposed tool can be used to assess the descriptive and predictive abilities of ten commonly-used probability models, Beta-K, Beta-P, Generalized Extreme Value (GEV), Generalized Logistic (GLO), Generalized Normal (GNO), Generalized Pareto (GPA), Gumbel, Log-Pearson Type III (LP3), Pearson Type III (P3), and Wakeby, for their accuracy and robustness in the estimation of annual maximum precipitations. The proposed decision support tool was tested using 5-minute, 1-hour, and 24-hour annual maximum precipitation data from a network of 21 rain-gauges located in the Ontario region in Canada. Results based on various numerical and graphical goodness-of-fit criteria have indicated that the GEV, GNO, and P3 models were the best models for describing the distribution of annual maximum precipitations in this region. The GEV distribution, however, was preferred to the GNO and P3 because it requires a simpler parameter estimation method and it was based on a more solid theoretical basis for representing the distribution of extreme random variables. Therefore, the GEV could be recommended as the most suitable model for describing the distribution of annual maximum precipitations in Ontario region based on the proposed decision support tool.

Asim *et al.* (2016) included rainfall probability analysis of previous 114 years rainfall data (1901-2014) with a major object to forecast the yearly rainfall of India. The observed values were computed by Weibulls formula. The annual rainfall values were estimated by two prediction models using Gumbel and Log Normal distributions. The rainfall data in the Log Normal and Gumbel distribution and their equivalent rainfall events were estimated by Root Mean Square Deviation (RMSD) or Root Mean Square Error (RMSE) for goodness of fit. It clearly indicates that the Gumbel distribution was found to be the best model for forecasting yearly rainfall (mm). Whereas Log Normal distribution is fairly close to the observed annual rainfall of previous 114 years (mm).

Dabaral *et al.* (2016) studied rainfall data recorded at Doimukh station for a period of 26 years (1988-2013) were used in this analysis. The 5 days total antecedent rainfall prior to the storm was calculated under three different season, i.e. pre-monsoon (November to February). The 5 days antecedent rainfall was classified into AMC-I, AMC-II and AMC-III groups for all seasons. Four probability distributions were fitted to 5 days antecedent rainfall data for different groups and 5 days antecedent rainfall at 1 to 100 years return period were calculated for the study site.

Sahu (2017) analyzed “Study on pattern of rainfall in rainshadow districts of Chhattisgarh state” was carried out to study the impact of rainfall on production of major crops at two rainshadow districts of Chhattisgarh state viz. Rajnandgaon and Kawardha. For this study, long term rainfall data (1962-2015) and crop data (2000-2014) were used. The rainfall data were collected from department of Agrometerology and crop data from DES (Directorate of Economics and Statistics). Rainfall variability and trend analysis were computed through Weather Cock and Mann Kandell software which are developed by CRIDA (Central Research Institute for Dryland Agriculture). It can be concluded from the analysis that the main rainy months in all the stations were during June to September. In other months, the rainfall was very less and corresponding CV was more than 100 % in all the stations.

Meshram and Singh (2018) analyzed exact estimation of runoff is very important task in physiographic unit and watershed management. For the design of surface runoff storage system, probabilistic estimation of 1-day maximum runoff is essential for safe and cost effective planning. In this study, 1-day and consecutive 2 and 3 days' maximum runoff from Bamhani Watershed, Madhya Pradesh (India) were computed. Daily runoff was estimated using SCS-CN model for a 200 year return period. Moreover, 1, 2, and 3-day maximum runoff was fitted with 3 probability distributions (i.e. log normal, log Pearson type III and Gumbel). The goodness of fit test (chi square) revealed that the log-Pearson type III distribution is the best fit distribution for the 1, 2 and 3 day maximum runoff from Bamhani watershed.

2.4 Land Use / Land Cover

Land use/land cover mapping studies using Remote Sensing have been attempted by NRSA by visual and digital interpretation with multi spectral data analysis system for smaller areas on an operational basis in India. Some relevant works reviewed are presented below:

Sharma *et al.* (2004) studied soil microbial C, N and P as affected by land-use change in a Himalayan watershed at Sikkim, India. The major land-uses considered were forests (dense and open), agroforestry types, open cropped and wasteland areas covering subtropical and temperate zones. Across the land-use, microbial C ranged from 219 to 864 mg/g, microbial N from 30 to 142 mg/g, and microbial P from 12 to 43 mg/g soils. The microbial C, N and P were positively related to each other. The microbial C:N ratio in these soils ranged from 6 to 11 and the microbial C:P ratio from 18 to 27. The conversion of forests into other land-uses resulted in a remarkable decline in the amounts of soil nutrients and microbial C, N and P. The microbial nutrients in the Himalayan region were very sensitive to land-use/ cover changes. Therefore, the conversion of forest to agricultural land should be reversed. Agroforestry systems should be included in agricultural land in mountainous regions.

Wakeel *et al.* (2005) studied the spatial and temporal pattern of land use/cover change in a micro watershed in Central Himalaya, India, during 1967–1997 period based on interpretation of satellite data and using a Geographic Information System (GIS). During the last 30 years the forest cover was altered drastically with increasing population pressure, agricultural activities and raw material extraction activities. Agricultural expansion at the cost of loss of forest cover was the most prominent change in the forests managed by the people. They found that Government Forest Department was able to resist losses of areas under their control to agricultural expansion, change of vegetal cover indicates the areas with broad leaved trees which were exploited by local inhabitants for their subsistence needs.

Wolter *et al.* (2006) studied the pace of Land Use/Land Cover (LULC) change in the Great Lakes, particularly in urban and suburban areas to understand the near-shore ecology. The work goal was to develop and refine environmental state indicators for the U.S. near-shore zone of the Great Lakes. Between 1992 and 2001 of the U.S. portion of the Great Lakes watershed experienced a 7.5 per cent (140,240 ha) increase in road area. Agricultural and forest land each experienced 2.3 per cent decrease in area. Over 38 per cent of wetland losses to development between 1992 and 2001 occurred within 10 km of a coastal area. They found that these land use change data will be useful as quantifiable indicators of landscape change over time and aid in future land use planning decisions for protection of the integrity of the Great Lakes ecosystem.

Munroe and Muller (2007) worked on issues in spatially explicit statistical land-use/cover change (LUCC) models in Western Honduras and the Central Highlands of Vietnam. They found that land users make decisions about their environment that are governed and influenced by political and institutional constraints at local, regional, national and international levels. However, due to the complex nature of coupled human–environment systems, LUCC statistical modeling presents conceptual as well as technical challenges. Careful consideration of these challenges, as well as implementing approaches to deal with them, is necessary in order for such models to inform policy and practice.

Li *et al.* (2008) selected 42 sampling sites in the riverine network of the upper Han River basin of China. Over the time period of 2005–2006, 252 water samples were collected and analyzed for physico-chemical variables in order to investigate their spatio-temporal variability in particular the relationship with land use and land cover. Analysis of variance (ANOVA) indicated significant spatial variability in pH, EC, TDS, turbidity, SPM, ORP and nitrogen across the basin. Meanwhile, nitrogen, ORP, IMn and turbidity generally displayed higher values in the rainy season. Correlation and regression analysis indicated that water temperature, IMn, and nitrogen were significantly related to vegetated coverage, and sub watersheds with higher vegetation cover had relative lower turbidity, SPM, IMn, nutrients and TDS. Bare lands had significant influence on nitrogen concentration in the riverine network, implying its large geologic sources in the basin. The research could provide critical information in sustainable land use practice for water resource conservation for the basin.

Alemayehu *et al.* (2009) studied the upper Agula watershed, known for poverty and resource degradation caused by natural and man-made calamities in semi-arid Eastern Tigray (Ethiopia), to address the issues of poverty and land resource degradation. The purpose of this study was to determine the land use and cover dynamics that it has induced. The change in land use and cover was assessed by integrating Remote Sensing and Geographic Information Systems (GIS). Two sets of aerial photographs were used to produce the land use/land cover map and assess land use change. The results revealed that a significant portion of the watershed was continuously under intensively cultivated (rain fed) land. The area under irrigation increased from 7 ha to 222.4 ha, dense forest increased from 32.4 ha to 98 ha. The study further showed that decreased soil erosion, increased soil moisture, reduced sedimentation and run off, stabilization of gullies and river banks, rehabilitation of degraded lands and increased recharge in the subsurface water. This study reconfirmed the importance of integrated watershed management as a key to improve the land cover of watersheds, as a contribution to poverty alleviation and sustainable livelihood.

Sreenivasulu and Bhaskar (2010) suggested that land use and land cover exerts considerable influence on the various hydrologic phenomenons such as interception, infiltration, evaporation and surface flow. Present study deals with the preparation of landuse / landcover maps of Devak catchment for the years 1958,79,90 and 98 by using Image Processing and Visual Interpretation Technique from the analysis of the IRS-1A L2B2 (FCC) data for the year 1990, IRS-1C LISS-III (digital data) for the year 1998 and SOI topographic maps for the year 1958 &1979. Results revealed a large change in the area of different land use categories during the period from 1958 to 1998. The open scrub and scattered tress covering an area of about 46.17 per cent in 1958 reduced to 9.90 per cent in 1998. While the area under mixed forest increased from 36.68 per cent in 1958 to 65.84 per cent in 1998. The agriculture with sparse habitation also increased from 7.09 per cent in 1958 to 13.92 per cent in 1998. The main river drainage covering an area of about 10 per cent of the total catchment.

Bahadur (2011) analyzed the changes in spatial patterns of agricultural land use during the period 1976–2000 along the altitudinal gradients in a watershed in Nepal. Land change patterns during this period were examined using information on land use derived from satellite images from 1976, 1990 and 2000. During the 24-year period from 1976 to 2000 agricultural land use increased by 35 per cent at a cost of loss of forestland. He found that overall land change patterns in the region are largely explained by elevation and the socioeconomic conditions of people living adjacent to the forestland, more specifically in sub-regional areas, trajectories reflect the signatures of institutions governing access to land. As sustainability of the watershed is dependent on forests, continued depletion of forest resources will result in poor economic returns from agriculture for local people together with loss of ecosystem services.

Panhalkar (2011) selected Dudhganga basin of southern Maharashtra for study which is facing severe land degradation problems. An attempt has been made to apply Remote Sensing and GIS for integrated watershed development of the study region. The parameters like slope, soil depth, texture and land use/ land cover are assessed by applying remote sensing and GIS techniques for the land capability classification of Dudhganga basin. Slope analysis has been carried out by using SRTM data. To assess Land use/ land cover conditions, Lands at ETM image of 2006 year is assessed by supervised classification techniques. Finally, Intersect Overlay Technique of GIS is used to integrate spatial information and to create Land capability classification of the Dudhganga basin. The analysis reveals that Class II, III, IV and VI are present in the study region. Out of that Class II which is much suitable for agriculture accounts 16.30 per cent. Class IV is a dominating class as far the areal extent is concerned with 34.05 per cent. The Class VI is most susceptible to land degradation which accounts for 28.61 per cent.

Singh (2012) suggested that land is a non-renewable natural resource, so it must be used judiciously. It is necessary to prepare suitable suggested land-use maps on a scientific basis to prevent the deterioration of the land and the environment. The optimum land-use planning of a region should suggest alternate land uses, primarily based on land characteristics like physiography, soil, surface and subsurface water resources, natural vegetation, existing land use and socio-economic conditions, without disturbing the ecological balance of the region.

Wang *et al.* (2012) worked on Spatio-temporal pattern analysis of land use/cover change trajectories in Xihe watershed. Human-induced land use/cover change has been considered to be one of the most important parts of global environmental changes. The main objective of this study is to quantify the spatio-temporal variability of land use/cover change, spatial patterns and make preliminary estimation of the role of human activity in the environmental change in Xihe watershed, Gansu Province, China. To achieve this objective multi-source and multi-temporal Remote Sensing (RS) images including Landsat ETM (30 June 2001), SPOT imagery (21 November 2003 and 5 May 2008) and CBERS02 CCD (5 June 2006)) were used due to the constraints of the availability of remotely sensed data.

Mandal *et al.* (2013) investigated the important soil quality indicators under different land use systems namely, sal forest, agroforestry, rainfed cropland and irrigated cropland to provide base line data for future research in lower north-western Himalayan region. The soil properties such as soil depth, texture, organic carbon, total N, available P, available K, CEC and soil pH were investigated for each land use system to assess relative soil quality index (RSQI). They studied that there are significant differences in soil quality parameters under different land use systems. They further studied that soil quality index (SQI) values varied from 337 in sal forest to 257 in rainfed cropland in Dungakhet village indicating the superiority of forest land use system in terms of maintaining greater SQI than other land-use systems. Similar trend was also observed in the other site of the study area. Analysis of data on RSQI revealed that the soil quality index for rainfed cropland was 23.74 per cent lower in Dungakhet and 19.88 per cent lower in Pasauli than the reference sal forest. In general, intensive tillage practices have degraded most of the important soil quality indicators. Therefore, reducing the intensive tillage practices and use of integrated inorganic and organic fertilizers could replenish the degraded soil quality for sustainable agricultural production in the study area.

Wang *et al.* (2013) selected two similar small watersheds in the western Loess Plateau of China to monitor land use/cover changes utilizing SPOT5 imageries. They developed the method of spatio-temporal analysis of land use/cover change by using pattern metrics of change trajectories and relative land use suitability index (R) in smaller watersheds, and make comparisons between the two similar small watersheds, taking water and soil conservation measures into consideration. They found that RS and GIS could be perfectly applied to make comparisons between different small watersheds with similar geographical backgrounds. Land use/cover spatiotemporal dynamic change characteristics can be preferably expressed by pattern metrics of change trajectories and R values based on topographical data. R value of both watersheds showed that there is still much to do for people in the two watersheds in consideration that all the R values are still lower than 0.7.

Jothiprakash *et al.* (2015) analyses of LULC change revealed that the change between 1966 and 2001 was slower than that between 2001 and 2009. The LULC analysis revealed a 74.84% increase in the built-up area with a 42.8% decrease in open spaces between the years 1966 and 2009, with substantial increase in urbanization. The impact of LULC on flood hydrograph for different return periods was ascertained by using the HEC-GeoHMS and HEC-HMS models. In the past 43 years, the increase in peak runoff and runoff volume is marginally varied by 3.0% and 4.45% for the 100-year return period and 10.4% and 12.2% for the 2-year return period respectively, although the built-up area increased by 74.84%. The flood inundation area is increased by 5.61% for the 100-year return period and 6.04% for the 10-year return period between the same time period. Further, a flood hazard analysis has been carried out and it showed that the area in highly hazardous zone is increased by 64.29% as compared to less hazardous zone where it is decreased by 32.14%. Overall, the total flood hazard area is increased by 22.27%. The developed flood plain and flood hazard maps can be used by the local Municipal body to prepare flood mitigation and early evacuation management plans during floods and as a criterion for insurance of any property by insurance organization.

Gong *et al.* (2017) studied evapotranspiration (ET/ is an important process in the hydrological cycle, and vegetation change is a primary factor that affects ET. In this study, we analyzed the annual and inter-annual characteristics of ET using continuous observation data from eddy covariance (EC) measurement over 4 years (1 July 2011 to 30 June 2015) in a semiarid shrub land of Mu Us Sandy Land, China. The Normalized Difference Vegetation Index (NDVI) was demonstrated as the predominant factor that influences the seasonal variations in ET. Additionally, during the land degradation and vegetation rehabilitation processes, ET and normalized ET both increased due to the integrated effects of the changes in vegetation type, topography, and soil surface characteristics. This study could improve our understanding of the effects of land use/cover change on ET in the fragile ecosystem of semiarid regions and provide a scientific reference for the sustainable management of regional land and water resources.

Mwalusepo *et al.* (2017) investigated Land use and land cover changes will continue to affect resilient human communities and ecosystems as a result of climate change. However, an assessment of land use and land cover changes over time in Indian Ocean Islands is less documented. The land use/cover data changes over 10 years at smaller geographical scale across Unguja Island in Zanzibar were analyzed. Downscaling of the data was obtained from SERVIR through partnership with Kenya-based Regional Centre for Mapping of Resources for Development (RCMRD) database and clipped down in ArcMap (Version 10.1) to Unguja Island. SERVIR and RCMRD Land Cover Dataset are mainly 30 m multispectral images include Landsat TM and ETM+Multispectral Images. Landscape ecology Statistics tool (LecoS) was used to analysis the land use and land cover changes. The data provide information on the status of the land use and land cover changes along the Unguja Island in Zanzibar. The data is of great significance to the future research on global change.

Borker *et al.* (2018) studied land use/land cover (LULC) information is essential for the selection, planning and implementation of management strategies to meet the increasing demands for basic human needs and welfare of the ever growing population. This paper illustrates the status of land use/land cover in the Rahat micro-watershed of Nagpur district of Maharashtra was carried out during the year 2010-11 using an integrated approach of remote sensing and Geographic Information System (GIS). Mapping land use/cover in IRS-P6 LISSIV data and SOI toposheet (1:50,000 scale) were used for Land Use/Land Cover Mapping of soils. The inventory data of land resources were evaluated using GIS and thematic maps were prepared. The land use/land cover classes identified are single crop, double crop, wasteland, forest and habitation. The study indicates that 80.90 per cent area of the watershed is under cultivation. The habitation exhibits light blue with coarse texture on the satellite data and covers an area of 1.86 ha representing 0.51 per cent of total area of watershed. The double crop land occupies an area of 125.77 ha representing about 34.6 per cent of the total geographic area (TGA) of the watershed. The single crop land occupies an area of 168.02ha representing about 46.3 per cent of the total geographic area (TGA) of the watershed.

2.5 Soil and Water Conservation Measures

The Planning Commission estimated that out of total land area of 328 M-ha of country, 174 M-ha is affected by erosion. Increasing importance was given to soil conservation works in the country's planning. Both mechanical and agronomical measures play a very vital role in erosion control on agricultural, forest and grass lands. Some relevant works reviewed are presented below:

Saxena (2005) standardized the suitable interventions adaptable for arable and non-arable land in a small watershed with the use of remote sensing and geographical information system. The database for GIS including soil map, slope map, soil depth map, HSG map, land use map and curve number map were prepared for identifying the appropriate soil and water conservation measures. For the arable land, PRT, contour vegetative bund and contour bund and for the non-arable land, V-ditch, contour trenches and staggered trenches were identified as major interventions. By analyzing the runoff and sediment yield for arable and non-arable land, standard dimensions of SWC measures were also recommended.

Singh (2005) conducted the activities and the measures for soil and water conservation relevant to the Kadmal watershed. On the basis of site condition feasible measures were proposed for the watershed. Contour bunds Puerto-rico terraces and stone wall terraces were proposed for arable lands and contour trenches staggered trenches and V ditches were proposed for non-arable land for the purpose of soil and water conservation. Loose stone check dams and gabbian structure were proposed for drainage line treatment.

Kumar (2006) studied under research of planning and designing of Kalora-II micro-watershed using remote sensing and GIS. The appropriate agricultural and engineering measures adaptable in the watershed were designed on the basis of rainfall analysis, land use capability classification and topography of the area. The class VI and VII land were proposed to be treated with afforestation and silvi-pastural system. The economic analysis of Kalora-II watershed shows that benefit-cost ratio under economic and financial evaluation is 1.3:1 and 1.6:1 respectively indicating that project is viable economically and financially.

Sadgir *et al*. (2006) analyzed that Continuous Contour Trench helps to increase the water levels in the surrounding areas / dug wells and tube wells which increases the yield of farms due to change in crop pattern from food grains to cash crops. This will also avoid loss of soil due to erosion, increase the grass coverage which will helpful for soil stabilization. Due to Continuous Contour Trench tree development is better than any other type of trenching. In draught prone area, there are two critical factors water and soil. So in such areas main objective is to conserve the soil and conserve water. Once soil and water conserved, vegetative growth sustain easily. To satisfy this objective economically and efficiently, refilled continuous contour trenching (RCCT) technology is the solution for sustainable watershed development.

Amsalua and Graaff (2007) studied land degradation resulting from soil erosion and nutrient depletion is a serious environmental and socio-economic problem in the Ethiopian highland watershed. Soil and water conservation technique such as stone terraces (ST) have extensively been introduced over the past decades to analyze the data. The results show that the factors influencing adoption and continued use of the stone terraces are different. Adoption is influenced by farmer's age, farm size, perceptions on technology profitability, slope, livestock size and soil fertility, while the decision to continue using the practice is influenced by actual technology profitability, slope, soil fertility, family size, farm size and participation in off-farm work. Perceptions of erosion problem, land tenure security and extension contacts showed no significant influence. They concluded that conservation interventions should focus not only on the biophysical performance of the measures but also on economic benefits that can be obtained at reasonable discount rates to the farmers in order to enhance sustained use of the measures.

Zhou *et al.* (2009) studied the effectiveness and economic benefits of selected conservation practices in sediment reduction by water erosion in major soil areas of Iowa. Three tillage systems [no-tillage (NT), strip-tillage (ST), and chisel plow tillage (CP)] and three conservation structures [grassed waterways (GS), grass filter strips (FS), and terrace systems (TS)] were investigated under a corn–soybean rotation using the Water Erosion Prediction Project (WEPP) model. Corn yields of some areas were statistically lower under NT than under CP while soybeans showed little response to tillage operations. Estimated annual sediment yield with the chisel plow system ranged between 0.7 and 56.9 T/ha. The WEPP simulations showed that NT and ST systems were very effective in reducing soil erosion and sediment yield by approximately 90 per cent in highly erodible lands compared to the CP system. The combination of conservation tillage with soil erosion control structures further mitigated soil loss and was more effective in areas with high water erosion potential than in the flat areas. They found that NT and conservation structures have greater environmental and economic benefits in areas with high water erosion potential. The use of no-till in flat areas such as central Iowa may not be economically favorable because of the limited benefit in reducing soil water erosion. They suggested that structural conservation practices coupled with tillage systems effectiveness were area-specific based on the soil and landscape in each area.

Pande *et al.* (2011) studied for the adoption of soil and water conservation in the ravines of Gujarat in the context of holistic development of small and marginal farms and their profitability. It is hypothesized that poor economic condition of farmers impedes their ability to make large-scale investment in conservation agriculture. The results have augmented that input and output prices prevailing in the region do not favor the farming enterprise. Thus it would have little impact on farm profitability and the incentive to adopt conservation on farm.

Panwar *et. al.* (2012) studied the impact of conservation measures on the hydrological behavior and community structure of small watersheds in the Shivaliks. Two watersheds (WM1 and WM2) of similar characteristics were delineated in 1959 and were calibrated for 10 years. In 1968, soil and water conservation measures along with sowing and planting of vegetation was carried out in WM2 and WM1 was kept as control. The amount of runoff generated showed a sharp increase in WM1 with increase in amount of rainfall. However, due to adoption of conservation measures, the treated watershed (WM2) maintained runoff at lower level throughout the range of rainfall as compared to the control watershed (WM1). An exponential relationship between soil loss and rainfall was observed in both treated and control watersheds. The amount of soil loss (t/ha) increased with increase in amount of rainfall. Soil loss from the treated watershed was always lower throughout the range of rainfall as compared to the control watershed due to adoption of conservation measures. Vegetation was observed to be a major controlling factor for reducing run off and soil loss from the watershed.

Ramos *et al.* (2015) facilitated the use of machinery, but has meant that most of the soil and water conservation measures, which were assets in the original plantations, have had to be eliminated. Soil and nutrient losses were simulated in scenarios with and without soil conservation measures, using SWAT, for years with different rainfall amounts and characteristics. The model was calibrated and validated using data collected in the basin during the period May 2010–December 2012. The annual rainfall during the study period ranged from 329.8 to 785 mm, with runoff rates of between 4.1 and 21% of total precipitation. In the scenario without conservation measures, annual soil losses ranged from less than 1 Mg per ha, in the driest year, to 13.9 Mg per ha, in the wettest. Average annual nutrient losses were around 2.7 kg nitrate per ha, 17 kg organic nitrogen per ha, 0.5 kg soluble phosphorus per ha and 5.5 kg organic phosphorus per ha. These results highlight the fact that soil and nutrient losses from vineyards contribute to non-point source pollution and also to economic losses for grape producers.

Saranga *et al.* (2017) studied conservation of soil in the UMC should be given the highest priority to reduce sediment yields in streams and to maintain the storage capacities of hydropower reservoirs. The sediment yields measured in the sub-catchments of the UMC before 1995 have revealed that soil erosion is intense in the contributing catchments and siltation in some reservoirs is at an alarming level. The situation in the Upper Uma Oya, a s ub-catchment of the UMC, is the worst, reporting the highest sediment yield measured for any catchment in Sri Lanka. Mahaweli Authority of Sri Lanka had embarked on two soil and water conservation projects in the Upper Uma Oya catchment from 1995 to 2005 together with monitoring of sediment yields in the stream. Sediment yield measurements in this catchment revealed that the wash load in the stream had been reduced by a factor of five after the implementation of conservation programs in 1995. Our temporal analyses showed that the role of the other key factors that control soil erosion on a hillslope such as erodibility, slope, erosivity and land use cover is minimal to generate a five-fold reduction in the wash load of the stream. Hence, we report that the conservation measures adopted in the critical areas of the Upper Uma Oya have been very successful and had greatly contributed to the reduction of soil erosion.

CHAPTER - III

MATERIAL AND METHODS

This chapter encompasses the methodology adopted in achieving the set of objectives in light of the basic ground data, the location of the study area and its characteristics features and other relevant component of the study.

3.1 Watershed Characteristics

3.1.1 Location

Kanor is a Village in Bhinder block in Udaipur District of Rajasthan State, India. It belongs to Udaipur Division and located 77 KM towards east from District headquarters Udaipur, 12 KM from Bhinder, and 367 KM from State capital Jaipur. The project area lies between 74°10' to 74°16' E longitude and 24°23' to 24°30' N latitude. The study area falls under agro climatic zone-IV A of Rajasthan i.e. "Sub humid Southern Plains of the Aravalli hills". The total watershed area is about 5388 ha.

3.1.2 Climate

The watershed is characterized by sub humid climate with rainfall received mostly during monsoon months of July to September. The temperature of the area in the range between 32 to 44ºC during summer while the temperature is ranges between 8 ºC to 30.90 ºC during winter season. Distribution of the rainfall in monsoon season is uneven and erratic marked by prolong rainless days.

3.1.3 Physiography

The Kanore watershed comprises of undulating uplands fields and hills. The general slope of the area is north-east to south-west direction.

3.1.4 Geology

Udaipur district is part of the peninsular region of India and thus possesses peninsular characteristics. Logically, it consists of rock groups of Archean system. The main rock formations of the area under study are phyllites, schist and quartzite.

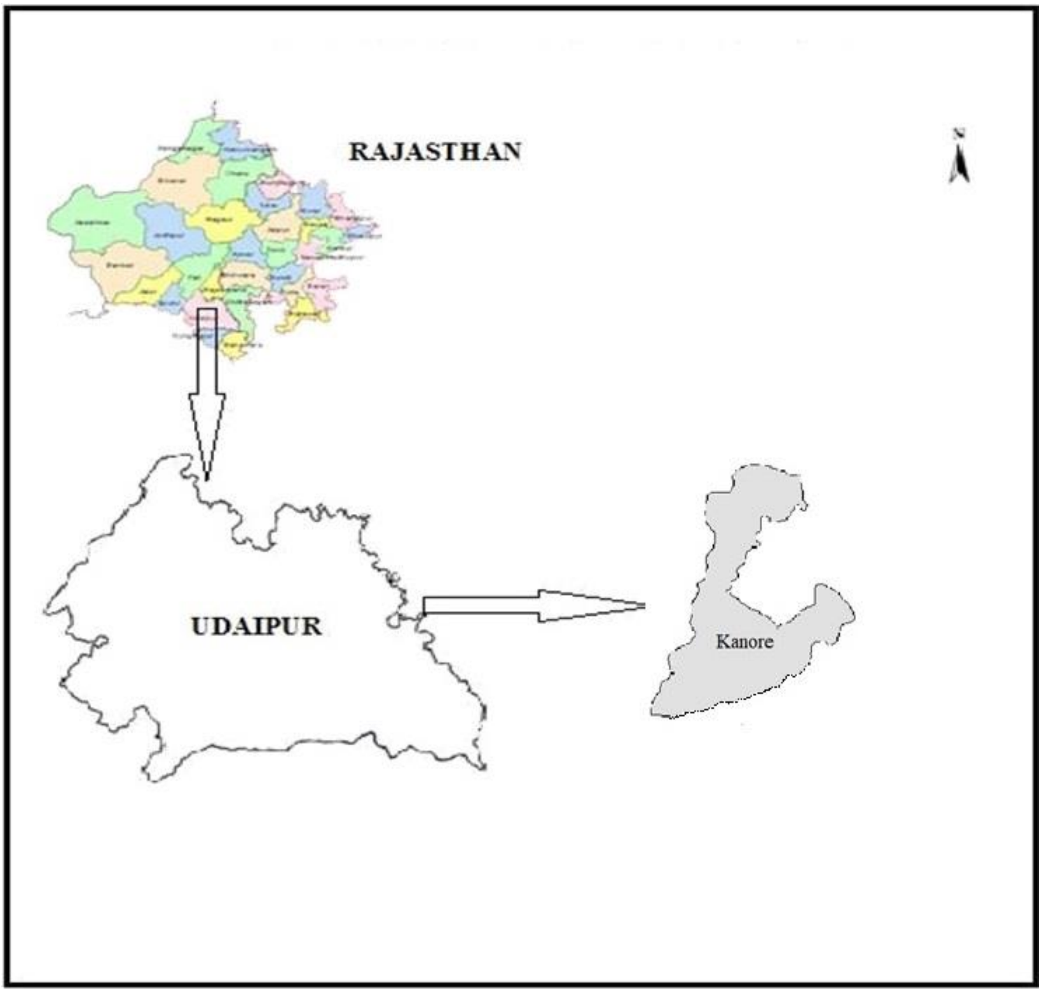

Fig. 3.1 Location map of study area

3.1.5 Cropping pattern

Maize, Urd, Moong, etc. are the commonly grown crops in Kharif season whereas, Wheat, Mustard, Gram, Linseed etc. are grown in Rabi season.

3.1.6 Present land use

Total area of watershed is 5388 ha, out of which 1269 ha land is under cultivation, 1444 ha land is private waste land, 2675 ha is govt. waste land, the total irrigated area of the watershed is about 785 ha and major source of irrigation is through well and talai. Kharif crop are mainly depend on the monsoon. The non-arable land is totally degraded and forest cover is poor in the watershed

3.1.7 Problems and need of the area

Problems and needs of agricultural land is specially related to soil and water conservation and dry farming practices, great degree of variations in the slope, poor depth of soils, profile characteristics infiltration rates, water holding capacity of controlled section of soil, rainfall distribution, intensity of rainfall, traditional practices, small and scattered holding and lack of financial resources.

Problems

- Erosion Problem – Due to heavy and high intensity of rainfall in monsoon season, variations in slope gradients and scarce vegetative cover, the problem of soil erosion by water is severe to acute in the watershed area.
- Crop Management Problem – Small and scattered land holding situated on varying slope gradients is one of the main hurdles for the better management practices and use of improved implements and other agricultural machines.
- Water Management Problem – Due to lack of soil and water conservation measures in the watershed area, most of the rain water is lost through surface runoff, very little amount of rainfall water enters into the soil profile and is used by the crop plants.

Needs

- Suitable soil and water conservation measures.
- Financial assistance for purchase of improved agricultural implements and tools and also for seasonal agriculture inputs.
- Suitable agro technique for dry land agriculture.

3.2 Data and Software Used

A specific frame work was developed for delineation of watershed and geomorphological analysis using topographic information, derived from remote sensing information with the help of Arc GIS 10.1

3.2.1 Data acquisition

The various information required for the study were procured from various sources. An overview of data collection is given below:

a. Topographic features were extracted from Geographical Toposheet at 1:50,000 scale which was procured from Survey of India (SOI).
b. Soil information and soil map of the area at 1:250,000 scale were gathered from the Regional Centre of the National Bureau of Soil Survey and Land Use Planning (NBSS & LUP), Udaipur, Rajasthan.
c. Remote sensing data of the area were used from satellite imagery IRS-IC-LISS-III dated 26.3.2009 at Regional Centre of the National Bureau of Soil Survey and Land Use Planning (NBSS & LUP), Udaipur, Rajasthan.
d. Daily rainfall data of 30 years (1987-2016) for the study was collected from Agro-Meteorological Observatory, CTAE, MPUAT, Udaipur.

3.2.2 Development of GIS database

The development of GIS data in the desired format is complex in nature particularly for hydrological analysis. Most of the desired data is georeferenced in nature except for the precipitation data. The GIS spatial database was composed of a number of thematic information on topography, soil, vegetation etc. Topography, drainage patterns and soil information were scanned using HP design jet copies CC 800 PS image scanner software. The scanned maps were then transferred into ArcGIS10.1 and edited using Arc tools. These edited maps were used for further analysis. Watershed is delineated by toposheet with the help of the editing tools in Arc Map 10.1. DEM file is acquired from the http://srtm.csi.cgiar.org/SELECTION/inputCoord.asp site. Delineated watershed is extracted from the DEM tile by the spatial analyst tool. The name given to the extracted DEM file is e. g. *kanore_dem.*

3.3 Procedure for Determination of Geomorphological Parameters

1. Fill

Provide *kanore_dem* as the input surface raster, and save the output raster as *kanore_fill* in your working directory. The main function of this tool is to remove imperfections in the DEM to enable water flow to the watershed outlet.

2. Flow Direction

This function computes the flow direction for a given grid. The value in any given cell of the flow direction grid indicates the direction of the steepest descent from that cell to one of its neighboring cells using the eight directions pour point (D8) method. Select *kanore_fill* as the input surface raster, and name the output raster as *kanore_fdr*.

3. Flow Accumulation

The function uses the flow direction grid to compute the accumulated number of cells that are draining to any particular cell in the DEM. Select *kanore_fdr* as the input flow direction raster, and save the output flow accumulation raster as *kanore_fac*.

4. Stream Network

Because the flow accumulation gives the number of cells (or area) that drain to a particular cell, it can be used to define a stream. It is assumed that a stream is formed when a certain area (threshold) drains to a point. This threshold can be defined by using the number of cells in the flow accumulation grid. Take *kanore_fac as an input,* select SetNull and give the output raster as *kanore_stream.*

5. Stream Link

Provide *kanore_stream* as the input stream raster, *kanore_fdr* as the flow direction raster, and name the output raster as *str_link*. This tool assigns a unique number to each link (or segment) in the stream raster.

6. Stream Order

This tool creates stream order for the stream network. Provide *kanore_stream* as the input for stream raster, *kanore_fdr* as the input for flow direction raster and name the output raster as *str_order.* Two methods are available for estimating stream order. Choose anyone of them.

7. Stream to Feature

This tool converts stream raster to a polyline feature class. Provide *kanore_stream* as the input for stream raster, *kanore_fdr* as input for the flow direction raster and save the output as *stream.shp.* When process completes, a shape file, named *stream* will be added to the map document.

One can find the value of different morphological parameters by the output file obtained in step 7 (stream.shp).

Note: Steps 1 to 7 are the hydrology tool of the spatial analyst tool (Arc Map 10.1).

3.4 Geomorphological Analysis

Geomorphological analysis is the systematic description of watershed's geometry and its stream channel system to measure the (I) Linear aspects of drainage network (II) Areal aspects of watershed and (III) Relief aspects of channel network. The morphological parameters directly or indirectly reflect the entire watershed based causative factors affecting runoff and sediment loss. The surface features are the fundamental unit of analysis prior to adopting any sophisticated tool to monitor the watershed responses in connection to any of the hydrologic processes acting on it. The parameters can be conveniently worked out from the toposheet using the capability of GIS tools. The dimensionless geomorphological parameters can be presented under different groups as shown in Table 3.1.

Table 3.1: Grouping of geomorphological parameters

S. No.	Groups	Geomorphological Parameters
1.	Linear Aspects of Drainage Network	Stream order, stream number, bifurcation ratio, stream length and stream length ratio
2.	Areal Aspects of Watershed	Drainage density, form factor, circulatory ratio and elongation ratio,
3.	Relief Aspects of Channel Network	Relief ratio, relative relief, ruggedness number and geometric number

3.4.1 Linear aspects of drainage network

Stream Order

The first step in a drainage basin analysis is designation of stream order, following a system introduced in the United States by Horton (1945). The smallest fingertip tributaries having no branches are designated as first order streams, where two first order streams join, a channel segment of second order is formed and so forth. The maximum order segment carries the sediment and flow of water at the outlet of the watershed.

Bifurcation Ratio (R_b)

The bifurcation ratio is defined as the ratio of number of streams of any order (N_u) to the number of streams of next higher order (N_{u+1}). It can also be determined by slope of regression line relating stream order and corresponding number. It is given by the formula

$R_b = N_u / N_{u+1}$ …3.1

Where,

N_u = No of streams of order u

N_{u+1}= No of streams of order u+1

Stream Length

All lengths of the drainage lines are measured with the help of statistical function of Arc/INFO. Stream lengths are defined in meter (m). To find out the mean length of the channel of order u, the total length is divided by the number of segments (N_u) of that order, thus,

$$\bar{L}_u = \frac{\sum_{i=1}^{N} L_u}{N_u}$$ …3.2

Where,

$\bar{L}_u$ = Average length of stream of order u

L_u = Length of stream of order u

Stream Length Ratio (R_L)

Horton (1945) defined the stream length ratio, R_L, as the ratio of mean length, $\bar{L}_u$ of segments of order u to mean length of segments of the immediate lower order, $\bar{L}_{u-1}$.

$$R_L = \frac{\bar{L}_u}{\bar{L}_{u-1}}$$ ...3.3

Where,

$\bar{L}_u$ = Average length of stream of order u

$\bar{L}_{u-1}$= Average length of stream of order u-1

Area of the watershed (A)

Area of watershed is defined as the area contained within the vertical projection of the drainage divide on a horizontal plane. The area is expressed in ha.

3.4.2 Areal Aspects of Watershed

Form Factor (R_f)

It is defined as the ratio of the watershed area (A) to the square of watershed length (L_b)

$$R_f = A / L_b^2 \qquad ...3.4$$

Where,

A = Area of watershed

L_b = Length of basin

Basin Shape Factor (S_b)

Basin shape factor has the significant influence on the runoff and sediment transport phenomenon. Horton (1932) defined the basin shape factor S_b, as the ratio between the square of the maximum length of watershed and the area of the watershed.

$$\mathbf{S_b = L_b^2 / A} \qquad \dots 3.5$$

Circulatory Ratio (R_c)

Circularity ratio is defined as the ratio of watershed area (A) to the area of circle (A_C) having equal perimeter as the perimeter of watershed.

$$R_C = \frac{A}{Ac} = \frac{4A\pi}{P^2} \qquad \dots 3.6$$

Where,

A_C = Area of circle having equal perimeter as the perimeter of watershed

P = Perimeter of watershed

Elongation Ratio (R_e)

Elongation ratio, R_c, is defined (Schumm, 1955) as the ratio of the diameter of a circle (D_c) with the same area as the watershed to the maximum length of the watershed (L_{bm}). This parameter is used to assess whether the shape of the basin approaches a circle or not.

$$R_e = \frac{D_c}{L_{bm}} = \frac{2 \times \sqrt{A/\pi}}{L_b} \qquad \ldots 3.7$$

Where, D_C = Diameter of circle with the same area as the watershed

Drainage Density (D_d)

The drainage density (D_d) is defined as the ratio of the total length of all streams of all orders within a watershed to the total area of watershed (A). Low D_d occurs in regions of highly resistant and permeable sub soil material.

$$D_d = \frac{\sum_{i=1}^{K}\sum_{i=1}^{N} L_u}{A} \qquad \ldots 3.8$$

Where,

D_d = Drainage density

K = Principal order = highest order stream

Constant of Channel Maintenance (C)

Schumn (1956) used the inverse of D_d as a property termed "constant of channel maintenance C" which may be defined as the area of basin surface needed to sustain unit length of stream channel. The C is expressed in sq. km per km.

$$C = \frac{1}{D_d} = \frac{A}{\sum_{i=1}^{K}\sum_{i=1}^{N} L_u} \qquad \ldots 3.9$$

Stream Frequency (F)

It is the number of stream segments per unit area of watershed.

$$F = \frac{\sum_{i=1}^{K} N_u}{A_k} \qquad ...3.10$$

Where,

A_k = Basin area of principal order (K)

3.4.3 Relief aspects of channel network

Maximum watershed relief (H)

Maximum watershed relief (H) is the elevation difference between basin mouth (discharge point) and the highest point on the basin perimeter. Maximum watershed relief is obtained from the available contour maps of the watersheds. It is expressed in meter.

Relative relief (R_R)

Melton (1957) defined relative relief, R_R as the ratio of the maximum watershed relief to the perimeter length. It is computed using following expression.

$$R_R = H/L_p \times 100 \qquad ...3.11$$

Where,

H = Watershed relief

L_p = Length of perimeter

Relief ratio (R_r)

Schumm (1956) defined the relief ratio (R_r) as the ratio of maximum watershed relief divided by the maximum watershed length. It is computed using following expression.

$$R_r = H/L_b \qquad …3.12$$

Where, L_b = Basin Length

Ruggedness number (R_N)

The product of relief (H) and drainage density (D_d) is called ruggedness number.

$$R_N = H \times D_d \qquad \ldots 3.13$$

Where, D_d = Drainage density

Geometric number

The geometric number is a ratio of ruggedness number to the slope of ground surface.

$$\text{Geometric Number} = H \times D_d / S_g \qquad \ldots 3.14$$

Where,

S_g = Slope of ground surface

3.5 Probability Analysis of Rainfall

Adequacy of rainfall to meet the consumptive needs of crops and other consumptive and non-consumptive water needs is a basic requirement of crop planning. Considerable rainfall variability in space and time coupled with inadequate and uneven distribution of available water resources in drought prone areas results in frequent crop failure and shortage of fodder and drinking water. Knowledge of rainfall is very useful to estimate the water availability periods for deciding the cropping pattern, water management and water harvesting practices and in estimating sensitivity to droughts. Determination of rainfall amount expected at various probability levels for different periods e.g. annual, seasonal etc. play an important role in estimating water deficit/surplus periods and their amounts at various probabilities.

The collected rainfall data were analyzed for probability distribution at different levels using Weibull’s technique.

3.5.1 Weibull’s method

This is a simple empirical technique for analysis of series of data for probability distribution at different levels. The probability of an event equal to or exceeded is given by the following formula.

$$P = \frac{m}{(n + 1)} \qquad ...3.15$$

Where,

P = Probability (fraction)

m = order number

n = length of record

Different steps involved in the analysis are:

a. Tabulation of data
b. Arrangement of data in descending order
c. Assigning order number, m, to data; i.e. m = 1 for the highest magnitude and every successive data in the descending order is assigned 2, 3, 4,… and so on till the last event for which m = n
d. Determination of probability, P, by using Weibull's equation
e. Plotting values of P on x-axis and the rainfall amount on y-axis on arithmetic paper
f. Determination of magnitude of rainfall at different probability levels.

The analysis of rainfall is useful for planning and designing purpose of water harvesting structure.

3.6 Land Use Capability Classification

Land use capability classification is a systematic arrangement of different kinds of land according to their properties that determine the ability of land to produce on virtually permanent basis.

It is the suitability of land for use without damage and based on the intensity of hazards and limitation of use. There are eight capability classification depicted by Roman numerals from I to VIII. The capability groups I to IV are the lands recommended to be put under agriculture with different levels of control and management and class V to VIII are the lands to put under non-agriculture uses. The land capability classes II to VIII are divided into sub classes on the basis of their limitation and hazards. Four kinds of limitation (erosion, wetness, root zone limitation and climatic) are recognized at the sub class level. Class I has no sub classes.

Each land capability class is represented by specific colour that is related to the mineral matter and organic carbon present in the soil. It is also related to parent

material from where the soil formation has taken place.

The land capability class I include lands which are suitable for intensive cultivation of all climatically adopted crops. It is represented by green colour.

Class II and III lands have increasing limitation and require special soil and water conservation measures. Class II and III are represented by yellow and red colour respectively.

Class IV land is marginal lands, for occasional or limited cultivation and require intensive soil and water conservation measures for erosion control and choice of crops on these lands is limited. It is represented by blue colour.

Class V land is nearly level and not suited for cultivation because of wetness, stoniness and adverse climatic conditions. It is represented by dark green colour.

Class VI land is economically not suitable for crop production but are suitable for pasture and forestry. It is represented by orange colour.

Class VII land is suitable for pasture and forestry. It is represented by brown colour.

Class VIII land is not suitable for any of the above uses and may be best put to use for wild life, recreation centers etc. It is represented by purple colour.

3.7 Soil and Water Conservation Measures

Soil and water conservation measures are broadly classified under two types: firstly, agronomical and vegetative measures and second, engineering/mechanical structures. In present study, engineering measures are being dealt in detail. Further, for a water harvesting system to function efficiently, the catchment of the structure must be treated scientifically with proper design of in-situ conservation measures for natural regeneration and growth of flora and fauna. The selection and design criteria of soil and water conservation measures are given in Table 3.4 and 3.5 respectively. For in-situ conservation, the engineering structure may be divided into three categories-

i. Structure for arable land
ii. Structure for non-arable land
iii. Structure for drainage line treatment

3.7.1 Structure for arable land

In-situ soil and moisture conservation may be ascertained by treating the land by providing engineering measures/structures along with the recommended agronomical practices viz. contour cultivation, strip cropping, inter-cropping, crop rotations, contour vegetative hedges etc. Vegetative/biological measures are effective only upto 2 per cent of land slope and where problem of erosion is not severe.

Various soil and moisture conservation structures may be selected on the basis of physiographic and spatial characteristics of the watershed.

3.7.1.1 Contour bund

Bunds are simply embankment type structures constructed across the land slope. When bunds are constructed on contours, they are called contour bunds but when constructed on field boundaries without reference to contour, are called field bunds. Contour bunds are constructed for the slope upto 6 per cent in low rainfall area and where soil moisture is limiting factor for crop production.

3.7.1.2 Puerto rico terrace (PRT)

PRT of dry stone is proposed along the contour which will develop into level bench terraces due to shifting of soil down the slope every time after ploughing. This type of terrace is also known as California terrace and is especially suitable for arable land when slope is more than 6 per cent and where depth of the soil is shallow. These are mostly constructed in the areas where stones are easily available at the site. For increasing crop productivity in rainfed areas, these terraces have been found very effective. PRT are generally constructed on field boundaries because it is not possible to follow absolute contour in the actual field conditions.

3.7.2 Structure for non-arable land

Non-arable lands may be utilized for increased in production by various utilization such as pastures, afforestation, silvi-pasture etc accordance with the capability of the land with proper conservation practices. Class V and VI land may be developed for pastures as per the depth of the soil and class VII for forestry plantation. Pasture development with afforestation is a common practice in the region.

3.7.2.1 Contour trenches

Contour trenches can be constructed both on hilly slopes as well as on degraded and sloping waste lands for soil and water conservation establishing vegetative cover. The recommended cross section is 0.3 m × 0.3 m. The object is to hold sufficient moisture in the soil to enable the berm to be revegetated and to support the planted tree. These trenches run perfectly level to use their capacity to the best possible advantage. Contour trenches are generally recommended to be constructed for the land having slope up to 30 per cent only, because for the slope above this, it is not stable and also technically not feasible.

Justification

i. To break the slope lengths and thereby reducing the velocity of flowing runoff.

ii. To retard the scouring action of runoff water and help in conserving moisture.

iii. To percolate the retained rain water through the soil slowly to benefit the better type of land in the middle and lower reaches of the watershed.

iv. To help in protecting the bunds or terraces in lower reaches of the watershed.

Design

Contour trenches are excavated at suitable interval (depending on slope) and their cross sections are designed to collect and convey the runoff expected from the inter-space between the successive trenches.

The recommended cross section of contour trench is as follows:

Width of trench = 0.30 m, Depth of trench = 0.30 m

3.7.2.2 Staggered trenches

Staggered trenches are excavated trenches of shorter length in a row along the contour with inter-spaces between them, constructed in a staggered manner. The vertical interval between the rows is restricted to impound the runoff expected from the catchment area without overflowing the trenches. The cross-sectional area of these trenches is designed to collect runoff expected from the most intense storms having recurrence interval of 10 years. The dugout soil is heaped upon the downstream side of the trench leaving a berm of 15 cm. Staggered trenches are recommended to be constructed for the land having slope greater than 30 per cent.

Justification

i. To collect runoff expected from intense storms.
ii. To conserve soil and moisture.
iii. To reduce the scouring action of runoff water.
iv. To percolate the runoff water slowly to benefit better type of land in middle and lower reaches.
v. To help in protecting the soil and water conservation measures in lower reaches of the watershed.

Design

The cross section is designed to collect runoff from intense storm at recurrence interval of 5 to 10 years.

Length of trench = 4.0 m

Width of trench = 0.3 m

Depth of trench = 0.3 m

Volume of trench = $4 \times 0.3 \times 0.3 = 0.36\ m^3$

3.7.2.4 Loose stone fencing wall and afforestation cum pasture development

Justification

The stone fencing wall stops the entrance of the cattle in the area and hence, protects the plantation from damage and grasses from grazing. It also reduces the velocity of water flow.

Design for loose stone fencing wall

A standard trapezoidal cross section is adopted.

Bottom width = 0.8 m

Top width = 0.6 m

Height of stone wall = 1.2 m

Cross sectional area of dry stone masonry = $(1/2) \times (0.8 + 0.6) \times 1.2 = 0.84\ m^2$

3.7.3 Structure for drainage line treatment

Drainage lines may be divided into three portions according to locations from the ridge line to outlet. The three portions may be termed as upper, middle and lower reaches. Structures are designed according to location in reach, slope and concentration of runoff. The cross sections of the structures for three reaches are decided on the basis of slope, catchment area and runoff volume. The commonly used structure for drainage line treatment is Loose Stone Check Dam (LSCD).

3.7.3.1 Loose stone check dam

Loose Stone Check Dam (LSCD) is specially adopted for gully control in small watersheds. These are constructed across the bed of gully and extended enough into the bottom and sides of the gully to prevent undercutting or by cutting around the ends. The cross section of LSCD for three reaches is shown in Fig. 4.12.

Justification

Loose stone check dam checks channel erosion till sufficient stabilizing vegetation is established to collect enough soil and water to ensure the eventual growth of protective vegetation. These dams make best use of loose stone present in the watershed area.

Design

The LSCDs for drainage line treatment were proposed in the individual drains. These drains were divided into three parts viz. upper, middle and lower reaches based on the catchment area, size and shape of drains and concentration of flow.

To construct LSCD, the trench is made across the gully to a predetermined depth. It forms the base of the dam on which the stones are laid in rows and are brought to a height, ranging from 0.5 m to maximum 1.0 m above the bed in different reaches.

According to the slope of nalla, three types of structure were proposed

i. Upper reaches: 20 m H.I.
ii. Middle reaches: 25 m H.I.
iii. Lower reaches: 35 m H.I.

3.7.4 Water harvesting structure

A structure constructed for collection and storage of runoff water from the upstream areas at suitable location is known as water harvesting structure. Harvested water may be utilized for human consumption, animal consumption and to provide supplemental irrigation during crop stress periods. The selection of site and potential runoff available for structure are the prime consideration in construction of water harvesting structure.

3.7.4.1 Anicut

Anicut is a weir structure constructed to harvest the excess runoff at suitable locations in downstream of catchment on lower reaches of drainage lines. It impounds the water against head wall and controls the damaging velocity of the runoff water providing safe disposal. This will help in recharging of surrounding wells and the stored water can also be used for lift or flow irrigation. Location of such structures should be at a place where maximum storage can be achieved with minimum cost.

The plan and cross section of Anicut are shown in Figures 4.13.

Design Consideration

i. The weir of Anicut is designed for sustaining the peak discharge resulting from the rainfalls in 25 years' recurrence intervals.
ii. Structure should also be checked against the yield of the runoff at 75 per cent probability level for its capacity of storage.
iii. The structure should be located at such a place where maximum submergence can be achieved with minimum crest length of the weir. A deep and narrow section of valley with steep side slopes and having hard rock on one or both sides of the valley is the best site for Anicut construction.
iv. The slope of the nalla bed should be less than 2 per cent so that maximum water can be stored in the valley or nalla. Large area of shallow water should be avoided as it causes excessive evaporation losses.

Table 3.2: Criteria for selection of different soil and water conservation measures and water harvesting structure

S. No.	Structure	Selection Criteria						
		Rainfall/ runoff (mm)	**Slope**	**Infiltration rate/seepage**	**Soil depth**	**Desired use**	**Economy**	**Others**
1.	Contour bund	< 600	< 6%	Moderate	Must not be Black cotton soil	In-situ moisture conservation	-	Construction
2.	P.R.T.	400-800	> 6%	Moderate	Shallow soil depth	Protection of valley slopes	Availability of loose stones	-
3.	S.W.T.	400-800	> 6%	Moderate	Shallow soil depth	Moisture conservation in valley	Availability of loose stones	-
4.	Contour trench	400-1200	10-30 %	Good	-	In-situ moisture conservation	-	-
5.	Staggered trenches	400-1200	> 20 %	Moderate	Shallow soil depth	In-situ moisture conservation	-	Hilly condition
6.	Loose stone check dam	400-1200	> 6 %	Good	Shallow soil depth	In-situ moisture conservation	Availability of loose stones	-
7.	Anicut	Large	< 2 %	Moderate	-	Water harvesting for supplement irrigation and ground water recharge	Natural submergence to be utilized	Where bank is available with deep gullies of good storage

(Singh, 1998)

Table 3.3: Criteria for design of different soil and water conservation measures and water harvesting structure

S. No.	Structure	Design Criteria					
		Spacing	Height	Cross section	Storage capacity	Surplus arrangement	Others
1.	Contour bund	By Ramser formula	24 hr rainfall excess	Seepage consideration	-	10 years return period peak runoff -	Must be on contours
2.	P.R.T.	-do-	0.45 m	$0.45 \times 0.60\ m^2$	-	-	On slopes
3.	S.W.T.	-do-	< 1.0 m	According to safe workmanship	-	-	In cultivated gullies
4.	Contour trench	-do-	0.30 m	$0.09\ m^2$	-	-	-
5.	Staggered trenches	10.0 m	0.30 m	$0.09\ m^2$	-	-	-
6.	Loose stone check dam	As per slope	0.6 m	$0.36\ m^2$	-	-	-
7.	Anicut	-	According to depth capacity curve	As per structural safety	Simpson's Rule	25 years return period	-

(Singh, 1998)

3.7.2.4 Loose stone fencing wall and afforestation cum pasture development

Justification

The stone fencing wall stops the entrance of the cattle in the area and hence, protects the plantation from damage and grasses from grazing. It also reduces the velocity of water flow.

Design for loose stone fencing wall

A standard trapezoidal cross section is adopted.

Bottom width = 0.8 m

Top width = 0.6 m

Height of stone wall = 1.2 m

Cross sectional area of dry stone masonry = $(1/2) \times (0.8 + 0.6) \times 1.2 = 0.84\ m^2$

3.8 Economic Analysis

The economic analysis of the structure was carried out by the economical evaluation method. Benefits and cost are summarized and compared to determine economic feasibility of a micro-watershed. Benefit cost ratios are discounted for time producing internal rate of returns. Benefit cost ratio is calculated in terms of financial and economic evaluation.

3.8.1 Economic Evaluation

It emphasizes depreciated values of yearly expenditure and benefits, which are expected during the life of a project.

Economic evaluation of B: C ratio

$$= \frac{\text{Present worth of incremental income@10\% discount rate}}{\text{Present worth of total cost}}$$

Present worth of money at the rate of 10 per cent discount is calculated as

$$PV = \frac{Q}{(1+0.1)^n}$$

Where,

PV= present value of money.

Q= amount of money today for calculating the PV.

n= numbers of years.

3.8.2 Financial Evaluation

It includes the expenditure and the interest to be paid along with such expenditure which exhaust every year, whether the project is complete or not or in the progress.

$$\text{Financial Evaluation of B: C ratio} = \frac{\text{Total benefits}}{\text{Total cost including interest}}$$

CHAPTER - IV

RESULTS AND DISCUSSION

4.1 General

The study was conducted for planning and designing of soil and water conservation measures at Kanore micro-watershed in Udaipur district. The present study reported in this dissertation consists of four parts. In first part, the watershed was delineated and geomorphological parameters were analyzed using remote sensing and GIS. In second part, probability analysis of rainfall and land capability classification was done. In third part, appropriate engineering measures were identified and designed for arable land and non-arable land along with design of water harvesting structures. In the last part, cost effectiveness of the micro-watershed was carried for analyzing its economic feasibility.

4.2 Digital Elevation Model (DEM)

Following the steps as discussed in Chapter-III i.e. material and methods, the TIN model of the study area was generated from digitized contour map of the study area. Using the TIN model, DEM of the study area was obtained. The elevation range of the present DEM varies between 350 to 505 m and is shown in Fig 4.1.

4.3 Delineated Watershed

On comparing the digitally delineated watershed boundary for the watershed with the manually delineated boundary a close (though not exact) and size match was observed between shape and size. The slight difference between shapes of digitally and manually delineated watershed could be mainly attributed to an element of the subjectivity associated with the manual delineation procedure. A digital watershed delineation procedure provides flexibility of delineating watersheds of various sizes by interactively choosing outlets/pour points along stream links on either main stream or its branches. The delineated watershed from the DEM is shown in Fig 4.1.

4.4 Geomorphological Analysis

The geomorphological analysis of the watershed was carried out to find the various geomorphic parameters. For the geomorphological analysis, the measurement was made from the digitized drainage pattern and watershed boundary. Watershed boundary and digitized drainage pattern is shown in Fig 4.4. The values of different geomorphological parameters were calculated by using the methodology as discussed in section 3.4. The calculated values are presented in the Table 4.1.

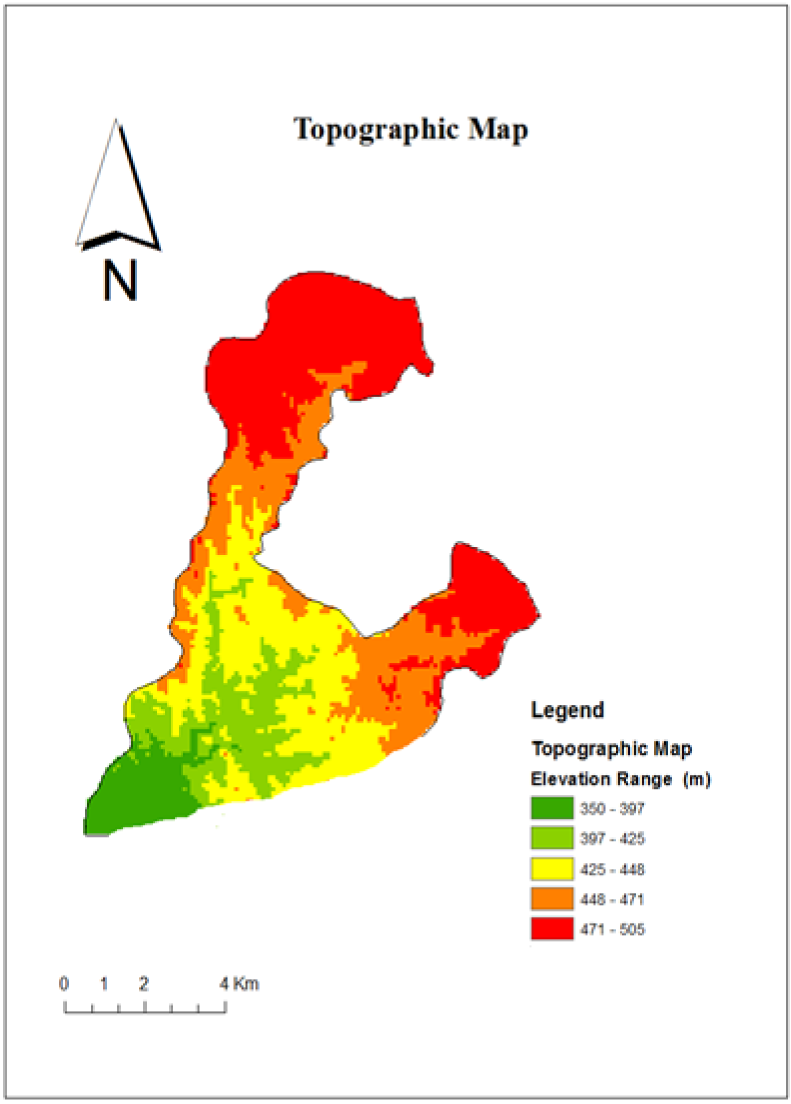

Fig.4.1: Topographic map of the study area

4.4.1 Stream Analysis

Stream analysis consisted of grouping of stream segment in different orders, measuring stream length, calculating cumulative stream length and mean stream length.

4.4.1.1 Relation between stream number and stream order

According to the Horton's law, the plot of logarithm of stream number (ordinate) as a function of stream order (abscissa) should yield a set of points lying along a straight line. For the present study, this graph was plotted for the watershed which shows a straight line, satisfying the Horton's law (Kumar *et al.*, 2001). From the Fig. 4.2, it is evident that the correlation coefficient for the straight line fit for the watershed is 0.9955, which is quite satisfactory.

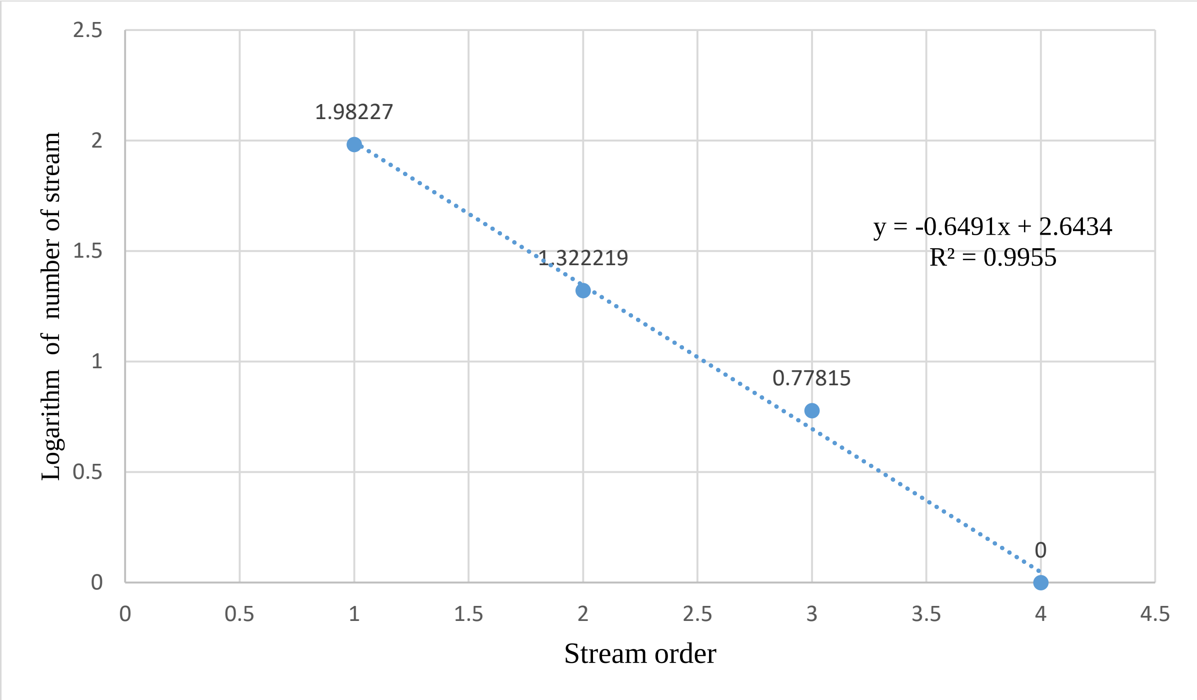

Fig. 4.2: Regression of logarithm of number of stream and stream order

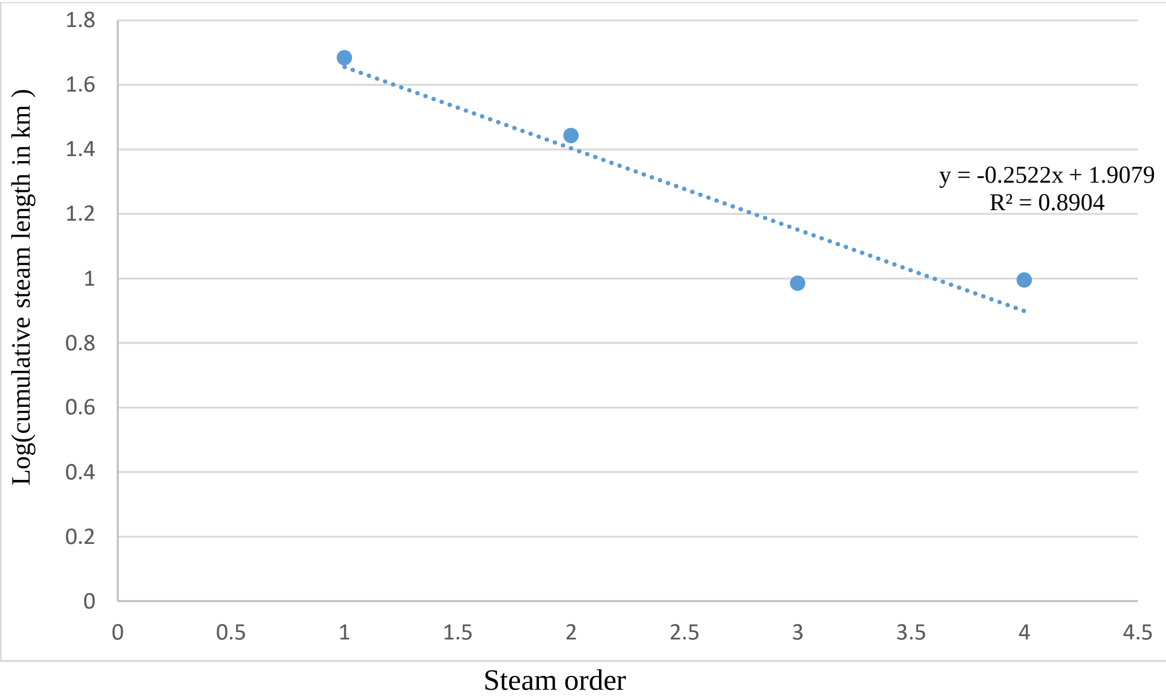

Fig. 4.3: Regression of logarithm of cumulative stream length and stream order

4.4.1.2 Relation between cumulative stream length and stream order

In the present study, an attempt has been made to establish the relation between the stream order and the cumulative stream length. The plot of logarithm of cumulative stream length along ordinate and stream order along abscissa for the watershed is a straight line fit as shown in Fig. 4.3. The straight-line fit indicates that the ratio between cumulative stream lengths is constant throughout the successive order of a basin and suggests that geometrical similarity is preserved in basins of increasing order (Kumar *et al.,* 2000). It is evident that the correlation coefficient for the straight line fit for the watershed is 0.8904, which is quite satisfactory.

4.4.2 Linear Aspects of Drainage Network

It refers to the analysis of stream order, stream number, bifurcation ratio and stream length ratio. After analysis, it was found that the watershed is of 4^{th} order type and drainage pattern is dendrite (Mittal, 2002). The numbers of stream of 1^{st}, 2^{nd}, 3^{rd} and 4^{th} order is 72, 15, 4, and 1 respectively and their corresponding lengths are 48.35 km, 27.73 km, 9.68 km, and 9.92 km respectively. However, in general, the mean length of the stream of the particular order increases with the increase in the order of stream which means that the mean length of a stream of a given order is greater than the immediate lower order but less than that of the next higher order. This confirms the property of the stream order number and their corresponding length. The other important property bifurcation ratio (R_b) reflecting geological and tectonic characteristics of the watershed estimated as 4.16 for the watershed which confirms the research of Horton (1945). The value indicates that the watershed has suffered less structural disturbance and the drainage pattern has not been distorted by structural disturbance (Nag and Chakroborty, 2003). The average stream length ratio estimated is 2.71 and RL_2, RL_3 and RL_4 are not close to each other which confirms the property that length ratio tends to be vary throughout the successive orders of steam segments in the watershed.

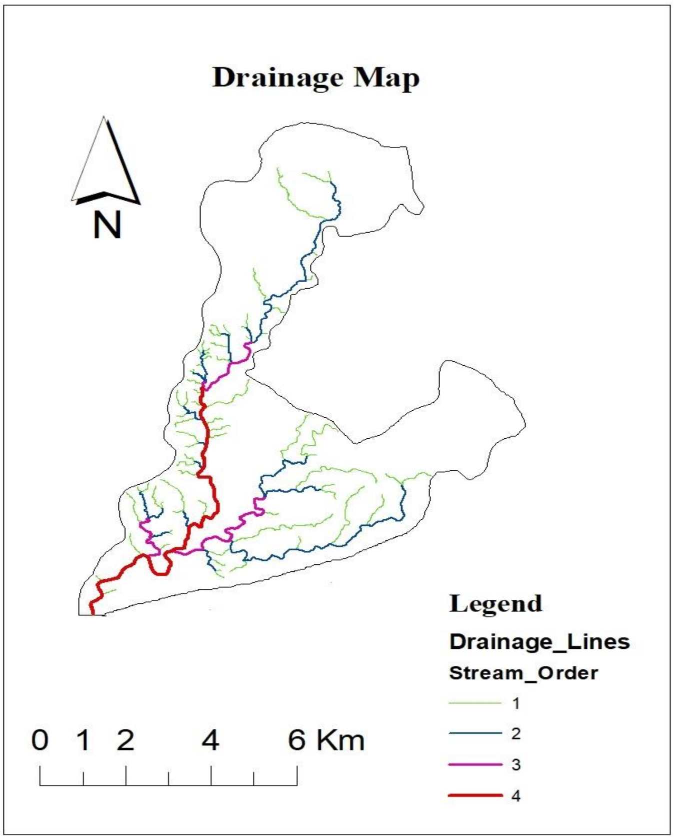

Fig. 4.4: Drainage Map of Watershed

4.4.3 Areal Aspects of Watershed

Under this aspect, the study gives the description of arrangement of area element mainly watershed shape which affects stream flow hydrographs and peak flow. The important parameters that describe the shape of the watershed viz. form factor, circulatory ratio and elongation ratio were computed. Referring Table 4.1, it shows that the value of form factor (R_f), circulatory ratio (R_c) and elongation ratio (R_e) are 0.15, 0.22 and 0.37 respectively. Therefore, greater is the elongation ratio than circulatory ratio indicates that watershed is approaching towards the elongated shape (Singh *et al.* 2003). In this case elongated watershed with low form factor (R_f) indicates that the watershed will have a flatter peak of flow for longer duration. Flood flow of such elongated watershed is easier to manage than from the circular watershed (Pandey *et al.* 2004).

Drainage density (D_d) and stream frequency are other important characteristics of watershed. The drainage density of watershed is 1.77 km/km^2 indicates the closeness of spacing of channels, thus providing a quantitative measure of the average length of stream channel for the whole watershed. Further, it gives an idea about the physiographical properties of the underlying soils. High value of D_d indicated that the region is having impermeable subsoil material under poor vegetative cover and watershed relief is low (Strahler, 1964). The value of stream frequency is 1.70 per km^2 indicating the increase in stream population with respect to increase in drainage density. Further, related to D_d another morphological characteristics property of drainage basin is constant of channel maintenance which was found to be 0.56 km^2/ km for the study area. It indicates the number of square meters of basin surface required to maintain one linear meter of channel.

4.4.4 Relief Aspects of Channel Network

This refers to the analysis of relief aspects of drainage basin and channel networks. Estimated value of relief is 155 m, based on which relief ratio (R_r) and relative relief (R_R) were found to be 0.015 and 0.27 respectively. This is an indication of erosion and reflects that the watershed be treated with soil and water conservation measures. Addition to these properties ruggedness number and geometric number were computed and values are 0.224 and 0.49 respectively. With low value of ruggedness number, it is evident that watershed is having steep slope.

Table 4.1: Morphological Characteristics of the Watershed under Study

S. No.	Characteristics	Estimated value
	Linear aspects	
1.	Area	5388 ha
2.	Perimeter	55.73 km
3.	No. of stream order	
	I	72
	II	15
	III	4
	IV	1
4.	Stream length (L_u)	
	I	48.35 km
	II	27.73 km
	III	9.68 km
	IV	9.92 km
5.	Average stream length	
	I	0.67 km
	II	1.84 km
	III	2.42 km
	IV	9.92 km

6.	Bifurcation Ratio (R_b)	
	B.R.$_1$	4.8
	B.R.$_2$	3.7
	B.R.$_3$	4.0
	Average	4.16
7.	Stream length ratio (L_u)	
	RL_2	2.74
	RL_3	1.31
	RL_4	4.09
	Average	2.71
	Areal aspects	
8.	Form factor (R_f)	0.15
9.	Circulatory ratio (R_c)	0.22
10.	Elongation ratio (R_e)	0.37
11.	Drainage density (D_d)	1.77 km/km^2
12.	Stream frequency (F)	1.70 per km^2
13.	Constant of channel maintenance (C)	0.56
14.	Length of overland flow	0.28 km^2/km
	Relief aspects	
15.	Relief	155 m
16.	Relief ratio (R_r)	0.015
17.	Relative relief (R_R)	0.27 %
18.	Ruggedness number (R_N)	0.224
19.	Geometric number	0.49
20.	Time of concentration (T_c)	51.37 min

4.5 Probability Analysis of Rainfall Data

The rainfall data of 30 years (1987-2016) for the study were collected from Agro-Meteorological Observatory, CTAE, MPUAT, Udaipur. These data were analyzed for probability distribution at different levels using Weibull's (1939) technique. The distribution of annual rainfall over 30 years (1987-2016) is shown in Fig 4.5. The maximum annual rainfall in the last 30 years was 850 mm received during the year 2014 whereas minimum is 268 mm recorded in the year 2005 (Fig. 4.5).

Table 4.2: Probabilities and recurrence intervals of annual rainfall for period (1987-2016)

Annual Rainfall (mm) in Descending Order	Year	Rank (m)	P = m / (n+1)	Recurrence Interval (T = 1/P)	% Probability
850	2014	1	0.0323	31.00	3.23
841	2006	2	0.0645	15.50	6.45
779	1994	3	0.0968	10.33	9.68
746	1989	4	0.1290	7.75	12.90
714	2016	5	0.1613	6.20	16.13
697	1992	6	0.1935	5.17	19.35
669	1998	7	0.2258	4.43	22.58
666	1990	8	0.2581	3.88	25.81
650	2007	9	0.2903	3.44	29.03
636	1996	10	0.3226	3.10	32.26
630	2008	11	0.3548	2.82	35.48
625	2011	12	0.3871	2.58	38.71
623	1988	13	0.4194	2.38	41.94
618	1997	14	0.4516	2.21	45.16
615	1991	15	0.4839	2.07	48.39
600	2012	16	0.5161	1.94	51.61
556	2003	17	0.5484	1.82	54.84
545	2009	18	0.5806	1.72	58.06
531	2001	19	0.6129	1.63	61.29
490	2013	20	0.6452	1.55	64.52
487	2015	21	0.6774	1.48	67.74
465	2010	22	0.7097	1.41	70.97
439	2000	23	0.7419	1.35	74.19
413	1999	24	0.7742	1.29	77.42
383	1987	25	0.8065	1.24	80.65
372	2002	26	0.8387	1.19	83.87
353	1993	27	0.8710	1.15	87.10
334	1995	28	0.9032	1.11	90.32
310	2004	29	0.9355	1.07	93.55
268	2005	30	0.9677	1.03	96.77

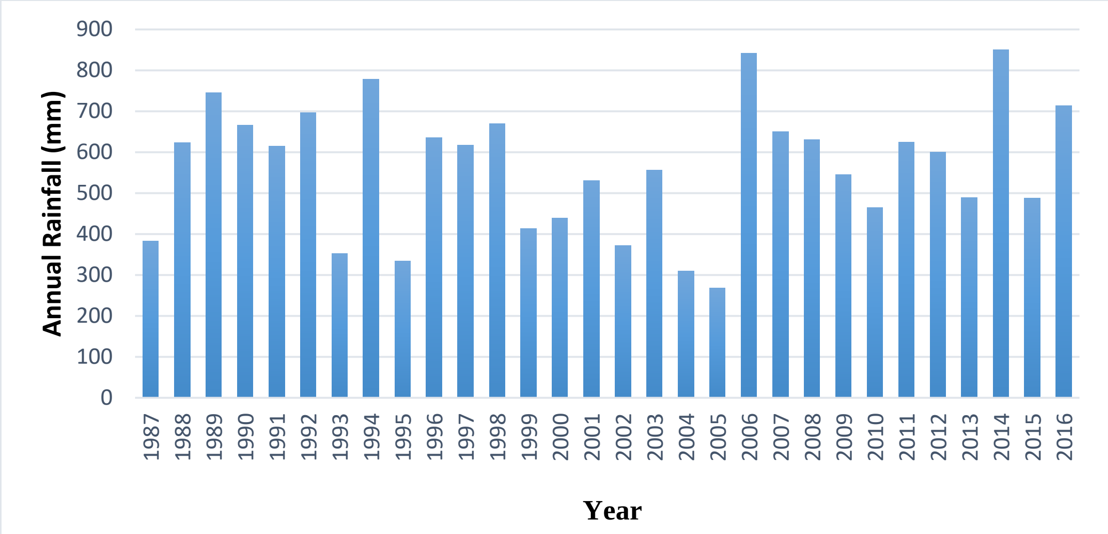

Fig 4.5: Distribution of Annual Rainfall for 30 Years (1987-2016)

The probability and recurrence interval of annual rainfall for the period 1987-2016 are shown in Table 4.2. The expected annual rainfall on different probability levels based on 30 years' data are shown in Fig 4.6. Annual rainfall at 10, 25, 50, 75 and 90 per cent probability levels were determined and are shown in Table 4.3. From table, it is inferred that at 75 per cent probability level, annual rainfall is 439 mm while at 50 per cent, the same are 600 mm. It is evident from the probability analysis that there is availability of excess runoff, thus conditions are favorable for proposing water harvesting structure.

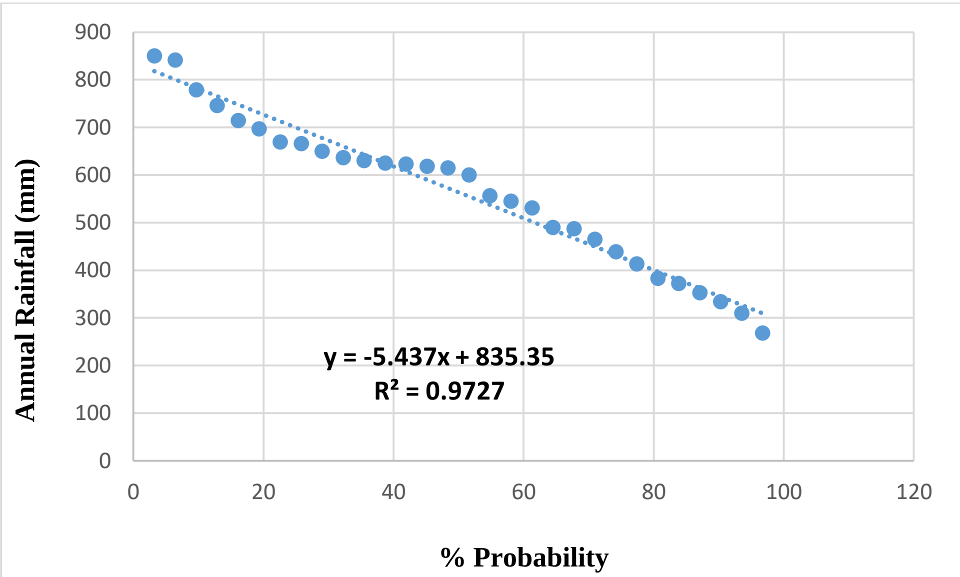

Fig 4.6: Annual Rainfall at different percent of probability based on 30 Years (1987-2016)

Table 4.3: Annual max. rainfall at different per cent of probabilities

Max. Rainfall	Rainfall (mm) at different per cent of Probabilities				
	10%	25%	50%	75%	90%
Annual	779	666	600	439	334

4.6 Land Use Capability Classification

Land use capability classification is a systematic arrangement of different kinds of land according to their properties that determine the ability of land to produce on virtually permanent basis. It is the suitability of land for use without damage and based on the intensity of hazards and limitation of use. There are eight capability classification depicted by Roman numerals from I to VIII. The land capability classes II to VIII are divided into sub classes on the basis of their limitation and hazards. Four kinds of limitation (erosion, wetness, root zone limitation and climatic) are recognized at the sub class level. Details of land classes of different blocks are shown in Table 4.4 and Fig 4.7. The table shows area under arable land is 4019.59 ha and under non-arable land is 1368.41 ha. On the basis of arable and non-arable land with consideration of the slope, soil and water conservation measures has been recommended.

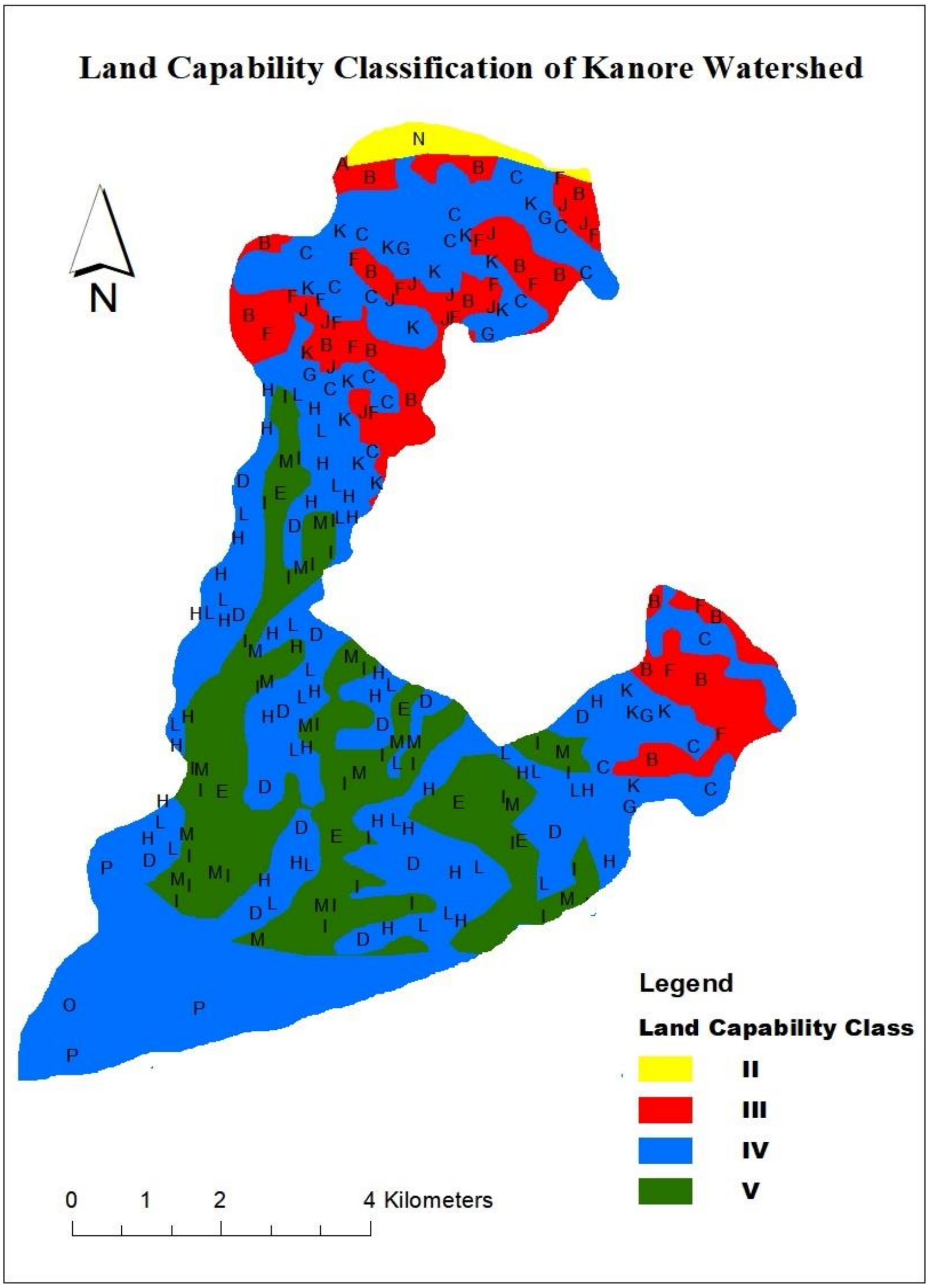

Fig.4.7: Land Use Capability Classification map of the study area

Table 4.4: Land use capability classification

S. No.	Block	Area (ha)	Soil mapping unit	LCC	Limiting factor
1	A	2.1	$\frac{fl-d_3}{A-e_2}$	III	Land has been moderately eroded (e_2)
2	B	553.74	$\frac{CL-d_5}{A-e_3}$	III	Land has been severely eroded (e_3)
3	C	572.31	$\frac{CL-d_5}{A-e_3}$	IV	Fallow land (e_3)
4	D	820.7	$\frac{CL-d_5}{A-e_3}$	IV	Waste land with moderately eroded (e_3)
5	E	988.37	$\frac{CL-d_3}{A-e_3}$	V	Area under Forest land (e_3)
6	F	191.07	$\frac{CL-d_5}{B-e_3}$	III	Land has been severely eroded (e_3)
7	G	390.07	$\frac{CL-d_5}{B-e_3}$	IV	Area under fallow land (e_3)
8	H	228.8	$\frac{CL-d_5}{B-e_3}$	IV	Area under waste land (e_3)
9	I	172.55	$\frac{CL-d_5}{B-e_3}$	V	Forest land
10	J	70.86	$\frac{CL-d_5}{C-e_3}$	III	Land has been moderate sloppy with severely eroded (e_3)
11	K	152.43	$\frac{CL-d_5}{C-e_3}$	IV	Fallow land has been moderately sloppy and severely eroded (e_3)
12	L	388.07	$\frac{CL-d_5}{C-e_3}$	IV	Waste land with severely eroded (e_3)
13	M	207.49	$\frac{CL-d_5}{C-e_3}$	V	Area under forest land
14	N	91.62	$\frac{C-d_6}{A-e_2}$	II	Land has been Clay surface with moderately eroded (e_2)
15	O	695.80	$\frac{C-d_6}{A-e_2}$	IV	Land has under fallow land with moderately eroded (e_2)
16	P	150.20	$\frac{C-d_6}{A-e_2}$	IV	Waste land with severely eroded (e_3)

4.7 Soil and Water Conservation Measures

The appropriate soil and water conservation measures for the watershed were designed on the basis of rainfall, land use capability classification and topography of the area. It is expected that after implementation of these measures, the rain water will be efficiently utilized and productivity will be increased. The criteria for selection and design of relevant activities and structures are summarized in a tabular form as shown in Table 3.2 and 3.3 respectively. However, a detailed soil and water conservation measures proposed in different blocks are presented in Table 4.24. Sample calculation for structures proposed in arable and non-arable area is presented in Appendix A-1 and A-2 respectively and design of Anicut is presented in Appendix A-3.

4.7.1 Contour bund

Contour bunds are proposed in Block-A Block-F and Block-J having land capability class III with the slope range of 1.75 to 5.60 per cent. The total area under contour bund is 264.03 ha. The total length of contour bund has been worked out to be 39604.5 m out of which 315 m is in Block-A, 28660.5 m is in Block-F and rest 10629 m is in Block-J. The contour bund design parameters are given in Table 4.5. The crest length of ramp-cum-waste weir in the contour bund was taken to be 1.2 m to provide passage to the bullocks, carts and implements etc.

Detailed and abstract estimates were prepared and presented in Tables 4.6 and 4.7 respectively. The recommended design is shown in Fig. 4.8. The total cost required for contour bunding was found to be Rs. 2976000. The cost of contour bund per hectare is estimated as Rs. 11271 (Table 4.25).

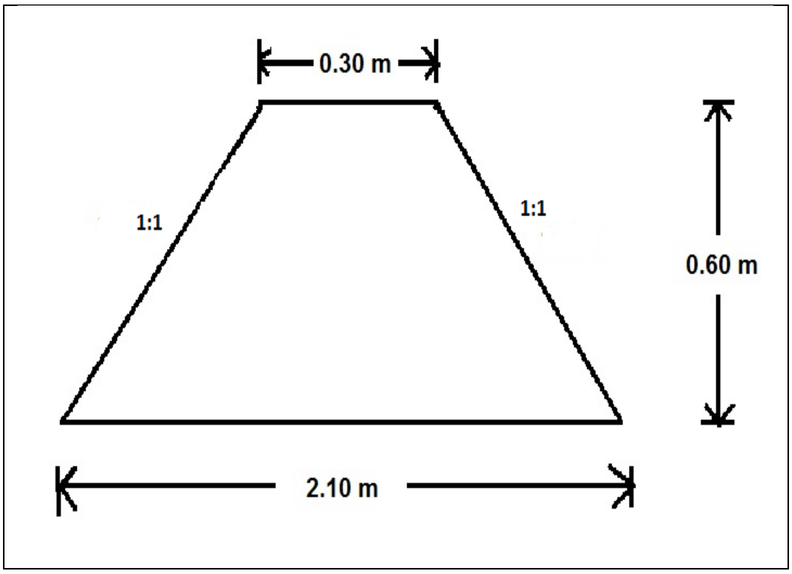

Fig 4.8: Cross section of Contour Bund

Table 4.5: Basic design data for Contour Bund

S. No.	Particulars			Parameters				
	Block	Area proposed under C.B. (ha)	Slope (%)	V.I (m)	H.I (m)	Side Slope	X-section (m^2)	Total length of C. B. (m)
1	A	2.1	1.75	0.77	44.0	1:1	0.54	315
2	F	191.07	3.80	0.98	25.78	1:1	0.51	28660.5
3	J	70.86	5.60	1.16	20.71	1:1	0.63	10629
							Total	39604.5

Table 4.6: Detailed estimate

Name of Work: Construction of Contour Bund **Area = 264.03 ha**

S. No.	Detail of Work	No.	Measurement		Quantity
			Length (m)	Cross-section (m^2)	
1	Dag belling 5 to 7.5 cm deep by manually	2	39604.5		79209 m
2	Earth work for bund in soil dry or moist including laying in layers of 15 cm, breaking of clods, sorting of grasses, pebbles etc. and dressing in hard soil				
	Block-A	1	315	0.54	170 m^3
	Block-F	1	28660.5	0.51	14616 m^3
	Block-J	1	10629	0.63	6696 m^3
				Total	21482 m^3

Table 4.7: Abstract of estimate

Name of Work: Construction of Contour Bund

S. No.	Item	Quantity	Rate (Rs)	Per	Amount (Rs)
1	Dag belling 5 to 7.5 cm deep by manually	79209	1.48	m	117229
2	Earth work for bund in soil dry or moist including laying in layers of 15 cm, breaking of clods, sorting of grasses, pebbles etc. and dressing in hard soil	21482	124.62	m^3	2677086
				Total	2794315
	Adding 6.5 % contingency or supervision charges				181630
				Grand Total	2975945
				Rounded off amount	2976000

(Source: Rate as per BSR, Gramin Vikas, GKN, Bhinder, Udaipur, 2017-18)

4.7.2 Puerto rico terrace

Puerto rico terrace (PRT) has been proposed in Block-B having land capability class III and average slope 9.40 per cent, to conserve soil and water. The area proposed under PRT is 553.74 ha. PRT increases land value by causing sedimentation of eroded fields. The total length of PRT is 83061 m. The total estimated cost required for PRT was worked out to be Rs. 96,79,400. The cost of PRT per hectare comes to be Rs.17480.

Recommended design, detailed estimate and abstract of estimate are shown in Fig. 4.9, Table 4.8, 4.9 and 4.10 respectively.

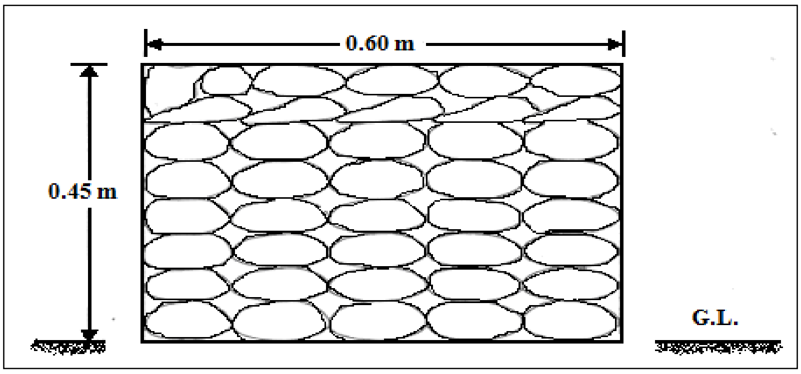

Fig. 4.9: Cross section of Puerto Rico Terrace

Table 4.8: Basic design data for Puerto Rico Terrace

S. No.	Particulars			Parameters			
	Block	Area proposed under PRT (ha)	Slope (%)	V.I (m)	H.I (m)	X-section (m^2)	Total length of PRT (m)
1	B	553.74	9.40	2.02	21.49	0.27	83061

Table 4.9: Detailed estimate

Name of Work: Construction of Puerto Rico Terrace Area = 553.74 ha

S. No.	Detail of Work	No.	Measurements			Quantity
			L	B	H	
1	Clearance of jungle, bushes, shrubs etc. including disposal and dressing of excavated material	1	83061	0.6	-	49836 m^2
2	Dag belling 5 to 7.5 cm deep by manually	2	83061	-	-	166122 m
3	Dry stone masonary up to 3 m height including loading, unloading, carriage and rehandeling of stone lead upto 200 m	1	83061	0.6	0.45	22426 m^3

Table 4.10: Abstract of estimate

Name of Work: Construction of Puerto Rico Terrace

S. No.	Item	Quantity	Rate (Rs)	Per	Amount (Rs)
1	Clearance of jungle, bushes, shrubs etc. including disposal and dressing of excavated material	49836	2.01	m^2	100170
2	Dag belling 5 to 7.5 cm deep by manually	166122	1.48	m	245860
3	Dry stone masonary up to 3 m height including loading, unloading, carriage and rehandling of stone lead upto 200 m	22426	389.84	m^3	8742551
				Total	9088581
				Adding 6.5 % contingency or supervision charges	590757
				Grand Total	9679338
				Rounded off amount	9679400

(Source: Rate as per BSR, Gramin Vikas, GKN, Bhinder, Udaipur, 2017-18)

4.7.3 Contour trenches

Contour trenches are an excavated trenches constructed along the contour and across the slope. For generation of the degraded land and effective in-situ rain water conservation, contour trenches have been proposed in Block-I representing land capability class V and slope 19.75 per cent. The total area under contour trench is 172.55 ha. The total length of contour trench is 25882.5 m (Table 4.11). The total cost of this work has been worked out to be Rs. 9,77,100 and cost per hectare is Rs. 5662. Recommended design, detailed estimate and abstract of estimate are shown in Fig. 4.10, Table 4.11, 4.12 and 4.13 respectively.

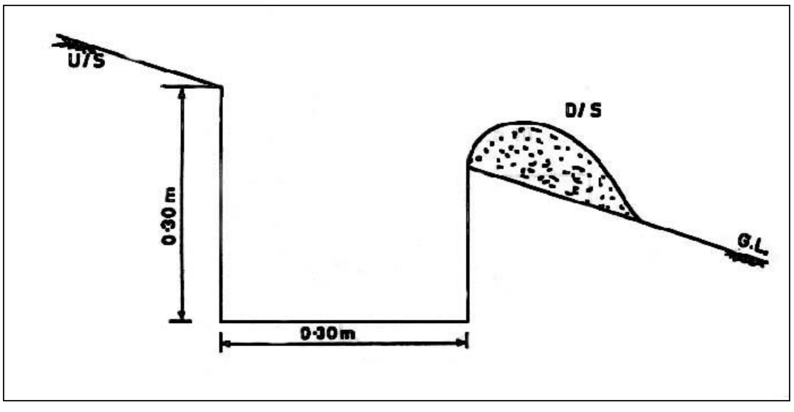

Fig. 4.10: Cross section of Contour trenches

Table 4.11: Basic design data for Contour Trenches

S. No.	Particulars			Parameters	
	Block	Area proposed under C.T. (ha)	Slope (%)	X-section (m^2)	Length of Contour Trenches (m)
1	I	172.55	19.75	0.09	25882.5
				Total	25882.5

Table 4.12: Detailed estimate
Name of Work: Construction of Contour Trenches **Area = 172.55 ha**

S. No.	Detail of Work	No.	Measurement (m)			Quantity
			L	B	H/D/T	
1	Dag belling 5 to 7.5 cm deep by manually	2	25882.5	-	-	51765 m
2	Excavation in stony or earthwork with kankar etc. including dressing of excavated material	1	25882.5	0.30	0.30	2329.425 m^3
3	Excavation of pits of size 0.45 m x 0.45 m x 0.45 m and at the interval of 3 m.	23800	0.45	0.45	0.45	2168.80 m^3

Table 4.13: Abstract of estimate
Name of Work: Construction of Contour Trenches

S. No.	Item	Quantity	Rate (Rs)	Per	Amount (Rs)
1	Dag belling 5 to 7.5 cm deep by manually	51765	1.48	m	76612.2
2	Excavation in stony or earthwork with kankar etc. including dressing of excavated material	2329.425	186.93	m^3	435439.415
3	Excavation of pits of size 0.45 m ×0.45 m × 0.45 m and at the interval of 3 m.	2168.80	186.93	m^3	405413.784
				Total	917465.39
				Adding 6.5 % contingency or supervision charges	59635.25
				Grand Total	977100.64
				Rounded off amount	977100

(Source: Rate as per BSR, Gramin Vikas, GKN, Bhinder, Udaipur, 2017-18)

4.7.4 Staggered trenches

Staggered trenches are excavated trenches of shorter length in row along the contour with inter space between them, constructed in a staggered tandem manner. The staggered trenches are proposed in Block-H, having slope greater than 30 per cent. The area under staggered trenches is 228.8 ha. The cross section of staggered trench is shown in Fig. 4.11. The staggered trenches are proposed to be constructed to collect runoff expected from intense storm at recurrence interval of 5-10 years. The total number of staggered trenches proposed in the area is 56033.

The total cost of work has been estimated as Rs. 57,38,900. The cost per hectare comes to be Rs. 25082 (Table 4.32). Recommended design, detailed estimate and abstract of estimate are shown in Fig 4.11, Table 4.14, 4.15 and 4.16 respectively.

4.7.5 Loose stone check dam

Loose stone check dam (LSCD) are proposed in the gullies to check erosion till the vegetative cover is established and to conserve enough soil and water for increasing the productivity of the area. It is designed on the concept that, in upper reaches the runoff concentration will be less because of less catchment area whereas for lower reaches, runoff concentration will be more. Therefore, rather constructing uniform cross sectional area of check dam from top to bottom of the drain, it is divided into upper, middle and lower reaches. On the basis of runoff concentration in the drain, the cross section of 0.50 m^2, 1.11 m^2 and 1.18 m^2 are proposed for upper, middle and lower reaches respectively.

Loose stone check dam has been proposed for the Block-K having total area of 152.43 ha. The total cost of work has been estimates to be Rs. 1,30,900. The cost per hectare worked out to be Rs. 858. (Table 4.25). Recommended design, detailed estimate and abstract of estimate are depicted in Fig 4.12, Table 4.17 and 4.18 respectively.

4.7.6 Loose stone fencing wall and afforestation cum pasture development

Loose stone fencing walls have been proposed in Block-I having total area of about 172.55 ha; where afforestation cum pasture development work is proposed. Lands in these blocks fall in land capability classes V with 19.58 per cent slope. These walls are constructed to protect the plantation and pastures. The total length of stone fencing wall to be constructed is 2487 m covering an area of about 172.55 ha. A trapezoidal cross section of 0.84 m^2 was recommended for fencing.

The total cost of work has been estimated to be Rs. 9,35,300.00. The cost per hectare comes out to be Rs. 5420. (Table 4.25). Detailed estimate and abstract of estimate are tabulated in Table 4.19 and 4.20 respectively.

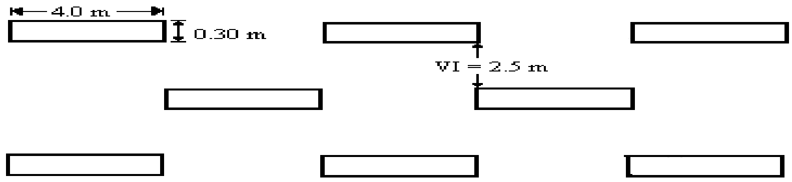

Fig.4.11: Cross section of Staggered Trenches

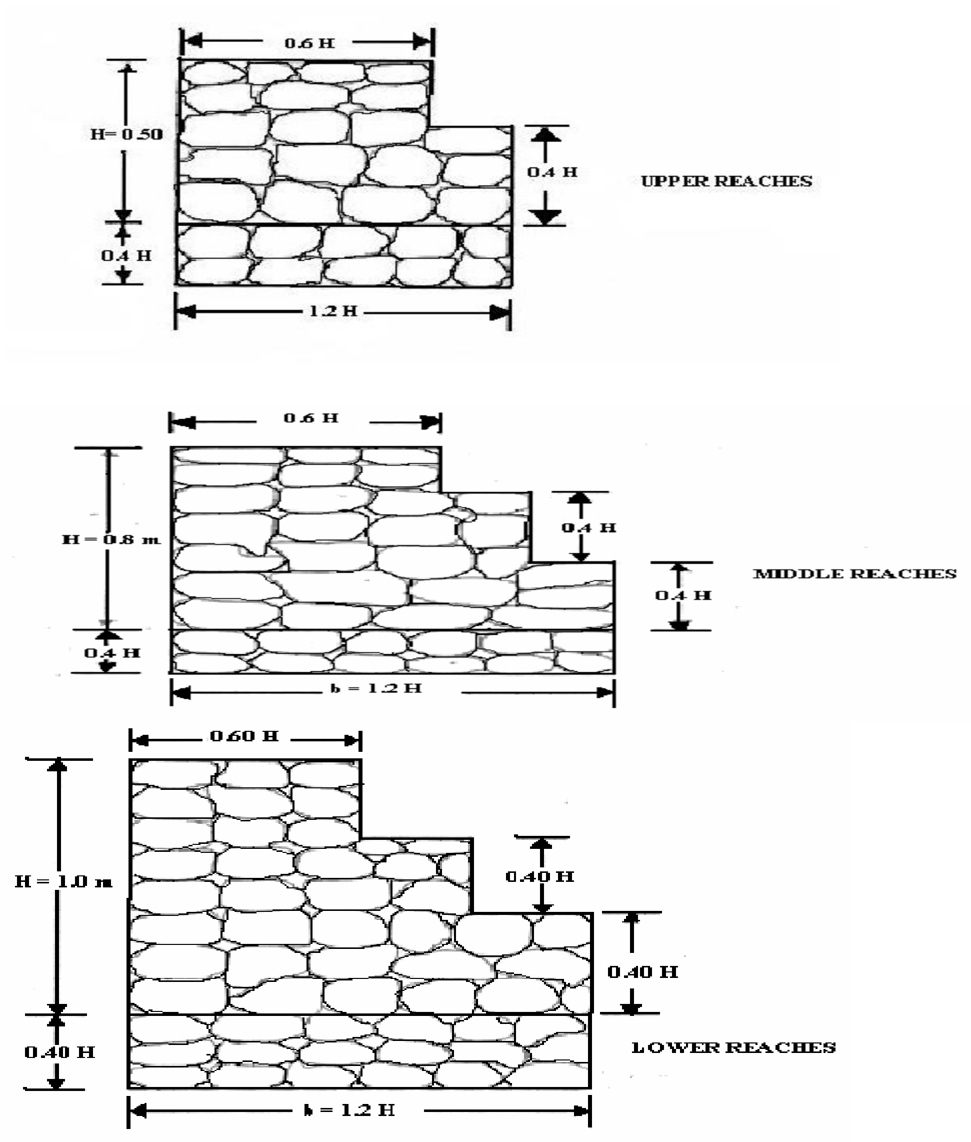

Fig.4.12: Cross section of Loose Stone Check Dam

Table 4.14: Basic design data for Staggered Trenches

S. No.	Particulars			Parameters	
	Block	Area proposed under S.T. (ha)	Slope (%)	X-section (m^2)	Total no. of S.T. (m)
1	H	228.8	32.50	0.09	56033

Table 4.15: Detailed estimate

Name of Work: Construction of Staggered Trenches **Area = 944.88 ha**

S. No.	Detail of Work	No.	Total No. of Staggered Trenches	Measurement (m)			Quantity
				L	B	H/D/T	
1	Dag belling 5 to 7.5 cm deep by manually	2	56033	4	-	-	448264 m
2	Excavation in stony soil or earthwork mixed with kankar, boulders etc. at H. I. = 10 m@ 250 trenches/ha	1	56033	4	0.30	0.30	20171.88 m^3
3	Excavation of pits of size 0.45 m x 0.45 m x 0.45 m and at the interval of 3 m.	1	56033	0.45	0.45	0.45	5106 m^3

Table 4.16: Abstract of estimate

Name of Work: Construction of Staggered Trenches

S. No.	Item	Quantity	Rate (Rs)	Per	Amount (Rs)
1	Dag belling 5 to 7.5 cm deep by manually	448264	1.48	m	663430.72
2	Excavation in stony soil or earth mixed with kankar, boulders etc. including dressing of excavated material with an initial lead of 30 m and lift 1.5 m	20171.88	186.93	m^3	3770729
3	Excavation of pits of size 0.45 m x 0.45 m x 0.45 m and at the interval of 3m.	5106	186.93	m^3	954464.58
Total					5388624.3
Adding 6.5 % contingency or supervision charges					350260.57
Grand Total					5738884
Rounded off amount					5738900

(Source: Rate as per BSR, Gramin Vikas, GKN, Bhinder, Udaipur, 2017-18)

Table 4.17: Detailed estimate

Name of Work: Construction of Loose Stone Check Dam Area= 152.43 ha

S. No.	Detailed of work	Length (m)	Earth work for foundation in hard soil		Dry stone masonry	
			C.S.A. (m^2)	Quantity (m^3)	C.S.A. (m^2)	Quantity (m^3)
1	Upper reaches	190	0.16	30.40	0.50	95.00
2	Middle reaches	125	0.35	43.75	1.11	138.75
3	Lower reaches	40	0.48	19.20	1.18	47.20
	Total	355	-	93.35	-	280.95

Table 4.18: Abstract of estimate

Name of Work: Construction of Loose Stone Check Dam

S. No.	Item	Quantity	Rate (Rs)	Per	Amount (Rs)
1	Excavation in stony soil or moist including disposal of excavated material lead of 30 m and lift of 1.5 m	93.35	124.62	m^3	11633
2	Dry stone masonry up to 2 m height including carriage and rehandling of stone up to 200 m	280.95	395.84	m^3	111211
				Total	122844
				Adding 6.5 % contingency or supervision charges	7984
				Grand Total	130828
				Rounded off amount	130900

(Source: Rate as per BSR, Gramin Vikas, GKN, Bhinder Udaipur, 2017-18)

Table 4.19: Detailed estimate

Name of Work: Afforestation cum pasture development Area = 172.55 ha

S. No.	Detail of Work	No.	Measurement (m)			Quantity
			L	B	H/D/T	
1	Dag belling 5 to 7.5 cm deep by manually	2	2487	-	-	4974 m
2	Dry stone masonry up to 1.2 m height for fencing	1	2487	1.2	0.7	2089 m^3
3	Planting					
	(i) Transportation and planting of samplings	-	-	-	-	5330 Plant
	(ii) Manure and fertilizers	-	-	-	-	5330 Plant
	(iii) Tending operation	-	-	-	-	5330 Plant

	(iv) Watering charges	3x5330				15990 Plant
4	Over seeding of grasses for pasture development in the area of 20 ha @ 5 kg/ha	-	-	-	-	100 kg

Table 4.20: Abstract of estimate

Name of Work: Afforestation cum pasture development

S. No.	Item	Quantity	Rate (Rs)	Per	Amount (Rs)
1	Dag belling 5 to 7.5 cm deep by manually	4974	1.48	m	7361
2	Dry stone masonry up to 1.2 m height for fencing	2089	395.84	m^3	826909
3	Planting				
	(i) Transportation and planting of samplings	5330 Plant	1.50	Plant	7995
	(ii) Manure and fertilizers	5330 Plant	2.00	Plant	10660
	(iii) Tending operation	5330 Plant	0.50	Plant	2665
	(iv) Watering charges	15990 Plant	1.00	Plant	15990
4	Over seeding of grasses for pasture development in the area @ 5 kg/ha	100 kg	66	kg	6600
				Total	878180
				Adding 6.5 % contingency or supervision charges	57081
				Grand Total	935261
				Rounded off amount	935300

(Source: Rate as per BSR, Gramin Vikas, GKN, Bhinder, Udaipur, 2017-18)

4.8 Water Harvesting Structure

Water harvesting structure Anicut is proposed in the watershed area on the basis of site conditions and functional utility.

4.8.1 Anicut

The proposed Anicut has catchment area of 390.07 ha. The height of Anicut is 3.0 m having the support of head wall extension on both sides. The harvested water will be utilized for supplemental irrigation to the down-stream fields through gravity flow. It will induce ground water recharge and the wells located in down-stream areas will be benefited. The 75 per cent of the submergence area may also be utilized for bed cultivation to raise the Rabi crops.

The storage capacity and cost of proposed anicut was estimated to be 0.504 ha-m and Rs.18,46,200 respectively. Recommended design, detailed estimate and abstract of estimate are presented in Fig. 4.13, Table 4.22 to 4.23 respectively.

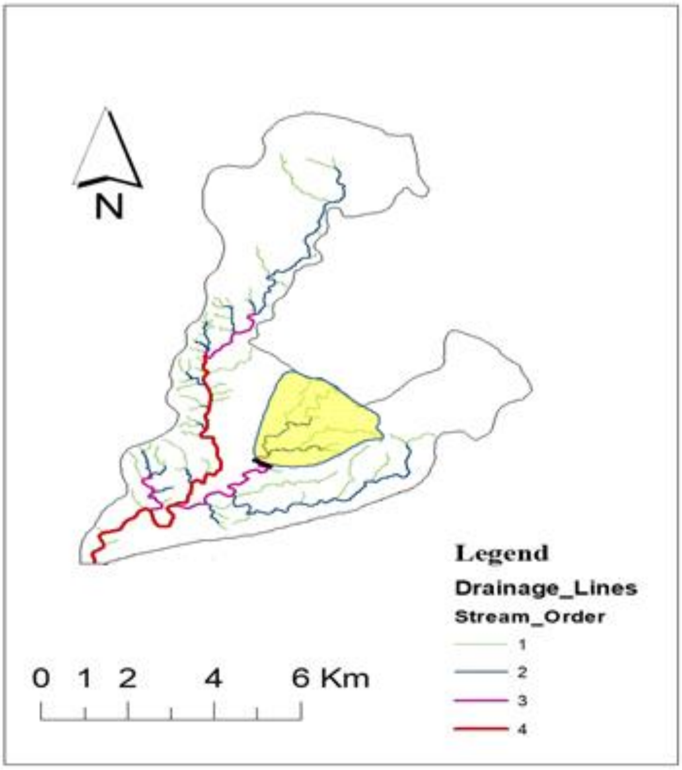

Fig 4.13: Location Map of Anicut

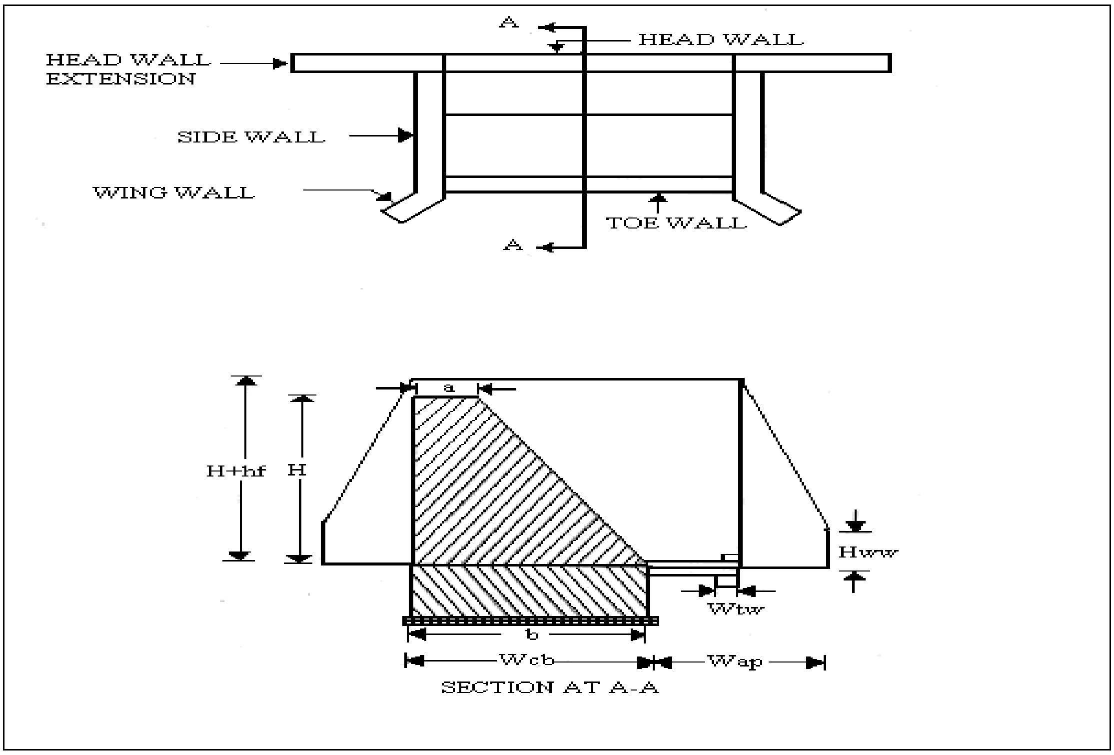

Fig.4.14: Cross section of Anicut

L = 32.00 m	H = 3.00 m	a = 0.60 m	b = 3.00 m
$H+h_f$ = 4.18 m	LHWE = 5.18 m	LSW = 6.58 m	LWW = 2.65 m
W_{ap} = 3.58 m	W_{cb} = 3.76 m		

Table 4.21: Detailed Estimate

Name of Work: Construction of Anicut

S. No.	Name of Work	No.	Measurement (m)			Quantity
			L	B	H/D/T	
1.	Dag belling 5 to 7.5 cm deep					
	(i) Head wall	2	32	-	-	64 m
	(ii) Head wall extension	4	5.18	-	-	20.72 m
	(iii) Side wall	4	6.58	-	-	26.32 m
	(iv) Wing wall	4	2.65	-	-	10.60 m
	(v) Apron	2	32	-	-	64 m
					Total	185.64 m
2.	Excavation of foundation in hard soil including dressing and disposal of excavated material					
	(i) Head wall	1	32	3.0	1.00	96.00 m^3
	(ii) Head wall extension	2	5.18	0.60	1.00	6.21 m^3
	(iii) Side wall	2	6.58	0.90	1.00	11.84 m^3
	(iv) Wing wall	2	2.65	0.60	1.00	3.18 m^3
	(v) Apron	1	32	3.58	0.60	68.73 m^3
	(vi) Cut-off wall	1	32	0.45	0.40	5.76 m^3
					Total	191.72 m^3
3.	Excavation of foundation in ordinary murrum including dressing and disposal of excavated material					
	(i) Head wall	1	32.00	3.00	0.5	48.00 m^3
	(ii) Head wall extension	2	5.18	0.60	0.5	3.10 m^3
	(iii) Side wall	2	6.58	0.90	0.5	5.92 m^3
					Total	57.02 m^3
4.	Excavation of foundation in compact murrum soil					
	(i) Head wall	1	32.00	3.00	0.5	48.00 m^3
	(ii) Head wall extension	2	5.18	0.60	0.5	3.10 m^3
	(iii) Side wall	2	6.58	0.90	0.5	5.92 m^3
					Total	57.02 m^3
5.	Cement concrete well mixed in cement mortar (1:4:8), size of aggregate up to 50 mm					
	(i) Head wall	1	32.00	3.00	0.3	28.8 m^3
	(ii) Head wall extension	2	5.18	0.60	0.3	1.86 m^3
	(iii) Side wall	2	6.58	0.90	0.3	3.51 m^3
	(iv) Wing wall	2	2.65	0.60	0.3	0.95 m^3
	(v) Apron	1	32.00	3.58	0.3	34.36 m^3
	(vi) Cut-off wall	1	32.00	0.45	0.4	5.76 m^3
					Total	75.24 m^3

6.	R.R. stone masonry in cement mortar including curing (1:6) for foundation					
	(i) Head wall	1	32.00	3.00	2.00	192 m^3
	(ii) Head wall extension	2	5.18	0.60	2.00	12.43 m^3
	(iii) Side wall	2	6.58	0.90	2.00	23.68 m^3
	(iv) Wing wall	2	2.65	0.60	1.00	3.18 m^3
	(v) Apron	1	32.00	3.58	0.30	34.36 m^3
					Total	265.65 m^3
7.	R.R stone masonry in cement mortar (1:6) including curing and finishing for super structure					
	(i) Head wall	1	32.00	3.00	3.00	288 m^3
	(ii) Head wall extension	2	5.18	0.60	4.05	25.98 m^3
	(iii) Side wall	2	6.58	0.90	4.05	49.50 m^3
	(iv) Wing wall	2	2.65	0.60	1.58	5.02 m^3
	(v) Toe wall	1	32.00	0.45	0.30	4.32 m^3
					Total	372.82 m^3
8.	Dry Stone kharanja 23 cm thick in cement mortar (1:6) for Apron	1	32.00	3.58	0.3	34.36 m^3
9.	Cement plaster including raking of joints and curing in cement mortar (1:4) 25 mm thick					
	(i) Head wall	1	32.00	-	3.00	96.00 m^2
		1	32.00	0.6	-	19.20 m^2
		1	32.00	-	3.76	120.32 m^2
	(ii) Head wall extension	2	5.18	-	4.18	43.30 m^2
		2	5.18	0.6	-	6.21 m^2
	(iii) Side wall	2	6.58	-	4.18	55.01 m^2
		2	6.58	0.6	-	7.89 m^2
		2	6.58	-	4.18	55.01 m^2
	(iv) Wing wall	2	2.65	-	1.58	8.37 m^2
		2	2.65	0.6	-	3.18 m^2
	(v) Toe wall	2	32.00	-	0.3	19.20 m^2
		1	32.00	0.45	-	14.40 m^2
					Total	448.09 m^2
10.	Flush Pointing in cement mortar (1:3)					
	(i) Head wall	1	32.00	-	3.76	120.32 m^2
	(ii) Head wall extension	2	5.18	-	4.18	43.30 m^2
	(iii) Side wall	2	6.58	-	4.18	55.01 m^2
	(iv) Wing wall	2	2.65	-	1.58	8.37 m^2
					Total	227 m^2

Table 4.22: Estimate of Material

Name of Work: Construction of Anicut

S. No.	Name of material	Quantity	Cement (Bags)	Sand (m^3)	Aggregate (m^3)	Stone (m^3)
1.	Cement concrete mixed in cement mortar (1:4:8)	75.24 m^3	301	32.97	63.93	-
2.	R.R. Masonry (1:6)	632.68 m^3	883	190.80	-	698.85
3.	Stone Kharanja	34.36 m^3	5	1.01	-	8.50
4.	Plaster 1:4, 25 mm thick	448.09	120	17.20	-	-
5.	Flush pointing (1:3) cement mortar	227	15	1.45	-	-
	Total		1324 or 66.20 MT	243.43	63.93	706.50

Table 4.23: Abstract of Estimates for Construction of Anicut

S. No.	Detail of work	Quantity	Rate (Rs.)	Per	Amount (Rs.)
1.	Dag belling of 5 to 7.5 cm deep	185.64	1.48	m	274.74
2.	Excavation of foundation in hard soil	191.72	124.62	m^3	23892.14
3.	Excavation of foundation in ordinary murrum	57.02	186.93	m^3	10658.74
4.	Excavation of foundation in compact murrum	57.02	251.25	m^3	14326.27
5.	Cement concrete well mixed in cement mortar (1:4:8), size of aggregate up to 50 mm	75.24	1125.25	m^3	84663.81
6.	R.R. stone masonry in cement mortar (1:6)				
	(i) For foundation	265.65	2259.66	m^3	600278.67
	(ii) For super structure	372.82	2259.66	m^3	842446.44
7.	Stone kharanja in cement mortar (1:6) for Apron	34.36	314.05	m^3	10790.75
8.	Cement plaster in cement mortar (1:4) 25 mm thick	448.09	148.00	m^2	43874.60
9.	Flush pointing in cement mortar	227	75.45	m^2	17127.15
10.	Carriage of construction material including loading, unloading, staking etc.				
	(i) Cement up to lead of 10 km	66.20	161.70	MT	10704.54
	(ii) Sand up to lead of 5 km	241.37	136.00	m^3	32826.32
	(iii)Aggregate up to lead of 2 km	63.93	54.00	m^3	3452.22
	(iv) Stone up to lead of 2 km	706.50	54.00	m^3	38115

Total	1733431
Adding 6.5% contingency or supervision charges	112673
Grand Total	1846104
Rounded off amount	1846200

(Source: Rate as per BSR, Gramin Vikas, GKN, Bhinder, Udaipur, 2017-18)

Table 4.24: Proposed soil and water conservation measures in different block of Kanore micro watershed

S. No.	Proposed measures	Block	Slope (%)	Area (ha)
1	Contour Bund	A, F, J	1.75, 3.80, 5.60	246.03
2	Puerto Rico Terrace	B	9.40	553.74
3	Contour Trench	I	19.75	172.55
4	Staggered Trenches	H	32.50	228.8
5	Loose Stone Check Dam	K	14.60	152.43
6	Afforestation Cum Pasture Development	I	19.58	172.55
7	Anicut	-	-	390.07

Table 4.25: Appropriate soil and water conservation measures, water harvesting structure for Kanore micro watershed

S. No.	Proposed measures	Area (ha)	Cost (Rs)	Cost/ha (Rs)
1	Contour Bund	246.03	2976000	11271
2	Puerto Rico Terrace	553.74	9679400	17480
3	Contour Trench	172.55	977100	5662
4	Staggered Trenches	228.8	5738900	25082
5	Loose Stone Check Dam	152.43	130900	858
6	Afforestation Cum Pasture Development	172.55	935300	5420
7	Anicut	-	1846200	-

4.9 Economic Analysis

The payback period was assumed as 10 years for estimating present worth of incremental income and cost incurred in the project.

The statement showing cost of cultivation and assessment of the returns from the effect of treatment is presented in Table 4.26. Cost of cultivation of principal crops has been taken from Directorate of Economics and Statistics. The net incremental rate of return has been computed to be Rs. 51.2 lacs per year.

The economic analysis of Kanore watershed shows that benefit-cost ratio under economic and financial evaluation comes out to be 1.54:1 and 2.17:1 respectively which indicates that project is economically and financially viable.

Table 4.26: Statement showing cost of cultivation and assessment of returns

Land Capability Class	Season	Name of Crop	Area (ha)	* Cost of Cultivation (Rs./ha)	Gross Return (Rs./ha)	Total Cost of Cultivation (Rs.)	Total Gross Return (Rs.)	Net Return (Rs. in Lacs)
(A) Return before project								
III, IV	Kharif	Maize	97	25344	27678	2458368	2684766	226398
		Sorghum	33	12045	15500	397485	511500	114015
		Black gram	52	16353	23593	850356	1226836	376480
	Rabi	Wheat	27	31630	53551	854010	1445877	591867
		Gram	6	14646	20667	87876	124002	36126
		Mustard	4	20829	37448	83316	149792	66476
		Barley	3	24094	35744	72282	107232	34950
							Total	**1446312**
(B) Return after project								
III, IV	Kharif	Maize	123	40145	53676	4937835	6602148	1664313
		Sorghum	42	25575	35835	1074150	1505070	430920
		Black gram	76	30353	53761	2306828	4085836	1779008
	Rabi	Wheat	47	53345	98656	2507215	4636832	2129617
		Gram	12	25876	45659	310512	547908	237396
		Mustard	7	42368	76348	296576	534436	237860
		Barley	5	50987	67846	254935	339230	84295
Incremental rate of return = 6563409– 1446312 = 5117097 per year							**Total**	**6563409**

Source: - (Cost of Cultivation of Principal Crops taken from Directorate of Economics and Statistics Jaipur 2017-18)

Table 4.27: Economic Evaluation (B:C Ratio)

Name of Work: Contour bund, Puerto rico terrace, Stone wall terrace, Contour trench, Staggered trench, Afforstation cum pasture development, Loose stone check dam, Anicut

No. of Years	Capital Cost (Rs.)	Repair and Maintenance Charges @ 10% (Rs.)	Expenditure on Survey and Execution @ Rs. 280/ha	Total Cost (Rs.)	Net Incremental Income (Rs.)	Present Worth of Total Cost @ 10% (Rs.)	Present Worth of Incremental Income (Rs.)	B:C Ratio
1	13315000		232400	13547400		13547400		**1.54:1**
2		1331500		1331500	5117097	1210455	4651906	
3		1331500		1331500	5372952	1100413	4440456	
4		1331500		1331500	5641599	1000376	4238617	
5		1331500		1331500	5641599	909432	3853288	
6		1331500		1331500	5641599	826757	3502989	
7		1331500		1331500	5641599	751597	3184536	
8		1331500		1331500	5641599	683270	2895033	
9		1331500		1331500	5641599	621155	2631848	
10					5641599	-	2392589	
					Total	**20650854**	**31791262**	

Table 4.28: Financial Evaluation (calculation for interest)

Name of Work: Contour bund, Puerto rico terrace, Stone wall terrace, Contour trench, Staggered trench, Afforstation cum pasture development, Loose stone check dam, Anicut

S.No.	Capital cost (Rs.)	Yearly loan installment (Rs.)	Amount on which the interest is to be paid (Rs.)	Amount of interest @ 12% (Rs.)	Total Amount Paid by cultivators (Rs.)
1	13315000	1331500	-	-	1331500
2		1331500	11983500	1438020	2769520
3		1331500	10652000	1278240	2609740
4		1331500	9320500	1118460	2449960
5		1331500	7989000	958680	2290180
6		1331500	6657500	798900	2130400
7		1331500	5326000	639120	1970620
8		1331500	3994500	479340	1810840
9		1331500	2663000	319560	1651060
10		1331500	1331500	159780	1491280
	Total	**13315000**			**20505100**

Table 4.29: Financial Evaluation (B:C Ratio)

Name of Work: Contour vegetative bund, Contour bund, Puerto rico terrace, Stone wall terrace, Contour trench, Staggered trench, v-ditch, Afforstation cum pasture development, Loose stone check dam, Anicut

No. of years	Capital Cost Including Interest (Rs.)	Repair and Maintenance Charges @ 10% of Capital Cost (Rs.)	Total Cost (Rs.)	Benefit Including 30% Subsidy (Rs.)	B:C Ratio
1	20505100		20505100	6151530	2.17:1
2	-	1331500	1331500	6465210	
3	-	1331500	1331500	6761620	
4	-	1331500	1331500	6930956	
5	-	1331500	1331500	6930956	
6	-	1331500	1331500	6930956	
7	-	1331500	1331500	6930956	
8	-	1331500	1331500	6930956	
9	-	1331500	1331500	6930956	
10	-	-	-	6930956	
		Total	**31157100**	**67895052**	

V – SUMMARY AND CONCLUSIONS

A study was conducted for planning and designing of Kanore micro-watershed using remote sensing and GIS. The project area lies between 74°10' to 74°16' E longitude and 24°23' to 24°30' N latitude Kanor is a Village in Bhinder block in Udaipur District of Rajasthan State, India.

In the present study, an effort has been made to highlight the use of remote sensing and GIS for the watershed planning. Remote sensing data of study area was used from satellite imagery IRS-1C-LISS-III dated 26-03-2009 at Regional Centre of NBSS and LUP, Udaipur, Rajasthan Firstly, watershed delineation was carried out using Arc/INFO 10.1 GIS tool. The input data for the digital delineation was the contour map of the study area derived from the SOI toposheets, from which Digital Elevation Model and topography of the study area were generated.

It was analyzed in the process of study that use of GIS can make the cumbersome geomorphological analysis as an easy task. The determination of geomorphological characteristics includes area and perimeter, stream number (order wise), stream length, basin length, stream frequency, bifurcation ratio, stream length ratio, form factor, circulatory ratio, elongation ratio, drainage density, relief ratio, relative relief, ruggedness number and geometric number. The calculated values of geomorphological characteristics were interpreted in terms of drainage basin characteristics.

Further, with the help of remote sensing and GIS, land use capability classification of the watershed was carried out. The area under arable and non-arable land was found to be 4019.59 ha and 1368.41 ha respectively. Probability analysis of rainfall data of 30 years (1987-2016) of Bhinder block was analyzed by Weibull’s technique which was further used for planning of water harvesting structure.

The total geographical area of the delineated watershed was determined to be 5388 ha and divided into fifteen different blocks on the basis of slope groups. The appropriate soil and water conservation measures for the watershed were planned and designed on the basis of rainfall, land use capability classification and topography of the area. Contour bunds, Puerto rico terrace and were proposed for the arable land while contour trench, staggered trench, and afforestation cum pasture development were proposed for non-arable land in the area. Structure like loose stone check dam was designed and proposed for drainage line treatment.

Water harvesting structure (Anicut) has been proposed in the watershed area on the basis of site condition and its functional utility. The cost of Anicut was estimated to be Rs. 18,46,200.00 and the storage capacity of the Anicut is 1.73 ha-m. The harvested water will be utilized for providing supplement irrigation to the nearby and downstream fields and also for livestock drinking. The well located in the downstream area will also be benefited due to continuous recharging.

The economic analysis of the designed structures has been made to check the economic feasibility of the project using economic and financial evaluation method. Benefit cost ratio of the project was estimated to be 1.54:1 and 2.17:1 by economical and financial evaluation respectively, which shows that the project is feasible from engineering and economic point of view.

Based on the above study following conclusions were drawn.

CONCLUSIONS

1. Low value of Bifurcation ratio (4.16) revealed that drainage pattern has not been distorted by structural disturbance whereas high value of elongation ratio (0.37) compare to circulatory ratio (0.22) indicates elongated shape of watershed.
2. Relief ratio (0.015) and relative relief (0.27 %) reflects that the watershed be treated with soil and water conservation measures.
3. Conventional method of morphometric analysis is time consuming, tedious and error prone. Integration of remote sensing and GIS allows reliable, accurate and updated database on morphometric parameters of a watershed.
4. Land use capability classification shows that about 4019.59 ha area takes under arable land whereas 1368.41 ha area is under non-arable land.
5. For the arable land, Contour bunds, Puerto rico terrace whereas for non-arable land Contour trench, Staggered trench, and Afforestation cum pasture development are proposed for the purpose of soil and water conservation.
6. Costs per hectare for Contour bunds, Puerto rico terrace were estimated to be Rs. 11271.00, Rs. 17480.00 respectively whereas for Contour trench, Staggered trench, and Afforestation cum pasture development the same has been estimated to be Rs. 5662.00, Rs. 25082.00, and Rs. 5420.00 respectively.
7. The cost/no. of loose stone check dam recommended for drainage line treatment with varying cross section on the basis of upper, middle and lower reaches was worked out to be Rs. 858.00.

8. The storage capacity and cost of proposed Anicut was estimated to be 1.73 ha-m and Rs. 18,46,200.00 respectively.
9. The Benefit cost ratio for the project was estimated to be 1.54:1 and 2.17:1 by economical and financial evaluation respectively which shows that the project is feasible from engineering and economic point of view.
10. The overall cost per hectare for all structures is estimated Rs. 13419.

REFERENCES

Aher, P.D., Adinarayana, J. and Gorantiwar, S.D., 2014. Quantification of morphometric characterization and prioritization for management planning in semi-arid tropics of India: a remote sensing and GIS approach. *Journal of Hydrology* **511** : 850-860.

Alam, N.M., Ranjan, R., Adhikary, P.P., Kumar, A., Jana, C., Panwar, S., Mishra, P.K. and Sharma, N.K., 2016. Statistical modelling of weekly rainfall data for crop planning in Bundelkhand region of central India. *Indian Journal of Soil Conservation* **44** : 336-342.

Alemayehu, F., Taha, N., Nyssen, J., Girma, A., Zenebe, A., Behailu, M., Deckers, S. and Poesen, J., 2009. The impacts of watershed management on land use and land cover dynamics in Eastern Tigray (Ethiopia). *Resources, Conservation and Recycling* **53** : 192-198.

Amsalua, A. and De Graaff, J., 2007. Determinants of adoption and continued use of stone terraces for soil and water conservation in an Ethiopian highland watershed. *Ecological Economics* **61** : 294-302.

Bahadur, K.C. 2011. Linking physical, economic and institutional constraints of land use change and forest conservation in the hills of Nepal. *Forest Policy and Economics* **13** : 603–613.

Baker, M.E., Weller, D.E. and Jordan, T.E., 2006. Comparison of automated watershed delineations. *Photogrammetric Engineering & Remote Sensing* **72** : 159-168.

Bansal., 2004. Analysis of 25 years rainfall data of Pantnagar by using Markov-chain model to predict the sequences of wet and dry days, CTAE, MPUAT, Udaipur. *Unpublished M.E. thesis* pp. 26-30.

Bhuriya, V. and Dev, P., 2014. Quantitative Morphometric Analysis of Pat River Basin in Meghnagar Area, Jhabua District, Madhya Pradesh, India. *International Journal of Fundamental & Applied Research* **1** : 51-59.

Bohner, J. and Bechtel, B., 2017. GIS in climatology and meteorology. *Comprehensive Geographic Information Systems Elsevier* **2** : 196-235.

Borkar, V.S., Gokhale, N.B., More, S.S., Wahane, M.R. and Khobragade, N.H., 2018. Mapping land use/cover using remote sensing and GIS techniques: A case study of rahat micro watershed of Nagpur district, India, *International Journal of Chemical Studies* **6** : 15-18.

Bose, A.S.C., Viswanadh, G.K., Giridhar, M.V.S.S. and Sridhar, P., 2012. Watershed Delineation and Stream Network Analysis Using GIS. *International journal of Watershed Engineering* **1** : 213-218.

Choudhari, P.P., Nigam, G.K., Singh, S.K. and Thakur, S., 2018. Morphometric based prioritization of watershed for groundwater potential of Mula river basin, Maharashtra, India. *Geology, Ecology, and Landscapes* **2** : 1-12.

Freitas, D.A., da Costa Freitas, C., Rosim, S. and de Freitas Oliveira, J.R., 2016. Drainage networks and watersheds delineation derived from TIN-based digital elevation models. *Computers & Geosciences* **92** : 21-37.

Dhabale, S., Singh, P.K. and Singh, R.S. 2014. Morphometric analysis of Chanvada micro-watershed using Remote sensing and GIS. *Journal of Soil and Water Conservation* **13** : 10-15.

Dhanya, C.T. and Kumar, D.N., 2010. Nonlinear ensemble prediction of chaotic daily rainfall. *Advances in Water Resources* **33** : 327-347.

Dabral, P.P., Choudhury, K. and Debbarma, S., 2016. Probability analysis of 5-day antecedent rainfall at different return periods and seasons for Doimukh (Itanagar), Arunachal Pradesh. *Indian Journal of Soil Conservation* **44** : 332-335.

Gong, T., Lei, H., Yang, D., Jiao, Y. and Yang, H., 2017. Monitoring the variations of evapotranspiration due to land use/cover change in a semiarid shrubland. *Hydrology and Earth System Sciences* **21** : 863.

Gowd, S.S., 2004. Morphometric analysis of Peddavanka basin, Anantapur district, Andhra Pradesh, India. *Journal of Applied Hydrology* **17** : 1-8.

Hollenhorst, T.P., Brown, T.N., Johnson, L.B., Ciborowski, J.J. and Host, G.E., 2007. Methods for generating multi-scale watershed delineations for indicator development in Great Lake coastal ecosystems. *Journal of Great Lakes Research* **33** : 13-26.

Horton, R.E., 1932. Drainage-basin characteristics. *Ecosystem, Transactions American Geophysical Union* **13** : 350-361.

Horton, R.E., 1945. Erosional development of streams and their drainage basins; hydro-physical approach to quantitative morphology. *Geological Society of America Bulletin* **56** : 275-370.

Ikbal, J. and Ali, S.A., 2017. Site Selection for Soil Conservation by Geometric Analysis of Watershed Using Remote Sensing and GIS. *International Journal of Scientific Research in Science and Technology* **8** : 369-378.

Ilorme, F. and Griffis, V.W., 2013. A novel procedure for delineation of hydrologically homogeneous regions and the classification of ungauged sites for design flood estimation. *Journal of Hydrology* **492** : 151-162.

Javed, A., Khanday, M.Y. and Rais, S., 2011. Watershed prioritization using morphometric and land use/land cover parameters: a remote sensing and GIS based approach. *Journal of the Geological Society of India* **78** : 63-75.

Kanth, T.A. and Hassan, Z., 2012. Morphometric analysis and prioritization of watersheds for soil and water resource management in Wular catchment using geo-spatial tools. *International Journal of Geology, Earth and Environmental Sciences* **2** : 30-41.

Kaur, R. and Dutta, D., 2002. GIS-based digital delineation of watershed and its advantage over conventional manual method-A Case Study on watersheds in Hazaribagh and Bankura Districts of Jharkhand and West Bengal. *Indian Journal of Soil Conservation* **30** : 1-7.

Khan, A., Richards, K.S., Parker, G.T., McRobie, A. and Mukhopadhyay, B., 2014. How large is the Upper Indus Basin? The pitfalls of auto-delineation using DEMs. *Journal of Hydrology* **509** : 442-453.

Kothari, A.K., Jain, P.M. and Kumar, V., 2009. Analysis of weekly rainfall data using onset of monsoon approach for micro level crop planning. *Indian Journal of Soil Conservation* **37** : 164-171.

Kumar, H. 2006. Planning and designing of Kalora-II micro-watershed using remote sensing and GIS. *Unpublished M.E. thesis,* CTAE, MPUAT, Udaipur, Rajashtan. pp. 37- 42.

Kumar, R., Lohani, A.K., Kumar, S., Chatterjee, C. and Nema, R.K., 2000. GIS based Morphometric Analysis of Ajay river basin upto Sarathh gauging site of South Bihar, *Journal of Applied Hydrology* **14** : 45-54.

Kumar, V., Singh, R.S., Singh, P.K. and Singhvi, B.S.M., 2007. Standardization of Suitable Soil and Water Conservation Measures Using Remote Sensing and GIS for Small Watersheds. *Journal of Agricultural Engineering* **44** : 67-73.

Li, S., Gu, S., Liu, W., Han, H. and Zhang, Q., 2008. Water quality in relation to land use and land cover in the upper Han River Basin, China. *Catena* **75** : 216-222.

Luo, Y., Su, B., Yuan, J., Li, H. and Zhang, Q., 2011. GIS techniques for watershed delineation of SWAT model in plain polders. *Procedia Environmental Sciences* **10** : 2050-2057.

Mandal, D., Dhyani, B.L., Kumar, A., Singh, C., Bihari, B., Muruganandam, M. and Madhu, M., 2013. Impact of different land use systems on soil quality in northwest Himalayan region. *Indian Journal of Soil Conservation* **41** : 200-205.

Mehra, G., 2012. GIS Based Delineation of Micro-watershed and its Applications: Mahendergarh District, Haryana. *Journal of Human Ecology* **38** : 155-164.

Meshram, S.G. and Singh, V.P., 2018. Probabilistic Estimation of Design Daily Runoff from Bamhani Watershed, India. *Hydrologic Modeling, Springer* **2** : 37-51.

Mishra, S.S. and Nagarajan, R., 2010. Morphometric analysis and prioritization of sub-watersheds using GIS and remote sensing techniques: a case study of Odisha, India. *International Journal of Geomatics and Geosciences* **1** : 501-510.

Mittal, H.K., 2002. *Evaluatory Study on Morphological Characteristics and Ground Water Status in Selected Treated Watersheds Unpublished Ph.D thesis*, Department of Soil and Water Engineering CTAE,: Udaipur. pp. 76-81

Munroe, D.K. and Müller, D., 2007. Issues in spatially explicit statistical land-use/cover change (LUCC) models: Examples from western Honduras and the Central Highlands of Vietnam. *Land Use Policy* **24** : 521-530.

Mwalusepo, S., Muli, E., Faki, A. and Raina, S., 2017. Land use and land cover data changes in Indian Ocean Islands: case study of Unguja in Zanzibar Island. *Elsevier* **11** : 117-121.

Nag, S.K. and Chakraborty, S., 2003. Influence of rock types and structures in the development of drainage network in hard rock area. *Journal of the Indian Society of Remote Sensing* **31** : 25-35.

Narendra, K. and Rao, K.N., 2006. Morphometry of the Meghadrigedda watershed, Visakhapatnam district, Andhra Pradesh using GIS and Resources at data. *Journal of the Indian Society of Remote Sensing* **34** : 101-110.

Nayar, V. and Natarajan, K., 2013. Quantitative Morphometric analysis of Kosasthalaiyar sub basin (Chennai basin) using remote sensing (SRTM) data and GIS techniques. *International Journal of Geomatics and Geosciences* **4** : 89-102.

Nguyen, T.H., 2016. Statistical Modeling of Extreme Rainfall Processes (SMExRain): A Decision Support Tool for Extreme Rainfall Frequency Analyses. *Procedia Engineering* **154** : 624-630.

Nookaratnam, K., Srivastava, Y.K., Rao, V.V. Amminedu, E. and Murthy, K.S.R. 2005. Check dam positioning by prioritization of micro-watersheds using SYI model and morphometric analysis – remote sensing and GIS perspective. *Journal of Indian Society of Remote Sensing* **33** : 25-38.

Norini, G., Zuluaga, M.C., Ortiz, I.J., Aquino, D.T. and Lagmay, A.M.F., 2016. Delineation of alluvial fans from Digital Elevation Models with a GIS algorithm for the geomorphological mapping of the Earth and Mars. *Geomorphology* **273** : 134-149.

Pande, V.C., Kurothe R.S., Singh H.B. and Tiwari, S.P. 2011. Incentives for Soil and Water Conservation on Farm in Ravines of Gujarat: Policy Implications for Future Adoption. *Agricultural Economics Research Review* **24** : 109-118.

Pandey, A., V.M. Chowdary and Mal, B.C. 2004. Morphological analysis and watershed management using GIS. *Hydrology Journal* **27** : 71-84.

Panhalkar, S., 2011. Land capability classification for integrated watershed development by applying remote sensing and gis techniques. *Journal of Agricultural and Biological Science* **6** : 46-55.

Panwar, P., Pal, S., Bhatt, V.K. and Tiwari, A.K., 2012. Impact of conservation measures on hydrological behaviour of small watersheds in the lower Shivaliks. *Indian Journal of Soil Conservation* **40** : 257-262.

Patle, G.T., 2008. Probability analysis of consecutive days annual maximum rainfall for the design of surface drains in semi-arid Maharastra. *Indian Journal of Soil Conservation* **36** : 144-147.

Praveen, J., Gowda, H.C., HombeNaik B.S., Barman D. 2011. Probability analysis of rainfall characteristics of Semiliguda in Koraput, Orissa. *Indian Journal of Soil Conservation* **39** : 9-13.

Ramos, M.C., Benito, C. and Martínez-Casasnovas, J.A., 2015. Simulating soil conservation measures to control soil and nutrient losses in a small, vineyard dominated, basin. *Agriculture, Ecosystems & Environment* **213** : 194-208.

Rao, B.K., Gaur, M.L., Kumar, G., Kurothe, R.S. and Tiwari, S.P., 2013. Morphological characterization and alterations in cross section of different order streams of Mahi river in Gujarat. *Indian Journal of Soil Conservation* **41** : 20-24.

Rao, N.K., Latha, S.P., Kumar, A.P. and Krishna, H.M., 2010. Morphometric analysis of Gostani River basin in Andhra Pradesh state, India using Spatial information technology. *International Journal of Geomatics and Geosciences* **1** : 179-187.

Rudraiah, M., Govindaiah, S. and Vittala, S.S., 2008. Morphometry using remote sensing and GIS techniques in the sub-basins of Kagna river basin, Gulburga district, Karnataka, India. *Journal of the Indian Society of Remote Sensing* **36** : 351-360.

Sadgir, P.A., Patil, G.K. and Takalkar, V.G., 2006, November. Sustainable watershed development by refilled continuous contour trenching technology. In *Proceeding of National Seminar on Rainwater Harvesting and Water Management*, pp.11-12.

Sahu, J., 2017. Study on pattern of rainfall in rainshadow districts of Chhattisgarh State *Unpublished M.Sc. thesis*, Indira Gandhi Krishi Vishwavidhyalaya, Raipur, pp. 22-31.

Saranga, D., Samarakoon, K.K., Adikari, S.B. and Hewawasam, T., 2017. Impact of soil and water conservation measures on soil erosion rate and sediment yields in a tropical watershed in the Central Highlands of Sri Lanka. *Applied Geography* **79** : 103-114.

Savita, R.S., Mittal, H.K., Satishkumar, U., Singh, P.K., Yadav, K.K., Jain, H.K., Mathur, S.M. and Davande, S., 2018. Delineation of Groundwater Potential Zones using Remote Sensing and GIS Techniques in Kanakanala Reservoir Subwatershed, Karnataka, India. *International Journal of Current Microbiology and Applied Science* **7** : 273-288.

Saxena, K.G., Wakeel, A., Rao, K.S., Maikhuri, R.K., 2005. Forest management and land use/cover changes in a typical micro watershed in the mid elevation zone of Central Himalaya, India. *Forest Ecology and Management* **21** : 229–242.

Sharma, K.K. and Dubey, S.K., 2013. Probability analysis of rainfall for planning water harvesting and Irrigation in semi-arid region of Uttar Pradesh. *Indian Journal of Soil Conservation* **41** : 14-19.

Sharma, P., Rai, S.C., Sharma, R. and Sharma, E., 2004. Effects of land-use change on soil microbial C, N and P in a Himalayan watershed. *Pedobiologia* **48** : 83-92.

Shoji, T., Kitaura H. 2006. Statistical and geostatistical analysis of rainfall in central Japan. *Computers & Geosciences* **32** : 1007–1024.

Singh, I. 1998. Planning and designing of appropriate soil and water conservation measures for Southern Rajasthan *M. E. (Ag.)* thesis, CTAE, RAU, Bikaner.

Singh, M. 2005. Planning and designing of appropriate soil and water conservation measures in Kadmal watershed. *Unpublished M.E. thesis,* CTAE, MPUAT, Udaipur. pp. 32-46.

Singh, P.K. 2000. Watershed management: design and practices. e-media publications, India. pp.74-87.

Singh, R.K., Bhatt, C.M. and Prasad, V.H., (2003). Morphological study of watershed using remote sensing and GIS techniques. *Hydrology Journal* **26** : 55-66.

Singh, S., 2012. Land suitability evaluation and land use planning using remote sensing data and geographic information system techniques. *International Journal of Geology Earth Environment Science* **2** : 1-6.

Sinha, A. K. 2012. An integrated approach of groundwater management in wakal river basin using Remote Sensing and GIS. *Unpublished Ph.D thesis,* CTAE, MPUAT, Udaipur, Rajashtan. pp. 82-89.

Sreedevi, P.D., Owais, S., Khan, H.H. and Ahmed, S., 2009. Morphometric analysis of a watershed of South India using SRTM data and GIS. *Journal of the Geological Society of India* **73** : 543-552.

Sreenivasulu, V. and Bhaskar, P.U., 2010. Change detection in landuse and landcover using remote sensing and GIS techniques. *International Journal of Engineering Science and Technology* **2** : 7758-7762.

Strahler, A. N. 1964. Quantitative geomorphology of drainge basins and channel networks. Section 4-11 in *Handbook of Applied Hydrology* (ed. by V. T. Chow), Mc Graw Hill, New York. pp. 54-69

Subramanya, K. 2015. Engineering hydrology. Mc graw hill education private limited, India. 50 pp. 34-38

Subudhi, C.R., Sahoo, M. and Senapati, S.C., 2012. Rainfall probability analysis for crop planning in Kandhamal district of Orissa, India. *Indian Journal of Soil Conservation* **40** : 247-251.

Thakkar, A.K. and Dhiman, S.D., 2007. Morphometric analysis and prioritization of mini-watersheds in Mohr watershed, Gujarat using remote sensing and GIS techniques. *Journal of the Indian society of Remote Sensing* **35** : 313-321.

Tetzlaff, B., Petra, K.,Vereecken, H., Wendland, F. (2009). Aerial photograph-based delineation of artificially drained areas as a basis for water balance and phosphorus modelling in large river basins. *Physics and Chemistry of the Earth* **34** : 552-564.

Wakeel, A., Rao, K.S., Maikhuri, R.K., Saxena, K.G. 2005. Forest management and land use/cover changes in a typical micro watershed in the mid elevation zone of Central Himalaya, India. *Forest Ecology and Management* **21** : 229–242.

Wang, D., Gong, J., Chen, L., Zhang, L., Song, Y. and Yue, Y., 2012. Spatio-temporal pattern analysis of land use/cover change trajectories in Xihe watershed. *International Journal of Applied Earth Observation and Geoinformation* **14** : 12-21.

Wang, D., Gong, J., Chen, L., Zhang, L., Song, Y. and Yue, Y., 2013. Comparative analysis of land use/cover change trajectories and their driving forces in two small watersheds in the western Loess Plateau of China. *International Journal of Applied Earth Observation and Geoinformation* **21** : 241-252.

Wolter, P.T., Johnston, C.A. and Niemi, G.J., 2006. Land use land cover change in the US Great Lakes basin 1992 to 2001. *Journal of Great Lakes Research* **32** : 607-628.

Zhou, X., Al-Kaisi, M. and Helmers, M.J., 2009. Cost effectiveness of conservation practices in controlling water erosion in Iowa. *Soil and Tillage Research*, pp.71-78.

Zope, P.E., Eldho, T.I. and Jothiprakash, V., 2016. Impacts of land use–land cover change and urbanization on flooding: A case study of Oshiwara River Basin in Mumbai, India. *Catena* **145** : 142-154.

ABSTRACT

Development programmes concerning optimum utilization of natural resources (soil, water and vegetation) are now increasingly oriented with a watershed as an integral unit. For giving practical shape to the systematic, scientific and rational approach of watershed, a proper delineation of watershed is pre-requisite. In the present study, delineation of watershed is done digitally in the remote sensing and GIS environment instead of manual delineation. The total area of Kanore watershed is 5388 ha. Further, the geomorphological characteristic of watershed has been studied using GIS technique. A quantitative morphometric analysis enables us to understand the relationship among different aspects of the drainage pattern of the watershed. With the help of the remote sensing and GIS techniques, the land use capability classification of the watershed was also done. It gives the systematic arrangement of land according to their properties that determine the ability of land to produce on virtually permanent basis. The treatable area of watershed under arable and non-arable land is 4019.59 ha and 1368.41 ha respectively. Rainfall data of 30 years (1987-2016) for Kanore were analyzed for probability distribution at different levels using Weibull's technique. At 75%, 50%, and 25% probability analysis level, annual rainfall is 439 mm, 600 and 666 mm respectively. The data were analyzed for designing purpose of water harvesting structure.

The appropriate agricultural and engineering measures adaptable in the watershed were designed on the basis of rainfall analysis, land use capability classification and topography of the area. Contour bund, Purto-rico terrace, were proposed for arable land whereas Contour trench, Staggered trench were proposed for non-arable land for the purpose of soil and water conservation. For the treatment of drainage line, loose stone check dams of different dimensions were proposed as per their available catchment area. The class V land was proposed to be treated with afforestation cum pasture development.

For harvesting of excess runoff, one water harvesting structure (Anicut) having storage capacity of 1.73 ha-m was designed. The cost of anicut was estimated to be Rs. 18.46 lacs. Overall cost per hectare of watershed treatment excluding the cost of water harvesting structure was estimated to be Rs. 13419.

The economic analysis of Kanore watershed shows that benefit-cost ratio under economic and financial evaluation is 1.54:1 and 2.17:1 respectively which indicates that project is economically and financially viable.

अनुक्षेपण

प्राकृतिक संसाधनों (मिट्टी, पानी और वनस्पति) के इष्टतम उपयोग से संबंधित विकास कार्यक्रम अब एक अभिन्न इकाई के रूप में जलविभाजन के साथ तेजी से उन्मुख हैं। जलविभाजन के व्यवस्थित, वैज्ञानिक और तर्कसंगत दृष्टिकोण को व्यावहारिक रूप देने के लिए, जलविभाजन का उचित चित्रण पूर्व-आवश्यक है। वर्तमान अध्ययन में, जलविभाजन का चित्रण मानवीय चित्रण के बजाय रिमोट सेंसिंग और जीआईएस पर्यावरण में डिजिटल रूप से किया जाता है। कानोड़ जलविभाजन का कुल क्षेत्र 5388 हेक्टेयर है। इसके अलावा, जीआईएस तकनीक का उपयोग करके जलविभाजन की भू-भौगोलिक विशेषता का अध्ययन किया गया है। एक मात्रात्मक आकृति विश्लेषण हमें जलविभाजन के जल निकासी तरीका के विभिन्न पहलुओं के बीच संबंधों को समझने में सक्षम बनाता है। रिमोट सेंसिंग और जीआईएस तकनीकों की मदद से, जलविभाजन की भूमि उपयोग क्षमता वर्गीकरण भी किया गया था। यह भूमि की व्यवस्थित व्यवस्था को उनके गुणों के अनुसार देता है जो भूमि की क्षमता को स्थायी रूप से स्थायी आधार पर निर्धारित करने की क्षमता निर्धारित करता है। कृषि और गैर-कृषि भूमि के योग्य जलविभाजन योग्य क्षेत्र क्रमश: 4019.5 हेक्टेयर और 1368.41 हेक्टेयर है। कानोड़ के लिए 30 वर्षों (1987-2016) के वर्षा आंकड़ों का विश्लेषण वेबुल की तकनीक का उपयोग करके विभिन्न स्तरों पर संभावना वितरण के लिए किया गया था। 75%, 50%, और 25% संभावना विश्लेषण स्तर पर, वार्षिक वर्षा क्रमश: 439 मिमी, 600 मिमी और 666 मिमी है। जल संचयन संरचना के उद्देश्य को डिजाइन करने के लिए आंकड़ा का विश्लेषण किया गया।

जलविभाजन में अनुकूलनीय उपयुक्त कृषि एवं अभियांत्रिक उपायों को वर्षा विश्लेषण, भूमि उपयोग क्षमता वर्गीकरण और क्षेत्र की स्थलाकृति के आधार पर डिजाइन किया गया था। समोच्च बांध, पुरतो-रिको सीढ़ी, कृषि भूमि के लिए प्रस्तावित किया गया था, जबकि समोच्च खाई, मिट्टी और जल संरक्षण के उद्देश्य से गैर-कृषि भूमि के लिए टेढ़ेखाई, का प्रस्ताव रखा गया था। जल निकासी लाइन के उपचार के लिए, उनके उपलब्ध पकड़ क्षेत्र के अनुसार विभिन्न आयामों के ढीले पत्थर की जांच बांध प्रस्तावित किए गए थे। वर्ग पंचम भूमि को वनीकरण सह चरागाह विकास के साथ उपचार का प्रस्ताव दिया गया था।

अतिरिक्त अपवाह की कटाई के लिए, 1.73 हेक्टेयर मीटर की भंडारण क्षमता रखने वाली एक पानी की कटाई संरचना (एनीकट) डिजाइन की गई थी। एनीकट की लागत रु. 18.46 लाख जल संचयन संरचना की लागत को छोड़कर जलविभाजन उपचार के प्रति हेक्टेयर की कुल लागत रु.13,419.

कानोड़ वाटरशेड के आर्थिक विश्लेषण से पता चलता है कि आर्थिक और वित्तीय मूल्यांकन के तहत लाभ-लागत अनुपात क्रमशः 1.54: 1 और 2.17: 1 है जो इंगित करता है कि परियोजना आर्थिक और वित्तीय रूप से व्यवहार्य है।

APPENDICES

APPENDIX A-1: Sample Calculation for Structures Proposed in Arable Land

i. Design and Sample Calculation for Contour Bund Design

On the basis of rainfall intensity data and according to the record, the maximum average rainfall in 24 hours occurred in 10 years is 16.5 cm for Udaipur. The infiltration is considered as 45% of the rainfall. For the soils, side slope of bund is 1:1 and seepage line is 4:1. Values of constants a and b are 3 and 2, respectively.

Average Slope = 3.8 %

Vertical Interval (VI) = 0.3[S/a + b]

= 0.3 (3.80/3 + 0.6) = 0.98 m

Horizontal Interval (HI) = (VI/S) × 100

= (0.98/3.80) × 100 = 25.78 m

R_e = 24 hours rainfall excess for 10 years recurrence interval

= Maximum rainfall – Infiltration = 16.5 – (0.45 × 16.5) = 9.08 cm

Depth of Impounding (d) = √ (Re × VI/50)

= √ (9.08× 0.98/50) = 0.42 m

Assuming freeboard = 0.10 m (20 % of d) and depth of flow = 0.12 m

Height of bund (H) = Depth of impounding + depth of flow + freeboard

= 0.42+0.10+0.10

= 0.62 m say 0.60 m

Top width, T_w = H/2 = 0.64/2 = 0.32 say 0.30m

Bottom width, (B_w) = T + (2×1×H)

= 0.30 + (2×1×0.60)

= 1.50 m

Storage capacity

Storage capacity (S_c) is determined by following equation:

S_c = (d/s + 1d) × (d/2)

Where,

d = Impounding depth

s = Slope (fraction)

So, S_c = {(0.42/0.038) + (1.5× 0.42)} × (0.42/2) = 2.45 m^3/m length

Design dimension

Height = 0.64 m   Top width = 0.30 m

Bottom width = 1.50 m   Storage capacity= 2.45 m^3/m length

Cross sectional area = 0.54 m^2

Sample Calculation (per ha)

length of bund = 150 m/ha

Cross sectional area = 0.54 m^2

Volume of earth work = 150 × 0.54 = 81 m^3

ii Design and Sample Calculation for Puerto Rico Terrace Design

Vertical Interval (VI) = (S/6.6) + 0.6

= (9.4/6.6) + 0.6 = 2.02 m

Horizontal Interval (HI) = (VI/S) × 100

= (2.02/9.4 × 100 = 21.49 m

Recommended cross section of PRT is,

Width = 0.60 m

Height = 0.45 m

Cross sectional area = 0.60 × 0.45 = 0.27 m^2

Sample Calculation

Length of terrace (L) = 150 m/ha

Cross sectional area = 0.27 m^2

Volume of dry stone masonry = 150 × 0.27 = 40.5 m^3

APPENDIX A-2*:* Sample Calculation for Structures Proposed In Non-Arable Land and Drainage Line Treatment

i. Sample calculation for Contour Trenches

Total length of contour trenches = 25882.5 m

Cross sectional area = 0.3 × 0.3 = 0.09 m^2

Volume of excavation = 25882.5 × 0.09 = 2329.42 m^3

ii. Sample calculation for Staggered Trenches

Length of trench = 4.0 m

Horizontal spacing between trenches = 12.5 m

Total no. of trenches per ha = 10000 / (12.5 × 4) = 200 trenches/ha

iii. Design and Sample Calculation for Loose Stone Check Dam

Upper reaches

Height of structure above bed, H = 0.5 m

Depth of foundation, D_f = 0.4 × H = 0.4 × 0.5 = 0.2 m

Top width, T = 0.6 H or 0.6 m, whichever is maximum =0.6 × 0.5 or 0.6 = 0.6 m

Base width, B = 1.2 H or 0.8 m whichever is maximum = 1.2 × 0.5 or 0.8 = 0.8 m

Cross sectional area of foundation = 0.20 × 0.8 = 0.16 m^2

Cross sectional area of dry stone masonry = 0.20 + 0.20 (0.8-0.6) + 0.5 x 0.6 = 0.54 m^2

Middle reaches

H = 0.8 m

D_f = 0.4 × H = 0.4 × 0.8 = 0.32 m say 0.35 m

T = 0.6 m

B = 1.2 × 0.8 = 0.96 m say 1.0 m

Cross sectional area of foundation = 0.35 × 1.0 = 0.35 m^2

Cross sectional area of dry stone masonry

= 0.35 + 0.35 (0.8 - 0.6) + 0.6 (0.8 + 0.35) = 1.11 m^2

Lower reaches

H = 1.0 m

D_f = 0.4 × H = 0.4 × 1.0 = 0.40 m

T = 0.6 m

B = 1.2 × 1.0 = 1.2 m

Cross sectional area of foundation = 0.40 × 1.20 = 0.48 m^2

Cross sectional area of dry stone masonry

= 0.48 + 0.5 (0.6-1.2) + 1.0 = 1.18 m^2

APPENDIX A-3: Design of Anicut

Height

The height of the Anicut (H) is decided on the basis of volume of runoff expected from the catchment and volume of water required to be stored. For the proposed Anicut, 3 m height has been found appropriate and therefore adopted.

Estimation of Peak Runoff Rate

Peak runoff rate is estimated by Dicken's formula

Dicken's Formula

$Q_p = C\ M^{3/4}$

Where, Q_p = Peak runoff rate, m^3/sec

M = Catchment area, km^2

C = Runoff coefficient = 11.4 (for Northern India)

$Q_p = 11.4 \times 3.9^{3/4} = 31.63\ m^3/sec$

Depth of flow over the crest

For the span of 32 m as per site condition, depth of flow over the crest (h) is given by

$h = (Q_p/ (1.71 \times L))^{2/3}$

$h = (31.63 / (1.71 \times 32))^{2/3} = 0.69$ m

Freeboard

It is elevation difference between top surface of the head wall and top of the head wall extension.

It is estimated by

$F_b = 1.5\ h_w$

Where, F_b = Freeboard (m)

h_w = Wave height (m) = $0.014\ \sqrt{D_m}$

Where,

D_m= Fetch length (m) =320 m

So, $h_w = 0.014\ \sqrt{320} = 0.25$ m

$F_b = 1.5 \times 0.25 = 0.38$ m

Net freeboard or total freeboard or total clearance above the crest level

h_f = Depth of flow + Freeboard = h + F_b = 0.67 + 0.38 = 1.05 m

Total height of Anicut = Effective height + Total freeboard = 3 + 1.05 = 4.05 m

Head wall

Length = 32.0 m

Height, H = 3 m

Bottom width, $b = H/\sqrt{(\rho-1)} = 3/\sqrt{(2.2-1)} = 2.74$ m, say 3.0 m

Where, ρ = density of stone masonry (2.2 t/m^3)

Top width, $a = b - 0.8H = 3 – 0.8 \times 3 = 0.60$ m

Depth of foundation may be taken as 2.0 m as per site condition.

Head wall extension

Length = $H + h_f + 1.0$

$= 3 + 1.05 + 1.0 = 5.05$ m say 5.0 m

As per site selection, the length of head wall extension is taken as 5.0 m.

Height = $H + h_f = 3 + 1.05 = 4.05$ m

Top width = Bottom width = Top width of head wall = 0.6 m

Side wall

Length = $1.75\ H + 0.75\ h_f + 0.45$

$= 1.75 \times 3 + 0.75 \times 1.05 + 0.45$

= 6.49 m say 6.50 m

Height = $H + h_f = 3 + 1.05 = 4.05$ m

Top width = 0.6 m

Bottom width = 0.90 m

Wing wall

Length = $2.25\ h_f = 2.25 \times 1.05 = 2.36$ m

Height = $1.5\ h_f = 1.5 \times 1.05 = 1.58$ m

Top width = Bottom width = 0.6 m

Apron

Length = crest length =32 m

Width = $0.75\ (H+h_f) + 0.45 = 0.75\ (3+1.05) +0.45 = 3.49$ m say 3.5 m

Depth = 0.6 m

Toe wall

Length = crest length = 32 m   Height = 0.30, Width = 0.45 m

Cut-off wall

Length = crest length = 32 m

Width = 0.45 m

Depth = 1.0 m

Stability checks of Anicut

After the estimation of the dimension of different component parts of the Anicut, it is very essential to check the stability of the structure for which various stability checks was as follows

i. Factor of safety against overturning

ii. Factor of safety against rupture from tension

iii. Factor of safety against sliding

iv. Crushing test

For stability checks, following parameters are calculated

W = Weight of damper unit length = W1 + W2

$W_1 = aH\rho = 0.6 \times 3 \times 2.2 = 3.96$T/m

$W_2 = (b-a) .\rho. H/2$

$= (3 - 0.6) \times 2.2 \times (3/2) = 7.92$ T/m

Water pressure at depth hf,

$P1 = \rho_w h_f = 1.0 \times 1.05 = 1.05$ T/m^2

Where, P1 = Water pressureat depth h_f (tonnes/m^2)

ρ_w = Density of water

Water pressure at depth $(H+h_f)$

$P2 = \rho_w(H+h_f)$

$= 1.0 \times (3 + 1.18) = 4.18$ T/m^2

Where, P_2 = Water pressure at depth $(H+h_f)$,

(tonnes/m^2)

Net horizontal water force,

$P = [(P_1 + P_2)/2] \times H$

$= [(1.05+4.05)/2] \times 3 = 7.65$ T/m

Pressure due to water at the crest of Anicut

$P_x = \rho_w h_f = 1.0 \times 1.05 = 1.05$ T/m^2

Force due to water above the crest of Anicut

$F = P_x.a = 1.05 \times 0.6= 0.63$ T/m

Uplift force

$U = ½ .C. \rho_w. H. b$

Where, U = Uplift force (T/m)

C = Coefficient of uplift = 0.6

ρ_w = Density of water

b = Bottom width of Anicut = 4.2 m

U = ½ × 0.6 × 1.0 × 3 × 3 = 2.70 T/m

A. Factor of safety against overturning

The weight of the structure creates restoring moment whereas water and uplift pressure cause overturning moment. For the structure to be safe against overturning, the ratio of restoring moment and overturning moment should be greater than 1.3.

Restoring moment, $M_r = W_1 (b – a/2) + W_2 (b - a) 2/3 + F (b – a/2)$

= 3.96 (3 - 0.6/2.0) + 7.92 (3 – 0.6) 2/3 + 0.63 (3 – 0.6/2.0)

= 25.13 T

Overturning moment Mo = $F_a(H/2) + F_b(H/3) + U(2/3)b$

Where, Fa = P1 H = 1.05 × 3 = 3.15 T/m

Fb = $(P_2 – P_1)$ × H/2 = (4.18 – 1.18) × 3/2 = 4.5 T/m

Mo = Fa(H/2) + Fb(H/3) + 2/3 Ub

So, Mo = (3.15 × 3/2) + (4.5 × 3/3) + (2.48 × 0.67x 2.75)

= 13.79 T

Factor of safety against overturning = Mr/Mo = 25.13/ 13.79

= 1.82> 1.3 Hence, the structure is safe against overturning.

B. Factor of safety against rupture from tension

Excess moment = Restoring moment – Overturning moment

= 25.13– 13.79 = 11.34 T

Total vertical force, ΣV = W1 + W2 + F – U

= 3.96 + 7.92 + 0.63 – 2.70

= 9.81 T/m

If X represents the position of the resultant measure from the top of the Anicut

X = Excess moment / Vertical force

= 11,34/ 9.81= 1.16 m

Here, b/3 = 0.92 m, 2b/3 = 1.84 m

The value of X is greater than 1/3rd and less than 2/3rd of base width. It means the resultant is passing through middle third so that there is no chance of developing any tension in the masonry and the structure will be safe against rupture from tension.

C. Factor of safety against sliding

The horizontal forces acting on the structure in the downstream direction may cause failure of the structure by sliding. In the sliding test, the ratio of total vertical force (ΣV) to the sliding force should be more than 1.0.

Factor of safety against sliding = $\mu \, \Sigma V / P$

Where, μ = Coefficient of sliding between bed material and masonry = 0.85

ΣV = Total vertical force = 9.81 T/m

P = Net horizontal water force or sliding force (T/m) = 7.65 T/m

So, Factor of safety against sliding = (0.85 × 9.81) / 7.65 = 1.09 >1.0

Hence, the structure is safe against sliding.

D. Crushing test

To avoid crushing of the masonry at the base, the maximum compressive stresses (Pc) at toe and head acting normal to the base must be less than permissible compressive stresses for the masonry (P_{cp} = 13.2).

P_c =[(ΣV) / b]* [(1 + 6e}/b]

Where, e = (b/2) – X

= (3/2) – 1.16= 0.34

So, P_c = (9.81 / 3)× [1 + (6 × 0.34) / 3]

= 5.49

The value of Pc calculated is less than the permissible limit i.e. P_{cp} = 13.2.

hence, the structure is safe against crushing.