SITE SUITABILITY ANALYSIS OF SOIL AND WATER CONSERVATION STRUCTURES IN KADIVALI WATERSHED USING REMOTE SENSING AND GIS

THESIS

Submitted in partial fulfilment of the requirements

for the Degree of

MASTER OF TECHNOLOGY

IN

AGRICULTURAL ENGINEERING

(SOIL AND WATER CONSERVATION ENGINEERING)

By

Miss. Gangarde Prachi Arjun
(ENDPM/2021/195)

DEPARTMENT OF SOIL AND WATER CONSERVATION ENGINEERING
COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY, DAPOLI

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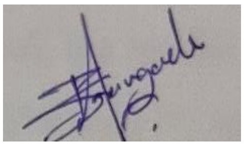
NOVEMBER, 2023

DECLARATION OF STUDENT

I hereby declare that the experimental work and its interpretation of the Thesis entitled **"SITE SUITABILITY ANALYSIS OF SOIL AND WATER CONSERVATION STRUCTURES IN KADIVALI WATERSHED USING REMOTE SENSING AND GIS."** or part thereof has neither been submitted for any other degree or diploma of any University nor the data have been derived from any thesis/publication of any University or scientific organization. The source of materials used and all assistance received during the course of investigation have been duly acknowledged and that no part of the thesis has been submitted for any other degree or diploma.



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CERTIFICATE

This is to certify that the thesis/dissertation entitled, **"SITE SUITABILITY ANALYSIS OF SOIL AND WATER CONSERVATION STRUCTURES IN KADIVALI WATERSHED USING REMOTE SENSING AND GIS"**submitted for the degree of M. Tech. (Soil and Water Conservation Engineering), of the College of Agricultural Engineering and Technology, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, is a bonafide research work carried out by Miss. Gangarde Prachi Arjun (ENDPM/2021/195) under my supervision and that no part of this thesis has been submitted for any other degree. The student had completed all the Course and Research requirement as per the norms in regular mode and has published one research paper from her M. Tech. work.

The assistance and help received during the course of investigation have been fully acknowledged.

Place: Dapoli

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Date:

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THESIS APPROVAL BY THE STUDENT'S ADVISORY COMMITTEE INCLUDING EXTERNAL EXAMINER

This is to certify that the thesis/project report entitled, "**SITE SUITABILITY ANALYSIS OF SOIL AND WATER CONSERVATION STRUCTURES IN KADIVALI WATERSHED USING REMOTE SENSING AND GIS**" submitted by **Miss. Gangarde Prachi Arjun** (ENDPM/2021/195) to the College of Agricultural Engineering and Technology, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, in partial fulfilment of the requirements for the **M. Tech.** (Soil and Water Conservation Engineering), in the subject having Irrigation and Drainage Engineering as Minor subjects of Department of Irrigation and Drainage Engineering has been approved by Student's Advisory Committee, Board of Studies of the Department and Evaluated by One/ Two External Examiner after an open Viva Voice examination in the presence of External Examiner on the same held on dated 7 Nov 2023

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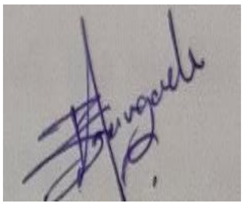

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LIST OF ABBREVIATIONS

Abbreviations	**Meanings**
<	Less than
>	Greater than
%	Per cent
°C	Degree Celsius
AMC	Antecedent Moisture Condition
CAET	College of Agricultural Engineering and Technology
Cm	Centimeter
DEM	Digital Elevation Model
E	East
et al.	And others
etc.	Etcetera
FAO	Food and Agricultural Organization
Fig.	Figure
g	Gram
GIS	Geographic Information System
GPS	Global Positioning System
ha	Hectares
ICAR	Indian Council of Agricultural Research
IDW	Inverse Distance Weighted
IMSD	Integrated Mission for Sustainable Development
ISRO	Indian space research organization
i.e.,	That is
kg	Kilo gram
km	Kilo meter
Km^2	Square kilo meter
LANDSAT ETM^+	Landsat Enhanced Thematic Mapper Plus
LISS	Linear Imaging Self Scanner
LU/LC	Land use/land cover
M	Million
m	Meter

m^3	Cubic meter
mm	Millimeter
Mha-m	Million-hectare meter
Mm/hr.	Millimeter per hour
N	North
NBSS-LUP	National Bureau of Soil Survey and Land Use Planning
No.	Number
NRSA	National Remote Sensing Agency
QGIS	Quantum Geographic Information System
RS	Remote Sensing
SCS	Soil Conservation Service
SOI	Survey of India
SRTM	Satellite Radar Topography Mission
USGS	Unites States Geological Survey
USDA	Unites States Department of Agriculture
Viz.	Namely
yr	Year

GLOSSARY

- **Watershed:** A watershed is an area of land that drains water into a specific waterbody.
- **Runoff:** Runoff is precipitation that does not soak into the soil but instead moves on the Earth's surface toward streams.
- **Infiltration:** Infiltration is the process by which water on the ground surface enters the soil
- **Percolation:** Percolation is the movement of water through the soil itself.
- **GIS:** It is a computer-based tool used to store, visualize, analyze, and interpret geographic data.
- **Erosion:** Erosion is the geological process in which earthen materials are worn away and transported by natural forces such as wind or water.
- **Spatial Distribution:** It is the arrangement of phenomenon across the earth’s surface.

CHAPTER I : INTRODUCTION

1.1 General

Soil and water are the most important natural resources and physical base for all life supporting system as water sustains life where soil acts as a medium. These two resources are too precious for the mankind as they meet all the needs and protect the environment as well as the civilization. Land degradation has become a major problem in both rainfed as well as irrigated areas of India. India is losing a huge amount of money from these degraded lands. Cost lost due to land degradations were established by various authors (Joshi and Agnihotri, 1984; Parikh and Ghosh, 1995; Joshi *et al*. 1996; Srinivasarao *et al.* 2013) in terms of declining crop productivity, land use intensity, changing cropping patterns, high input use and declining profit. Loss of production in India at Rupees 68 billion in 1988-1989 was estimated by (Reddy, 2003) using the National Remote Sensing Agency dataset. Additional losses resulting from salinization, alkalinisation and water logging were estimated as Rs. 8 billion. Of late, in a comprehensive study made on the impact of water erosion on crop productivity it was revealed that soil erosion due to water resulted in an annual crop production loss of 13.4 Mt in cereal, oil seeds and pulse crops (Sharda *et al*. 2010). out of a total reported geographical area of 329 Mha of India, about 146.8 Mha are degraded by various factors.

Water erosion and wind erosion together account for 70% of the total degraded land and the remaining 30% is due to salinity, acidity and combination of other factors. Annual soil loss of India is estimated as 5334 Mt along with these 8.4 Mt of major nutrients also lost. Annually, 2052 million tonnes of soil are carried by rivers out of this nearly 480 million tonnes are being deposited in various reservoirs which results in 1-2% loss of storage capacity per year (Dhruva Narayana and Rambabu, 1983). According to National Commission on Agriculture, reservoirs in India are silting up at a rate of three to four times faster than the designed rates. It is a matter of concern that out of 329 Mha geographical area, about 145 Mha is under cultivation and there is no scope to bring more area under cultivation

1.2 Introduction to Watershed and morphometric characteristics

Watershed management is a non-ending process where data has to be collected, analysed to recognise problems and design plans to protect and improve resource sustainability. Thus, the watershed level approach in managing of natural resources, the negative impacts on the system can be found. Hence there is lot more scope for improvement of resource sustainability for future generations. Detailed morphometric analysis of a watershed is beneficial in understanding the effect of fluvial morphometry on its natural resources. Morphometry is the measurement and mathematical evaluation of the configuration of earth's surface layout, shape and dimension of its landforms. (Agarwal,1998). It gives a quantitative interpretation of the drainage system. Which is a major aspect of the characterization of watershed (Strahler, 1964). The morphometric analysis such as linear aspect (stream length, stream order, basin length, mean bifurcation ratio, bifurcation ratio), areal aspect (circulatory ratio, elongation ratio, stream frequency, drainage density, basin area, basin shape, drainage texture) and relief aspect (relief ratio, basin relief, basin slope, relative relief, gradient ratio and ruggedness number) of watershed is determined to obtain the general characteristics of the watershed (Strahler, 1964).

1.3 Introduction to Runoff and SCS-CN Method

There are various hydrological models used in the India for runoff estimation. These models are essential tools for water and environmental resources management. Runoff prediction models can be grouped in three main classes: empirical, conceptual and physically based models.

Soil Conservation Service Curve Number Method (SCS-CN), introduce and developed by U. S. Department of Agriculture (USDA), is the most popular technique across the world for estimation of runoff. It is simple, predictable and stable conceptual model which estimates direct runoff depth from rainfall depth. This method requires less input data such as daily rainfall with least information of soil - vegetation. This method depends on only a single conceptual parameter called potential retention (S) or its corresponding transformation called as curve number (CN). However, the prediction accuracy of this method is mainly depending on accurate selection of CN. Curve number for a given area varies as a function of runoff generating characteristics. These parameters are originally based on same empirical data taken from mid-western U. S. and therefore while adopting to other geographic location on climatic situation they always need validation or modification. USDA has developed the SCS-CN method. Due to its simplicity, it become the most popular method for small watershed (Mishra and Singh, 2002).

The runoff from the chaskaman catchment computed using various empirical methods such as Khosla's formula, Inglis and DeSouza formula, Coutagine relationship, Department of irrigation, India and Strange's table method (Dalavi *et al*. 2018). The computation of runoff using different empirical equations such as Inglis and DeSouza formula, Khuzla's formula, Khosla's formula, Indi Irrigation Department and SCS-CN Method (Kumar *et al*. 2016). The conventional SCS-CN Method is widely adopted for estimation of direct runoff volume.

1.4 Introduction to soil and water conservation structures

Appropriate soil and water conservation structures play a vital role in maintaining and improving productivity in a watershed. Also, it maintains the ecological balance Water and erosion control structures are integral part of any soil and water conservation program and are major components of the watershed management. Adoption and implementation of an appropriate water resource development plan could even minimize the severity of drought permanently. In rainfed areas, small increment in the available water can substantially boost the crop yield and minimize the risk of crop failure. Due to soil degradation and scarce, fault managed water resources have led to the execution of watershed management activities throughout Africa, Asia and Latin America (Singh *et al*. 2001).

The Watershed based approach for planning of various from the watershed will be drained to common outlet and such a runoff in the watershed will be managed by various morphological characteristics related to shape, size, and relief of the watershed. The various conservation measures in watershed can be adopted for conserving soil and water resources (Saptarshi and Raghvendra, 2009).

1.5 Use of remote sensing and GIS

The technique of remote sensing and GIS can be used to locate the appropriate sites for soil and water conservation structures in watershed after formulating various criteria norms. By combination of remote sensing and GIS techniques it becomes a powerful tool for identifying sites for construction structures (Durbude and Venkatesh, 2004)

Need of soil and water conservation are growing day by day, remote sensing and GIS have been shown to be very effective and efficient. Global positioning system (GPS) is useful and easy to find location of various structures. The main purpose of the study is to suggest soil and water conservation measures for reduction of soil erosion, runoff and improvement in soil and availability of groundwater so eventually it is beneficial for the nation as well as individual farmer.

Keeping these needs in view, the present study, "Site suitability analysis of soil and water conservation structures in Kadivali watershed using remote sensing and GIS." was undertaken with the following objectives.

Objectives:

1. Digital delineation of Kadivali watershed and morphometric analysis of watershed using remote sensing and GIS.
2. Estimation of runoff from rainfall using SCS-Curve Number method.
3. To suggest suitable sites for soil and water conservation measures based on rainfall-runoff relationship.

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CHAPTER II : REVIEW OF LITERATURE

This chapter deals with the review of literature related to the "Site suitability analysis of soil and water conservation structure in Kadivali watershed using Remote Sensing and GIS." Review has been collected and presented here.:

2.1 Delineation of watershed

Kaur and Dutta (2002) analyzed and compared the manual delineation (AISLUS) and digital delineation of watershed procedure on test watershed in Hazaribagh (Jharkhand) and Bakura (West Bengal). The study shows that manual delineation of watershed had drawback such as slight change in the actual watershed shape and size, while Digital delineation overcomes this drawback and provides more accurate shape and size of the delineated watershed

Rashedul (2004) delineated the watershed using GIS tools of Southern Manitoba Region of Canada. The ANU DEM was used. It was found that DEM gives more accurate delineation. Using delineated watershed, rainfall-runoff hydrograph was simulated by HEC-HMS using SCS curve number method for the three small watersheds of the region. This simulated and actual hydrograph was compared. It was found that, the actual and computed hydrograph were quite similar Using HEC-HMS model.

Luo *et al*. (2011) studied that watershed delineation based on digital elevation models (DEMs) to set up SWAT model. The study stated that the watershed delineation in low-lying plain areas faces some issues. Streams can't be found by SWAT model, routing processes were affected by the water-control projects etc.

Bose *et al.* (2012) made an attempt to delineate 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 4E3CS in watershed atlas of India. 4E3C4 sub watershed was delineated in GIS into 11 mini watersheds. 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. The total length of all streams for the entire watershed was found to be 4691.23 kms representing a dense drainage network. Present study shows that GIS is found to be flexible and is relatively easy to apply on large areas enabling collecting of all data and information in a common data base for watershed delineation and stream network analysis.

Rahman *et al*. (2014) studied the small-scale catchment delineation in coastal area of Bangladesh on GIS based approach. To delineate the catchment ArcGIS 10.2.2 software and Digital Elevation model (DEM) was used. This study concludes that ArcGIS can be efficiently used in catchment delineation. But accurate DEM is the precondition for such sort of delineation and field verification should be mandatory in the GIS based approach. GIS based catchment delineation should also require field verification.

Giridhar *et al.* (2015) studied the methodology of the DEM in order to facilitate interactive watershed delineation of Kaddam watershed of Godavari River basin. With the help of DEM file generated, Soil and Water Assessment Tool is used. The result shows that, the stream line generation, number of sub-basins, which were found as 58 numbers and sub-basins area was established.

Khadri *et al*. (2016) delineated the watershed in Amravati tehsil using geomorphological investigations through remote sensing and GIS techniques. Satellite remote sensing data as well as topographic data were utilized in this study to find the watershed and groundwater potential zones with the help of latest available techniques. The results demonstrated the presence of various hydro geomorphological zones showing their groundwater potentialities varied from excellent to poor. The study area covering Pedhi watershed showed excellent to good ground water quality whereas the Kholad and Kapasi watersheds showed moderate to poor ground water quality

Kaviya *et al*. (2017) studied the watershed delineation using GIS in Selaiyur area, Chennai. GIS automated tools use were in the watershed delineation. The technological advances given by GIS and the increasing availability and quality of DEMs have expanded the application potential of DEMs to many hydrologic, hydraulic, water resources. GIS ArcHydro gives increased efficiency, a typical hydrographical analysis. The results can be effectively used in land use planning and watershed studies, hydrological modelling, reservoir operation and planning.

Litan Kumar (2018) studied limitation of automatic watershed delineation tools in coastal region of the Sabarmati River. CARTOSAT-1 (20 m), ASTER V2 (30 m) and SRTM (90 m) are used to delineate basin area of the river. Digital Elevation Models (DEMs) have been used with ArcGIS Hydrology, ArcHydro and ArcSWAT automatic watershed delineation tools. The best results with an error of only 0.75% they got in delineation of Sabarmati River using ASTER V2 (30) DEM by ArcSWAT, as compared to the area stated in India WRIS.

Li *et al.* (2019) found a method of watershed delineation for flat Terrain using Sentinel-2A imagery and DEM for Taihu basin. They observed traditional digital elevation model (DEM) may not generate realistic drainage networks due to large depressions and small elevation differences in local-scale plains. Hence, they found a new method for solving the problem of watershed delineation, using the Taihu basin as a case study. Rivers, lakes, and reservoirs were obtained from Sentinel-2A images with the Canny algorithm on 8 Google Earth Engine (GEE), rather than from DEM, to compose the drainage network. Catchments were delineated by modifying the flow direction of rivers, lakes, reservoirs, and overland flow, instead of using DEM values.

Amaru and Dwiratna (2020) made an attempt to study application of Geo WEPP-TOPAZ model to delineate stream network and watershed at upper Citarum watershed. The reason of this study was to apply the TOPAZ model in GeoWEPP for watershed modelling. The TOPAZ model used a DEM to generate topographic parameterization. DEM has been processed and then distinguished a hillslope; a channel based on channel network. Stream order has been assigned for channel section in accordance with the watershed channel network.

Kareem *et al.* (2021) studied watershed basins delineation using GIS and Digital Elevation Model (DEM) to the region NI-38-14 Karbala-Al-Najaf Plateau, Iraq. The satellite image is downloaded from the USGU website in the form of a Digital Elevation Model (DEM). To calculate the morphometric properties GIS technology is used. The number of watersheds extracted in the Karbala-Al-Najaf plateau is 150 watersheds with different areas, large area is 4882 km^2, while the small area is about 1km^2, and between those areas there are various areas. The largest recorded watershed circumference reached 580 km^2 in area (4882 km^2), while the lowest recorded perimeter is 8 km for the area (1 km^2).

Puppala and Madapala (2022) used ArcGIS 10.2 software to delineate and analyse the Krishna Watershed in India. ASTER GDEM tiles lying in the study area were downloaded, mosaicked, clipped to the basin extents and processed to derive basin properties. The result of LULC showed that in the period 1995-2005, a large proportion of land was converted to developed land or built-up area, with an increase of almost 50% with respect to the initial area in 1995 and 3% increase in agricultural land was observed. The maps offer quantifiable LULC change detection and would be invaluable as input for other applications such as hydrological modelling and LULC change prediction.

2.2 Morphometric analysis of watershed using remote sensing and GIS

Strahler (1957) performed a quantitative analysis of watershed geomorphology. It includes two classes, scale measurement and a dimensionless number. Linear scale measurement includes some of the length dimension or its products, drainage density, constant of channel maintenance, basin perimeter and relief. Dimensionless properties that may be applied to the systematic description of drainage basins developed by normal processes of water erosion included stream order numbers, stream length and bifurcation ratios, mean slopes, relief ratios and hypsometric curve properties.

Avinash *et al*. (2010) studied the hydrological drainage characteristics of all the seven watersheds (I- VII) of the Gurpur River basin. The average values of bifurcation ratio (Rb) of sub- watersheds indicate the structural control is not as pronounced as the geomorphic control for development 8 of drainage network. Analysis of the shape parameters indicates that the Gurpur basin is in an elongated form. Computed value of stream frequency (F) in the sub- basins

II, II and VI indicates the occurrence of steep ground slopes, with less permeable rocks while drainage density (Dd) indicates the nature of the surface strata of the river basin is moderately permeable.

Mallik *et al*. (2011) concluded that, measurement of drainage density (Dd) is a useful numerical measure of landscape dissection and runoff potential. On the one hand, the Dd is a result of interacting factors controlling the surface runoff, on the other hand, it is itself influencing the output of water and sediment from the drainage basin. They categories the watershed into four classes based on Dd value i.e., low (< 2.0 km km), moderate (2.0-2.5 km km*), high (2.5-3.0 km) and very high (3.0 km km).

Kanth and Hassan (2012) they attempted to carry out detailed study of linear and shape morphometric parameters in 19 watersheds of Wular catchment and their prioritization for soil and water resource management. Following Strahler's stream ordering scheme, it was found that in Wular catchment the total number of streams were 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.

Sreedevi *et al*. (2013) attempted to study on drainage morphometry and its influence on hydrology of peddavanka watershed, South India and they revealed that SRTM DEM and GIS based approach in 9 evaluation of drainage morphometric parameters and their influence on hydrological characteristics at watershed level is more accurate than the conventional methods.

Manjare *et al*. (2014) concluded that quantitative analysis of morphometric parameters is immense utility in river basin evaluation, watershed analysis for soil and water conservation and natural resource management at micro level. The morphometric parameters evaluated using GIS helped to understand various terrain parameters such as nature of bedrock, infiltration capacity, runoff.

Patil *et al*. (2015) studied the morphometric Characteristics of Karwadi-Nandapur micro watershed and concluded that purpose of the fluvial morphometry is to derive information in quantitative form about the geometry of the fluvial system that can be correlated with hydrologic information. The watershed is having low drainage density due to presence of highly permeable subsoil material which is under dense vegetation and the relief is low. The development of stream segments in the watershed area is more or less affected by rainfall. The present study demonstrates the usefulness of GIS for the morphometric properties determined for this watershed will be useful for the sound planning of water harvesting and groundwater recharge projects on watershed basis.

Prithiviraj and Vekateswaran (2016) found that Kousika Manadi sub basin is a 6th order drainage basin. Dendritic drainage pattern is seen in the hilly and plateau parts of the drainage basin indicating the homogeneity in texture and structural control. From the study it can be concluded the areas drained by drainage 10 orders of 1st, 2d and 3rd have Bifurcation ratio between 3.0 to 6.4, indicating that these are not distorted by geological structures. The Bifurcation ratio in case of the 4 to the 5 drainage orders, it is less than 3.0. The presence of the maximum number of the first order segments shows that the sub basin is subjected to erosion and also that some areas of the sub basin are characterised by variations in lithology and topography.

Sah and Das (2017) highlighted the two major constrains, stream matching and spatial matching, associated with source combining. In this work stream matching in terms of number of streams and length of streams were Controlled by a method of automatic stream generation from downscaled DEM and flow accumulated raster. Stream generated from downscaled DEM shows superior results in terms of both the basic stream parameters. The superiority is basically due to its ability of stream generation at greater head extent thus promotes further DEM downscaling for correct estimation of number of streams for each order and Length of each order stream.

Afreeda and Balaji (2018) attempted to study morphological parameters of the three sub watersheds falling in Nilgiris District of Tamilnadu. They used four different DEM sources viz., Toposheet, ASTER, SRTM and Cartosat data for delineating watershed boundary and geographical information system (GIS) was used in evaluation of linear aspects of morphometric parameters. The stream length ratio between streams of different order in the study arca shows there is a different variation due to changes in slope and topography. The lower values of bifurcation 11 ratio indicates that watersheds have suffered less structural disturbances and the drainage patterns has not been distorted because of the structural disturbances.

Singh *et al*. (2019) studied the morphometric analysis of Mewado Ka Math Micro-Watershed using remote sensing and GIS located in Udaipur district of Rajasthan state. The value of form factor (R_I), circulatory ratio (Rc) and elongation ratio (Re) are 0.12, 0.36 and0.39 respectively. This is an indication of erosion and reflects that the watershed be treated with soil and water conservation measures.

Gunjan *et al*. (2020) conducted an analysis for Rampur watershed of Mahanadi River basin, and its 9 sub- watersheds for prioritization according to the linear, aerial and relief characteristics. The drainage networks for all 9 sub- watersheds showed dendritic to sub-dendritic drainage pattern after the morphometric analysis and the difference in stream length ratio was because of the changes in topography and slope. The values of drainage density were found to below five for all the 9 sub-watersheds. This value shows the characteristic feature is coarse, and sub-surface strata are permeable. Prioritization has made according to higher erosion and areas with vulnerable soil loss.

Patil *et al*. (2021) studied on determination of geomorphological characteristics of Asond watershed using GIS techniques which is located in Ratnagiri district. Asond watershed covered area 510.76 ha. Basic physical geomorphological characteristics of watershed such as drainage network, shape, size, etc. were derived from digital elevation model (DEM). The drainage pattern is dendritic in nature and it is influenced by general topography of area which shows that area have homogeneous rock. Circulatory ratio is calculated as 0.44 which indicates strongly elongated and highly permeable homogenous geologic materials. The elongation ratio of watershed is calculated as 0.90. It was observed that the watershed is Oval.

Kale *et al*. (a) (2022) delineated and analysed morphometric characteristics of Kudavale watershed located in Dapoli having area of 1314.48 ha. Delineation was done by using Arc GIS 10.2 and Digital Elevation Model (DEM) has been collected ISROs geospatial Bhuvan. They were found that there were 43 streams in watershed with fourth order as highest stream order. The results were formulated as watershed have gentle to steep slope terrain, medium dense vegetation and less permeable with medium precipitation.

Lakshminarayana *et al*. (2022) made an attempt to determine the morphological parameters of the Tidi watershed in Udaipur district of Rajasthan, of detailed study, ASTER DEM was used for delineation of the watershed boundary, and GIS was used in evaluation of morphometric parameters. The Tidi watershed occupies an area of 114.36 km^2 with a dendritic drainage pattern. The study area is designated as fifth order basin. The results from the morphometric analysis of the watershed are very beneficial for developing and designing conservation structures of soil and water and watershed management measures.

Mallikarjuna *et al.* (2023) studied morphometric analysis of Hirerayakumpi watershed in Krishna river basin using by DEM and GIS techniques. The drainage network of micro watershed was delineated and the parameters required for morphometric analysis are estimated by using QGIS 2.6.1 software. Study area has dendritic drainage pattern with stream order 5 th. The bifurcation ratio estimated as 1.45 indicate that the watershed has suffered less structural disturbance. The drainage density of watershed is 2.54 km/km^2 which indicates the closeness of spacing of channels. The values of form factor and circulatory ratio of watershed indicate that the watershed is approaching towards the fern shape. The low value of ruggedness number shows that watershed is having gentle slope. The research of morphometric analysis study helps to plan the selection and adoption of the soil and water conservation measures.

2.3 SCS-CN Method for runoff estimation

Hawkins (1975) assumed an input error of t 10 per cent and found that runoff prediction is more sensitive to CN chosen for a considerable precipitation range up to 9 inches. Therefore, he emphasized the importance of accurate curve number in estimation of storm runoff.

Yu (1998) gave theoretical justification of SCS for runoff estimation. The SCS-CN method is widely used to estimate runoff from small to medium sized watersheds. The most critical assumption of SCS-CN method is that ratio of the actual retention to the potential is the same as the actual runoff to the potential runoff, but this assumption has not been theoretically or empirically justified. They reported that the exact relationship between rainfall and runoff in the SCS method can be derived theoretical if two simple but realistic assumptions are made.

Sundar Kumar *et al*. (2010) stated that soil conservation service curve number (SCS-CN) method that would be widely used for predicting direct runoff volume for a given rainfall event. A detailed land cover and soil survey using remote sensing and GIS techniques showed larger part of watershed was dominated by coarse soils with high hydraulic conductivities. Whereas, a smaller part covered with medium textured soils and impervious surfaces. The analysis indicated that the combination of remote sensing and SCS model makes the runoff estimate more accurate and faster, the runoff estimated using SCS curve number model were comparable with the runoff measured by the conventional method.

Geena and Ballukraya (2011) estimated runoff from an agricultural watershed namely the red hills watershed, which is about 83.59 km and part of Korattaliyar river basin catchment, situated in Thiruvallur district of Tamil Nadu state in India using SCS model. The results show that a good correlation exists between rainfall and runoff and a minimum of about 66 mm rainfall per month is required to generate runoff in the area.

Sailakumar *et al*. (2012) has used SCS-CN method for runoff assessment in the delta region of Krishna basin. The land use and land cover map has been developed by using Remote Sensing and GIS system. They compared the runoff obtained from SCS-CN method with the runoff measured by conventional method. They concluded that SCS-CN is fairly perfect system for assessment of runoff.

Sindhu *et al*. (2013) studied morphological features of Nallur Amanikere watershed for estimation of surface runoff using SCS-CN method. The thematic layers such as land use/land cover and soil maps were derived from remote sensing data and overlayed through ArcGIS software to assign the curve number on polygon wise. The daily rainfall data of 6 rain gauge stations in and around the watershed (2001- 2011) was used to estimate the daily runoff from the watershed using Soil SCS-CN method. The runoff estimated from the SCS-CN model was then used to know the variation of runoff potential with different land use land cover and with different soil conditions.

Zende *et al*. (2014) reported research study using SCS-CN and GIS to estimate the surface Runoff from Yerala river basin, located in upper Krishna basin, Western Maharashtra, India. Hydrologic soil group map has been prepared according to soil characteristics and type of land use/land cover for the estimation of runoff from river basin. Daily rainfall data from 10 rain gauge stations for the year of 1998 to 2011 (14 years) was used to calculate the runoff using SCS-CN method. They concluded that annual runoff values in the river basin can be studied for reliable accuracy along with the spatial variation of soil type and land use type.

Yaligar *et al*. (2015) estimated the runoff using SCS-CN method for Chaka block, Allahabad district of Uttar Pradesh. For calculating CN value of Chaka block, the hydrologic soil group in block was considered as ‘C’. The weighted CN for the entire block was calculated and found to be 78 which was corresponded for AMC II. Potential maximum retention ‘S’ value for AMC II is found to be 71.64 mm. Maximum rainfall and runoff depth details of the storm events for the study period during 1994 to 2011. It was noted that among the selected storm events maximum rainfall of 203 mm occurred in Sept. 1, 2000 giving the highest runoff value of 169.89 mm for the entire Chaka block. Also, maximum value of runoff volume calculated is 2609.33 ha-m for the same storm event.

Ningaraju *et al*. (2016) estimated runoff using SCS-CN and GIS method in ungauged Kharadya mill watershed, India. In this paper Soil Conservation Services Curve Number (SCS-CN) method and the Geographical Information System (GIS) was used for runoff estimation of ungauged Kharadya milli watershed in Mandya district, Karnataka, with an area of 23.95 sq.km. The average annual rainfall was 749 mm from 2003 to 2013. The runoff was varied between 35.47 mm to 240.16 mm. The land use details of study area were obtained by integration of GIS and remote sensing. Around 58.63% of watershed consists of gravelly clay soil and 39.49% area is cultivable crop land.

Satheeshkumar *et al*. (2017) estimated the volume of runoff contributed in the river or streams by using SCS-CN method to propose artificial recharge structures in Pappiredipatti watershed. The runoff volume represented 6.6% of the overall annual rainfall. The natural, rainy and dry conditions measured, the curve numbers are 85.92, 72.8, and 93.46 respectively. The rainfall ranges from 2000 to 2014 from 169-191 mm. In the watershed, rainfall ranges from 410 and 1650 mm. The estimated total annual runoff was 181.7 mm and the calculated average runoff volume over fifteen years was 32,682,501 mm. A correlation coefficient (r) value of 0.84 was highly associated with the rainfall runoff relationship. The research has been used effectively for the establishment of watershed and water supply planning.

Srivalli and Singh (2017) estimated the runoff for the watershed using SCS-CN number and GIS for Gadela watershed situated in the Udaipur district, Rajasthan. They analysed the rainfall data from 1995 to 2006 and found the average runoff as 184.04 mm. The maximum runoff was observed during 2006 which is about 62% of the total rainfall and the minimum runoff found in the year of 1999 which is about 18%. It is observed that the basin wise average runoff was 184.39 mm of the average rainfall 535.65 mm.

Zeenat Ara and Zakwan (2018) used modified SCS-CN method for analysing the runoff generated over the command area. Total runoff generated over the study area during the year 2007 was computed as 17.98 mm. In the month of July peak runoff was observed, which contributed 39.85% of the total.

Pathan and Joshi (2019) estimated runoff using SCS-CN method and ArcGIS for Karjan reservoir basin Estimation of direct rainfall-runoff is always efficient but is not possible for un-sampled location of the basin. Use of remote sensing and GIS technology was useful to overcome the problem for estimating runoff. The method used in this study is SCS-CN Model. The daily rainfall data of 5 rain gauge stations are collected and used for the daily runoff calculation using SCS-CN model and GIS. The linear regression model is used for verification of runoff obtained from SCS-CN method. It is found that the results obtained from runoff obtained from SCS -CN model demonstrate deviations from the observed runoff. Linear regression model is closely agreeing with the observed runoff from the basin in comparison to the SCS -CN model.

Gabale and Deshpande (2020) studied the geospatial technique for runoff estimation based on SCS-CN method in Sudha river basin of Indrayani river. The integration of remote sensing data of Sudha watershed and application of the SCS CN model in a GIS environment had helped us to provide a powerful tool for estimation of runoff at the selected site. The Soil Conservation Service Curve Number (SCS-CN) method were used to estimate runoff. It is simple, predictable and stable conceptual method. RS and GIS were effectively used to manage spatial and non-spatial data base that represent the hydrologic characteristics of a watershed. The land use and land cover map, soil map and rainfall data were collected from various sources and processed.

Kumar *et al*. (2021) studied surface runoff estimation of Sind river basin using integrated SCS-CN and GIS techniques. The SCS-CN method remains the most popular and frequently used method as runoff curve number (CN) is a crucial factor of the SCS-CN method and depends on land use/land cover (LULC), soil type and antecedent soil moisture condition (AMC). Besides this, various parameters, such as Hydrological Soil Characteristics (HSG), precipitation (P), Potential Maximum Retention (PMR), Antecedent Moisture Condition (AMC), Weighted Curve Number (WCN), are the mandatory inputs to the SCS-CN model. In the results, the daily runoff from the Sind River basin for ten years, i.e., 2005 to 2014, has been used. As a result, the average annual surface runoff calculated for the Sind River basin is 133.71 mm. The total average volume of runoff is 35.04 × 10 8 m 3, representing 17.21% of the total average annual rainfall

Kale *et al*. (b) (2022) estimated runoff of Kudavale watershed in Dapoli Tehsil. By using SCS- CN method and GIS approach. They were used Arc GIS software using Landsat 8 satellite imagery collected from USGS earth explorer to produce land use land cover map. The rainfall data of 30 years (1990-2019) were used to estimate runoff. The study found that area under agricultural land, forest land, barren land and residential area was 15.42 %, 59.90 %, 21.22 % and 3.4 %, respectively. Average runoff of watershed was 1532.27 mm.

Alataway A. (2023) studied SCS- CN and GIS based approach for estimating runoff in western region of Saudi Arabia. Wadi-Rahjan catchment in Western Saudi Arabia has been taken as a case study to determine the potential runoff estimates. Various parameters including the digital elevation model (DEM), land use land cover (LULC), hydrologic soil groups (HSGS), and rainfall data were included. The curve number (CN) was estimated using LULC and HSG layers. Based on the results of calculations, the study area is classified into three HSGs, namely, B, C, D. CN for a normal condition is 90 while wet and dry conditions are 97 and 80, respectively. Results obtained from the SCS-CN method's calculations reveal a yearly runoff result that varies from 194 mm to 295 mm. A higher percentage of runoff water (35%) in a runoff range from 289 to 295 mm, followed by 24%, ranged 269 to 288 mm. An interesting rainfall-runoff regression evaluation reveals a good 0.90 correlation.

2.4 Site suitability analysis of Soil and Water conservation structures

Girish Kumar *et al.* (2008) conducted the study to identify potential sites for construction of rainwater harvesting structures in the Bakhar watershed of Mirzapur district, Uttar Pradesh, India using remote sensing and GIS techniques. using remote sensing various thematic maps such as Lineaments, LULC and Geomorphology etc. are prepared. By integrating these layers along with geology and drainage suitable water harvesting sites are identified. The composite layer, obtained by multiplication of the layers weightage and rank as score, were further averaged into four classes of Excellent 200), Good (121-200), Moderate (81 120) and poor (< 80).

Gavade *et al*. (2011) revealed that Solapur district is facing the problem of scarcity of water throughout the year. Due to plain relief and temperate climate this district experiences less rainfall. Moreover, construction of major irrigation projects has limited scope due to topographical. social, financial and environmental constraints. To check this problem, they constructed Check dams, percolation tank, bore well, dug well, dug cum bore well and farm pond in various parts of Solapur district.

Sankar *et al*. (2012) carried out study in Panoli village covering an area of 17.41 lakh ha. The main objective of the study was generation of action plans in the micro watersheds for land and water resources improvement to increase the crop productivity. For this study ArcGIS 9.3 and ERDAS Imagine 9.1 was used for the preparation of drainage map, contour map, DEM, slope map, land use/ land cover map and generation of land and water resources development plan. The results drawn from the study area were 6 check dams, 4 farm ponds, 6 percolation tanks, 14 gabion structures and 51 vegetative barriers were proposed in the study area for development of watershed and conservation planning.

Zende *et al*. (2013) studied sub-river basin of Krishna River, covering an area of 3035 km2 and lies in west part of Maharashtra state. The entire study area is divided into 9 sub watersheds. The drainage density of sub watersheds was varying between 2.07 to 3.26 km km-2 and the low drainage density values of sub watershed SWS5 indicate that it has highly resistant, impermeable subsoil material with dense vegetative cover and low relief. The elongation ratio varies from 0.20 to 0.35 which indicates low relief and gentle ground slope. The high value of circularity ratio for SWS8 sub watershed 0.6 indicates the late maturity stage of topography. The compound parameter values were calculated and the sub watershed with the lowest compound parameter was given the highest priority. The sub-watershed SWS3 was a minimum compound parameter value of 1.68 and SWS8 was a maximum compound parameter of 3.08, hence provided with immediate soil conservation and water storage structures.

Bamne *et al*. (2014) made an attempt to study suitable sites for water harvesting structures in Narli nala watershed, Gangapur, Aurangabad. The various thematic maps such as land use map, group map, hydrological soil slope map and drainage map are laid over each other and five check dams were proposed on 2nd and 3rd order drainage and satisfies the conditions of land use, soil type and slope as 14 per IMSD guidelines. As per IMSD guidelines the suitable sites for percolation tanks are not found, due to soils with low runoff potential were not found.

Haji *et al*. (2015) concluded that Water conservation structures are extremely important to Conserve precious natural resources. Keeping this in view, GV53 and GV54 watershed is selected for planning suitable sites for construction of water conservation structures using remote sensing and GIS techniques. The potential sites for water conservation structures in GV53 and GV54 watersheds were identified through modern technologies of remote sensing and GIS and 14 check dams and 7 percolation tanks at appropriate sites are proposed. Proposed check dam could be useful for protective irrigation and percolation tank augment ground water table.

Ammar *et al*. (2016) stated that Harvested rainwater is an alternative source of water in arid and semi-arid region around the world. Many researchers have developed and applied various methodologies and criteria to identify suitable sites and techniques for rainwater harvesting. Determining the best method or guidelines for site selection, however, is difficult. The most important criteria for the selection of suitable sites for RWH were slope, land use/cover, soil type rainfall, distance to settlements/streams and cost. The success rate of RWH projects tended to increase when these criteria were considered, but an objective evaluation of these selection methods is still lacking. Most of the studies now select rainwater harvesting sites using geographic information systems in combination with hydrological models and multi-criteria analysis.

Regulwar and Ambhore (2017) concluded that, by classifying the study area into 8 land capability classes considering the slope parameter soil conservation structure contour bunding is suggested for class I to IV i.e., for arable lands. The main aim to provide soil conservation structure in this type of arable land is reducing erosion while keeping desired soil moisture. Contour trenching should provide in the non-arable land that is for land capability class V to VII. All thematic maps such as land use land cover, soil map, slope map and stream network are overlaid and cross operation has been done by using GIS and best suitable location for check dams are suggested in the study area.

Ahmad and Verma (2018) demonstrated the selection of an acceptable site for water storage using multi-criteria strategies based on RS and GIS in the upper Sheonath River basin in Chhattisgarh province. The SCs-CN equation, including hydrological soil group, slope, land use, lineament, stream order and basin area, calculated runoff capacity.

Ibrahim *et al*. (2019) made a study in which various thematic maps are combined and computed land use land cover categories using LANDSAT image data and applied supervised classification using the ENVI-5 software. They too extract drainage and slope map from DEM and then found the most suitable site for water harvesting in their study area was intense at the cultivated zone and the loamy texture was suitable soil. They used Triangulated Irregular Network (TIN), drainage layer and contour line to construct the dams. The height of the dam was calculated by contour lines and that was used to calculate the volume of dams by ArcGIS 10.4.1. The location of the dam was preferred as the drainage was narrow and straight to acquired economical construction.

Yogesh *et al*. (2020) made an attempt to identify the suitable zones for water conservation activity. Multi- criteria evaluation is carried out using Geographic Information System (GIS) technique. Different layers which were considered for multi-criteria evaluation: slope, land use land cover, soil texture, lithology, soil depth, soil erosion, wells, lineaments and drainage network. Analytical Hierarchy Processes (AHP) is used for weighted sum to find suitable sites for implementation of water conservation activity using selected criterions. The site suitability map was classified into four classes: highly suitable, moderately suitable, less suitable and not suitable with area of 19.19%, 26%, 49.03% and 5.78, respectively. This map will help for selection of suitable sites for construction of Mati Nala Bund (MNB), Check Dam, Cement Nala Bund (CNB) and Continuous Contour Trenches (CCT) for conservation of groundwater resource in the region

Sabita *et al*. (2021) made an attempt to study Assessment of land suitability for rain-fed cultivation in undulating terrains of red and lateritic zones, a GIS-based multi-criterion decisionmaking approach characterized the agricultural land suitability in Kashipur and Chhatna blocks (RLZs) of West Bengal, India. The land suitability analysis included multiple factors like slope, land use/cover, soil moisture, erosion, depth, texture, pH, geology, the proximity of the surface, and groundwater. This study mapped the spatial distribution of four potential land types, viz., unsuitable (8.52%), marginally suitable (41.58%), moderately suit- able (38.22%), and highly suitable (11.69%).

Surve *et al*. (2022) made an attempt for Planning of appropriate soil and water conservation structures for Tetavali watershed The SRTM DEM (30m) is used to prepare thematic layers *viz*. slope map, drainage map, drainage density map. LANDSAT-8 image is used to prepare the Land use/ land cover map of study area. Lithology map and Geomorphology map is downloaded from Bhukosh geological survey of India portal. Integration of all thematic layers with assigned ranking gave suitability map of study area. Study found thirteen suitable structures for water harvesting. 6 farm ponds, 3 check dams, 2 percolation ponds, 1 cement nala bund and 1 earthen nala bund found suitable with 278.36 ha area suitable for water harvesting structure construction and 103.64 ha of watershed not suitable for water harvesting structures.

Rejani *et al*. (2022) concluded in order to make western Vidarbha zone of Maharashtra more resilient to the impact of climate change, suitable in situ moisture conservation measure and rainwater harvesting structure were planned using a novel and robust approach with geospatial techniques. Out of the total area, conservation furrow is found suitable for 51.5% of the area and contour cultivation for 22.5% area. Also, adoption of suitable water harvesting structures like percolation tanks, farm ponds and check dams are also very essential for the sustainable water management for climate resilient agriculture in western Vidarbha zone of Maharashtra.

Gadakh *et al.* (2023) made an attempt to study Remote sensing and GIS based site selection for effective soil and water conservation measures in the Warana river basin. Indian Remote Sensing Satellite data was used to create a land use land cover map and extract information on morphometric parameters. These factors were combined with other thematic information including land use land cover, drainage, slope, and soil to find potential locations for soil and water conservation structures such as nala bunds, check dams, percolation tanks, and continuous contour trenches. The study included multi criteria evaluation in GIS to identify potential zones for water conservation. Weighted sum analysis was used to identify ideal locations for water conservation operations. The program Arc 10.5 was used to analyze remotely sensed data and delineate the watershed. Overall, the study is useful for building watershed management plans and selecting appropriate areas for soil and water conservation structures and water conservation activities.

CHAPTER III : MATERIAL AND METHODS

This chapter deals with the description of the study area, collected data, methodology adopted for morphometric analysis, estimation of runoff, suggesting suitable sites for soil and water conservation structures in Kadivali watershed and other relevant components of the study.

3.1 Study Area

The present research work was conducted at Kadivali village, which is adopted by Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli.

3.1.1 Location

The village Kadivali is located in Dapoli tehsil of Ratnagiri district in the state of Maharashtra in India. It is situated 25 km away from Dapoli and 139 km North from district headquarters Ratnagiri. Kadivali village is located in between 17°82 N Latitudes and 73°24 E Longitude. The total geographical area is 1649.04 ha. The location map of the study area is shown in Fig 3.1

3.1.2 Climate

The study area has hot and humid summer season, a very wet monsoon season and drier and cooler winters. The study area experiences maximum rain during the months of July to September. The average annual rainfall, recorded in these months is 3500 mm. The average annual temperature of the study area ranges between 28 to 36ºC during summer and 25.30 to 26.30ºC during winter season. It is near to Arabian sea. There is chance of high humidity throughout the year. The study area has relative humidity highest at 89% and least at 46%.

3.1.3 Topography

The Kadivali watershed has undulating land, hills and mountainous terrain. The general slope of the area is from north west to south east direction.

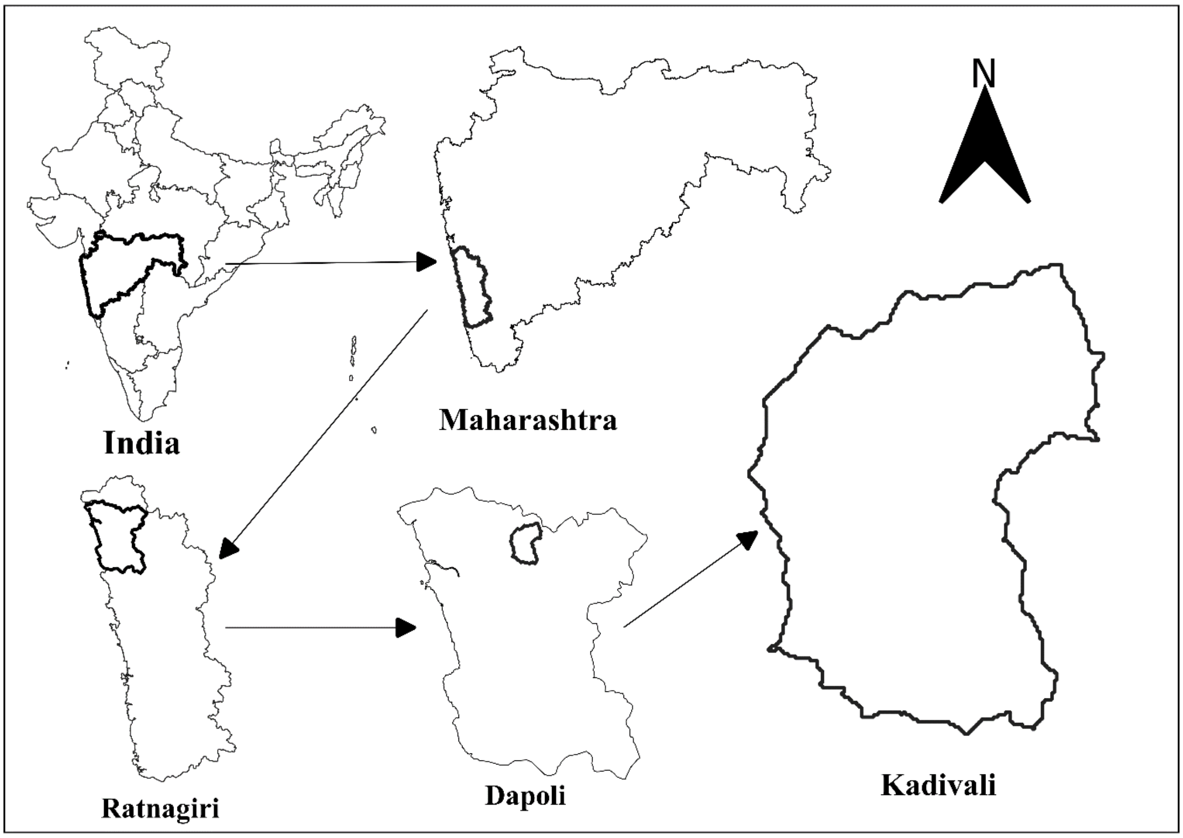

Fig 3.1 Location map of the study area

3.2 Data Availability

3.2.1 Software Used

The software QGIS 3.18.3 has been used for processing the remote sensing data for delineating watershed and generating various thematic maps like stream order map, slope map, soil map, geomorphology map, contour map, lithology map etc. QGIS is a free and open-source cross platform software that allows users to create, edit, visualize and analyse geospatial information.

3.2.2 Data Acquisition

The various information required for the study was obtained from various sources. An overview of data obtained is given below:

1. Daily rainfall data for past 32 years (1990-2022) has been collected from Department of Agronomy, College of Agriculture, Dapoli.
2. Digital Elevation Model (DEM) has been collected from Bhuvan captured by Cartosat-1 satellite having spatial resolution of 2.5m (Website: https://bhuvan.nrsc.gov.in).
3. The shape file of the study area has been downloaded from DIVA GIS. (Website: http://www.diva-gis.org/Data).

4. LISS III satellite image of 30 m spatial resolution dated 11.02.2019 collected from Bhuvan (Website: https://bhuvan.nrsc.gov.in).

5. Soil data has been collected from NBSS LUP, Nagpur

   (Website: https://bhukosh.gsi.gov.in/Bhukosh/Public).

6. Geology data has been collected from Geological Survey of India

   (Website: https://bhukosh.gsi.gov.in/Bhukosh/Public).

7. Geomorphology data has been collected from Geological Survey of India

   (Website: https://bhukosh.gsi.gov.in/Bhukosh/Public).

8. Lithology data has been collected from Geological Survey of India

   (Website: https://bhukosh.gsi.gov.in/Bhukosh/Public).

9. Lineaments data has been downloaded from Geological Survey of India

   (Website: https://bhukosh.gsi.gov.in/Bhukosh/Public).

10. Toposheets 47G1 E43N/1, 47G5 E43N/5 of study area has been downloaded from Survey of India portal (Website: https://www.surveyofindia.gov.in/).

3.3 Procedure for Delineation of Watershed from Digital elevation model (DEM)

Watershed is an area which drains rain water to a single outlet into a large stream, river, lake or pond. Watershed delineation is the process of identifying the boundary of a watershed, It plays an important role in watershed management. To find watershed ridge called Watershed delineation. Digital Elevation Model (DEM) is the digital representation of the land surface elevation with respect to any reference datum. DEM is often used to refer to any digital representation of a topographic surface. Watershed can be delineated manually using paper, maps or digitally in GIS. The DEM can be created from a variety of sources. In this study, the digital elevation model (DEM) was downloaded from ISRO's geoportal 'Bhuvan' which is captured by Cartosat-1 satellite having spatial resolution 2.5 m. For delineation of watershed various operations were performed on DEM in QGIS 3.18.3 software like fill, Strahler order, Upslope area, adding pour point, Polygonise and clipping the watershed from DEM.

3.3.1 Steps involved in delineation of watershed in QGIS:

The delineation of watershed can be area based or point based.

1. **DEM acquisition:** The first input required for watershed analysis is DEM. The digital elevation models (DEMs) are the type of raster GIS layer. DEM data file contains the elevation of terrain over a specified area, usually fixed grid internal over the 'Bare

Earth'.

2. **Fill Sink:** Fill Sink (Wang and Liu) tool used to identify and fill surface depressions in digital elevation models. Sink should be filled for proper delineation of study area. If the sinks are not filled, drainage network may not be continuous.

3. **Strahler order:** Strahler order tool gives the actual direction of flow as per slope assigning a fix pixel value.

4. **Upslope area:** Upslope area tool gives the streams where the flow is getting accumulated from all directions. Raster calculator tool was used to alter the pixel values of flow accumulation to increase or decrease the number of streams.

5. **Snap pour point:** The pour point is added on the required flow accumulation stream by using identify feature, which was considered as outlet point of watershed.

6. **Polygonise:** Polygonise tool takes the Strahler order and upslope area as input and gives desired watershed boundary as output. The watershed area was clipped from the DEM using clip raster tool.

The complete procedure of Digital delineation of watershed is illustrated in Figure 3.2.

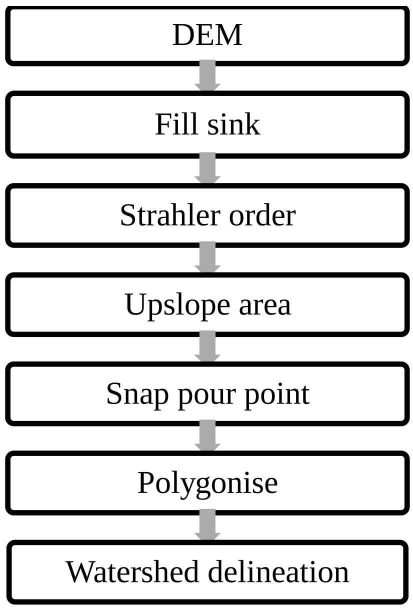

Fig 3.2 Flow chart of Digital delineation of watershed

3.4 Morphometric Analysis of Watershed

Morphometric of the watershed is the measurement and mathematical analysis of landforms. It plays a vital role in understanding the geohydrological characteristics of a drainage basin in relation to the terrain feature and hydrological behaviour of the watershed. Watershed analysis based on morphometric parameters is very important for watershed planning since it gives idea about the basin characteristics regarding slope, topography, soil condition, runoff characteristics and surface water potential. Morphometric analysis requires measurement of (I) Basic parameters (II) Linear aspects (III) Areal aspects and (IV) Relief aspects of drainage basin. The parameters can be conveniently worked out from the delineated watershed obtained from DEM by using GIS tools where it is an effective tool for the analysis of spatial information. Grouping of morphometric parameters is shown in table 3.1.

Table 3.1: Grouping of Morphometric parameters

Sr. No.	Aspects	Morphometric Characteristics
1.	Basic parameters	Watershed area, Watershed perimeter, Length, Stream order, Maximum elevation and Minimum elevation
2.	Linear aspects	Bifurcation ratio, Mean bifurcation ratio, Stream length, Mean stream length, Stream length ratio
3.	Areal aspects	Drainage density, Stream frequency, Form factor, Compactness coefficient, Length of overland flow, circulatory ratio, elongation ratio and Constant of channel maintenance
4.	Relief aspects	Maximum watershed relief, Relief ratio, Relative relief and Ruggedness number

3.4.1 Basic parameters

The formulae for computation of basic morphometric parameters have shown in Table 3.2.

i. Perimeter of watershed (P)

An outer border of a watershed that encloses the area is known as the Perimeter of the watershed (P). This is measured along the divided watershed and can be used as a detector for the size and shape of the watershed. It is estimated using QGIS 3.18.3 software.

ii. Area of the watershed (A)

It is defined as area from which water drains to a common stream and boundary determined by opposite ridges (Strahler 1964). The area is expressed in hectares. It is estimated using QGIS 3.18.3 software.

iii. Length of the watershed (L_b)

It is defined as the length of the straight line from the mouth of the stream to the farthest point of drainage divide. The standard formula mentioned as above was used for the calculation of basin length, However, however certain software’s like QGIS 3.18.3 can automatically estimate the basin length.

iv. Stream Order (U)

The stream order represents the degree of stream branching with a watershed. Each length of stream is designated by its order. Stream Ordering has proposed by (Strahler, 1964). The order of stream is termed as the calculation of the position of a stream in the hierarchy of streams. The smallest (unbranched) streams are first order and where the two first order streams join together, they form second order streams and two second order streams come together they form third order and so on, whereas two different order streams come together; they will remain as the highest one. The highest order stream is known as trunk or principal stream.

v. Maximum elevation (H)

Maximum elevation is defined as the elevation of highest point of the watershed. It is expressed in meters. It is estimated using QGIS 3.18.3 software.

vi. Minimum elevation (h)

Minimum elevation is defined as the elevation of lowest point of the watershed. It is expressed in meters. It is estimated using QGIS 3.18.3 software.

Table 3.2: The formulae for computation of basic morphometric parameters

Morphometric parameters	Formula	References
Area (A)	QGIS 3.18.3 software analysis	-
Perimeter (P)	QGIS 3.18.3 software analysis	-
Stream Order (U)	Hierarchical Order	Strahler, 1964
Basin length (L)	$L = 1.312\ A\ b^{0.568}$ L is a length of basin (km)	Schumm, 1956
Maximum elevation (H)	QGIS 3.18.3 software analysis	-
Minimum elevation (h)	QGIS 3.18.3 software analysis	-

3.4.2 Linear aspects

The linear aspects of watershed are concerned with the stream and its network. In general, these are one dimensional property deals with length parameters. The formulae for computation of Linear aspects of morphometric Parameters has shown in Table 3.3

i. Bifurcation Ratio (R_b)

According to (Schumm, 1956) the bifurcation ratio is termed as the proportion of the number of streams of any given order to the number of streams of the next higher order. Strahler has also demonstrated that bifurcation proportion shows a tiny number of differences with various areas or environmental influences instead of where geological influence is predominant. Besides, the R_b is an indicative parameter for basin shape. Lengthened basins have lower bifurcation ratio values, whereas circular basins have higher bifurcation ratio values (Aravinda and Balakrishna, 2013). The value of R_b ranges from 2 to 4.

ii. Stream Number (N_u)

Stream number (N_u) is defined as the total number of streams of that order. Stream number is inversely proportional to stream order. So, stream number decreases as stream order increases. (Horton, 1945) states that the numbers of stream segments of each order form an inverse geometric sequence with order number.

iii. Stream Length (Lu)

The stream length (Lu) of particular order is defined as the total length of all streams of that order. It is measured with respect to streams orders by using GIS software which is proposed by (Horton, 1945). Horton's law of stream lengths supports the theory that geometrical similarity is preserved generally in watershed of increasing order (Strahler, 1964). The stream length decreases as the order increases.

iv. Mean stream length (Lsm)

Mean stream length **(**Lsm**)** is defined as the ratio of total length of streams of particular order to the Total number of stream segments of that order and it is denoted by Lsm. It is observed that mean stream length increases with the stream order.

v. Stream Length Ratio (R_L)

The stream length ratio (R_L) is defined as the ratio of the mean of segments of one order to mean length of segments of the next lower order (Horton, 1945). It has major relationship with surface flow, discharge and erosion stage of the basin. An increasing trend in stream length ratio from lower order to higher order indicates their geographic stage. Therefore, there is no classification of R_L.

Table 3.3: The formulae for computation of Linear aspects of study area

Morphometric parameters	**Formula**	**References**
Stream Length (Lu)	Length of the Stream in km	Horton, 1945
Mean Stream Length (Lsm)	Lsm = Lu/Nu Where, Lu = Total stream length of order 'u' Nu = Total no. ofstream segments of order 'u'	Strahler,1964
Stream Length Ratio (R_L)	R_L = Lsm / Lsm-1 Where, Lsm =Mean stream length of a given order Lsm-1=Mean stream length of next lower order	Horton, 1945
Bifurcation Ratio (R_b)	R_b = Nu / Nu +1 Where, R_b = Bifurcation Ratio Nu = No. of stream segments of a given order Nu +1= No. of stream segments of next higher order	Schumm, 1956
Mean bifurcation Ratio (R_{bm})	Average of bifurcation ratios of all orders	Schumm, 1956

3.4.3 Areal aspects of drainage network

Areal aspects are two dimensional components. It deals with the total projected area and includes description of arrangements of areal parameters. The formulae for computation of Areal aspects of study area have shown in Table 3.4

i. Form Factor (F_f)

Form factor (F_f) is defined as the ratio of basin area to the square of the basin length (Horton, 1932). If the value of form factor is small, the basin will be more elongated. The basins with high form factors have high peak flows of shorter duration, whereas, elongated watershed with low form factors have lower peak flow of longer duration. The value of form factor would always be greater than 0.78 for a perfectly circular basin.

ii. Circulatory Ratio (R_c)

Circularity ratio (Rc) is the ratio of the basin area to the area of circle having the same circumference perimeter as the basin and expresses the degree of circularity of the basin (Miller, 1953). He stated the basin of the circularity ratios ranges from 0.4 to 0.5 are strongly elongated and highly permeable homogenous geologic materials.

iii. Stream frequency (Fs)

Stream Frequency (Fs) is the ratio of total number of all the streams in the watershed to the area of watershed. A large basin may contain as many accessible tributaries per unit of area as a small drainage basin usually contains a larger stream or streams (Horton, 1932).

iv. Elongation Ratio (Re)

Elongation ratio (Re) is defined as the ratio between the diameter of the circle of the same area as the drainage basin and the maximum length of the basin (Schumm,1956). According to Strahler (1964), the values of elongation ratio generally vary from 0.6 to 1.0 over a wide variety of climate and geologic type. If elongation ratio values near to 1.0 are the characteristics of the region of very low relief, while values in the range of 0.6 - 0.8 usually occur in the areas of high relief and steep ground slope (Strahler 1964). These values are further classified as circular (>0.9), oval (0.9-0.8) and less elongated (<0.7).

v. Drainage Density (D_d)

Drainage density (D_d) is the ratio of total stream length of all the streams in the watershed to the area of watershed. It helps in determining the permeability and porosity of the watershed. In general, low value of drainage density is preferred in regions of high resistant or highly permeable sub soil materials, under dense vegetation cover and where relief is low. High drainage density is preferred in regions of weak or impermeable surface materials, sparse vegetation, and mountainous relief. The drainage density is affected by the factors like rock type, run off intensity, soil type, infiltration capacity and percentage of rocky area. Low drainage density leads to coarse drainage texture.

vi. Length of the overland flow (L_g)

Length of overland flow (L_g) is known as half the reciprocal of drainage density (Horton, 1945). It is the length of flow of water over the ground before it becomes concentrated in definite streams. According to (Schumm, 1956), the highest value of the length of the overland flow indicates more surface runoff and the lowest value of the length of the overland flow indicates less surface runoff. It is denoted by L_g.

vii. Compactness coefficient (C_c)

The compactness coefficient (C_c) is termed as the ratio of the catchment's perimeter to the circumference of an equivalent circular area and is indicated as Cc. Compactness coefficient indicates the relationship of a basin with that of a circular basin having the same area. A circular basin yields the shortest time of concentration before peak flow occurs in the basin. Cc is equal to 1 indicates that, the basin completely behaves as a circular basin. Cc > 1 indicates more deviation from the circular nature of the basin.

viii. Constant of channel maintenance (C)

It is the inverse of drainage density (Schumn, 1956). Constant of channel maintenance is defined as the area required for maintaining 1 km of a stream. The regions of weak rock types or no vegetation and less soil infiltration should have low constant of channel maintenance (< 0.3) on the other hand, values (> 0.5) show higher infiltration and permeability, good vegetation and resistant rock type. rest of the watersheds have moderate infiltration and permeability of the surface material, moderate vegetation, moderate resistant rocks (Sakthivel *et al*.2019)

Table 3.4: The formulae for computation of Areal aspects of study area

Morphometric parameters	Formula	References
Drainage Density (D_d)	D_d = Lu/A Where, D_d = Drainage Density (1/km) Lu = Total streamlength of all order A = Area of the basin (km^2)	Horton, 1932
Stream Frequency (Fs)	Fs = Nu/A Where, Fs = Stream Frequency Nu = Total no. of streams of all orders A = Area of the basin (km^2)	Horton 1932
Form Factor (F_f)	$F_f = A/Lb^2$ Where, A = Area of the basin L_b = Basin length	Horton, 1932
Circulatory Ratio (Rc)	$Rc = 4\pi A/ P^2$ Where, A = Basin area (km^2) P= Perimeter of the basin (km)	Miller, 1953
Elongation Ratio (Re)	Re= √A /π / Lb Where, A= Area of the basin (km$^{2)}$ Lb= Basin length (km)	Schumm, 1956
Compactness coefficient (Cc)	$Cc = 0.2821\ P/A^{0.5}$ Where, P = Area of the basin (km$^{2)}$ A= Basin length (km)	Horton, 1945
Length of overland flow (Lg)	Lg = 1 / 2 D_d Where, Lg = Length of overland flow D_d = Drainage Density	Schumn, 1945
Constant of channel maintenance (C)	C = 1/ D_d Where, C = Constant of channel maintenance, D_d = Drainage Density	Schumm, 1956

3.4.4 Relief aspects of channel network

The formulae for computation of Relief aspects of study area have shown in Table 3.5

i. Maximum watershed relief (B_h)

Maximum watershed relief (B_h) is the elevation variation between basin mouth (discharge point) and the highest point on the basin perimeter. It is the vertical maximum difference between the lowest and highest points of the basin. It is expressed in meter.

ii. Relative relief (R_R)

Relative relief (R_R) is defined as the ratio of total watershed relief and its perimeter. It is an indication of the elevation of the basin from peak to the outlet point.

iii. Relief ratio (Rr)

The relief ratio (Rr) is defined as the ratio of maximum relief to horizontal distance along the longest dimension of the basin parallel to the principal drainage line (Schumm, 1956). The relief ratio increases with decreasing drainage area and size of the watershed of a given drainage basin (Gottaschalk, 1964). Relief ratio is inversely proportional to the drainage area and the size of given drainage. It shows steepness of relief in the basin.

iv. Ruggedness number (R_n)

Ruggedness number (R_n) is defined as the product of the maximum basin relief and drainage density. Since Ruggedness number depends on slope and drainage density, its lower value indicates lower stream flow velocity which suggests less prone to soil erosion. An extreme high value of ruggedness number occurs when both variables are large and slope is not only steep but also long (Strahler, 1964). It is dimensionless quantity.

Table 3.5: The formulae for computation of Relief aspects of study area

Morphometric parameters	Formula	References
Maximum watershed Relief (B_h)	B_h = H-h H = Maximum elevation H = Minimum elevation	Strahler, 1952
Relative relief (R_R)	R_R = 100 (H/LP) Where, R_R = Relative relief H = Total relief of the basin Lp =Length of perimeter	Schumm, 1956
Relief Ratio (Rr)	Rr = H / L_b Where, H = Basin Relief (km) L_b = Basin length (km)	Schumm, 1956
Ruggedness Number(R_n)	Rn = H x D_d Where, H = Basin Relief (km) D_d = Drainage Density	Strahler, 1964

3.5 Estimation of runoff using SCS Curve Number Method:

3.5.1 SCS curve number method

The SCS-Curve Number method has been established in 1954 by the United States

Department of Agriculture (USDA-SCS, 1985), which computes direct runoff using an empirical equation that, requires the rainfall and a watershed coefficient as inputs (Geetha and Pathan, 2019). The Soil conversation Services-Curve Number approach is revolved around the water balance calculation and two fundamental premises had been proposed. The first presumption states that, the ratio of the actual quantity of direct runoff to the maximum possible runoff is equivalent to the ratio of the amount of actual infiltration to the quantity of the potential maximum retention. The second presumption states that the amount of initial abstraction is some fraction of the probable maximum retention. The Soil Conservation Service Curve Number approach is often used empirical method to estimate the direct runoff from a watershed in the study area. This method requires daily rainfall, soil type and land use as input.

as per first assumption,

$$\frac{F}{S} = \frac{Q}{P-Ia} \quad \text{……… (3.1)}$$

The water balance equation is,

$$P = Q + Ia + F \quad \text{……… (3.2)}$$

Where,

P = Total rainfall depth during storm in mm

Q = Direct runoff depth in mm

Ia = Initial abstraction in mm

F = Actual retention in mm

S = Potential retention in mm

Combining equation (3.1) and (3.2) i.e., the infiltration losses are combined with surface storage by the relation of

$$Q = \frac{(P-Ia)^2}{P-Ia+s} \quad \text{……… (3.3)}$$

This is the basic equation for computation of the depth of direct runoff from a storm by SCS method.

To eliminate the need to estimate the two variables Ia and S in Equation 3.14 a regression analysis was made on the basis of recorded rainfall and runoff data from small drainage basins. It estimates that initial abstractions are 20% of the potential retention. The following average relationship was found;

$$Ia = 0.2\ S \quad \text{……… (3.4)}$$

Combining equation (3.3) and (3.4), we get;

$$Q = \frac{(P - 0.2\,S)^2}{P + 0.8\,S} \qquad \ldots\ldots\ldots (3.5)$$

This is the general equation for the SCS - CN method.

For Indian conditions, initial abstraction can be 10% or 30% of the potential retention depending upon antecedent moisture conditions and hydrological soil type. The potential maximum retention S has been converted to the CN. This relationship between S and CN is given by,

$$S = \frac{25400}{CN} - 254 \qquad \ldots\ldots\ldots (3.6)$$

Where, CN is known as curve number which is taken from SCS handbook of hydrology (NEH, Section-4) Curve number is a parameter which represents the retention of catchment or perviousness. It is the dimensionless quantity varies between 0 to 100 ($0 < CN < 100$). For CN = 0, watershed is completely pervious (ideal condition) and for CN = 100, watershed is completely impervious. As CN value increases, imperviousness also increases. CN is assigned to each watershed or portion of watershed based on land use, antecedent moisture conditions (AMC) and soil type.

The SCS curve number is a purpose of the ability of soils to allow infiltration of water with respect to land use/ land cover (LU/LC) and antecedent soil moisture condition (AMC) (Satheeshkumar *et al*. 2017). Based on U.S soil conservation service (SCS) soils are distributed into four hydrologic soil groups such as group A, B, C & D with respect to rate of runoff and final infiltration.

3.5.2 Antecedent moisture condition (AMC)

Antecedent Moisture Condition (AMC) refers to the water content present in the soil at a given time. It is an important factor to determine CN value. CN values varies with the antecedent moisture conditions (AMC) and classified hem as I, II, III, according to soil conditions and rainfall limits for dormant and growing seasons. classification of AMC is shown in Table 3.6, since standard table for CN values (ranges 1 to 100), considering LU/LC and hydrological soil group are given for AMC II, following equations (Chow, 1988) are used to convert CN from AMC II (average condition) to AMC I (dry condition) and AMC III (wet condition).

For AMC I,

$$CN\ I = \frac{CN\ II}{2.281 - 0.01281\ CN\ II} \qquad \ldots\ldots\ldots (3.7)$$

For AMC III,

$$CN\ III = \frac{CN\ II}{0.427 - 0.00573\ CNII} \qquad \ldots\ldots\ldots (3.8)$$

Table 3.6 Group of Antecedent Moisture Condition (AMC)

AMC Group	Soil characteristics	Total five-day Antecedent rainfall(mm)	
		Dormant Season	**Growing Season**
I	Wet condition	Less than 13	Less than 36
II	Average condition	13-28	36-53
III	Heavy rainfall	Over 28	Over 53

3.5.3 Hydrologic soil groups

The soil is classified by the natural resource conservation service into four hydrological soil groups based on soil's runoff potential. The hydrologic soil groups (HSG) are divided into A, B, C, and D for the classification of soils in the watershed. The soils of group A indicated low runoff potential, high infiltration rate, the soils of group B indicated moderate infiltration rate, moderately well drained to well drained. The soils of group C pointed to moderately fine to moderately rough textures, moderate rate of water transmission and the soils of group D pointed to slow infiltration and possible high runoff. The soil conservation service classification is given in Table 3.7.

Table 3.7 Soil conservation service classification (USDA 1974)

Hydrologic Soil Group (HSG)	Soil Textures	Runoff potential	Water transmission	Final infiltration (mm/h)
Group A	Deep, well drained sand and gravels	Low	High rate	> 7.5
Group B	Moderately deep, well drained	Moderate	Moderate	3.8 - 7.5
Group C	Shallow sandy loam soil with moderate to fine texture	Moderate	Moderate	1.3 - 3.8
Group D	Clay soil that swells significantly when wet	High	Low rate	< 1.3

Runoff Curve Numbers (CN) for Hydrologic Soil Cover Complexes (Under AMC-II Conditions) are given in Table 3.8:

Table 3.8 Runoff Curve Numbers for hydrological soil cover complexes under AMC-II conditions for Indian conditions

Sr. No.	Land use	Land Cover		Hydrological soil groups			
		Treatment or practice	**Hydrologic condition**	**A**	**B**	**C**	**D**
1.	Fallow	Straight row	--	77	86	91	94
	Row crops	Straight row	Poor	72	81	88	91
			Good	67	78	85	89
		Contoured	Poor	70	79	84	88

			Good	65	75	82	86
		Contoured and terraced	Poor	66	74	80	82
			Good	62	71	78	81
2.	Small Grain	Straight row	Poor	65	76	84	88
			Good	63	75	83	87
		Contoured	Poor	63	74	82	85
			Good	61	73	81	84
		Contoured and terraced	Poor	61	72	79	82
			Good	59	70	78	81
3.	Closed seeded Legumes or rotation meadow	Straight row	Poor	66	77	85	89
			Good	58	72	81	85
		Contoured	Poor	64	75	83	85
			Good	55	69	78	83
		Contoured and terraced	Poor	63	73	80	83
			Good	51	67	76	80
4.	Pasture or range	-	Poor	68	79	86	89
			Good	39	61	74	80
		Contoured	Poor	47	67	81	88
			Good	6	35	70	77
5.	Meadow	-	Good	30	58	71	78
6.	Woods	-	Poor	45	66	77	83
			Good	25	55	70	77
7.	Farmsteads	-	-	59	74	82	86
8.	Road	-	-	72	82	87	89
9.	Hard surface	-	-	74	84	90	92

(Source: Murty and Jha, 2009)

3.5.4 Methodology adopted for estimation of runoff

The methodology and step by step procedure for estimation of runoff by SCS-Curve number method is shown in Fig 3.3. which shows the flow chart for model development of runoff. The various steps are involved in the following manner as follows, the land use land cover map is obtained in QGIS from satellite image LISS III, Soil texture data was obtained from NBSS LUP, Nagpur and Rainfall data collected. Determined the soil type and converted them into hydrological soil groups like A, B, C, D according to their infiltration capacity of soil. The superimpose land use map on the hydrological soil group maps obtained each land use soil group with polygon and finally, find out the area of each polygon then assigned a curve number to each unique polygon, based on standard SCS-Curve number. The curve number for each drainage basin of area weighting calculated from the land use soil group polygons within the drainage basin boundaries (Kudoli and Oak, 2015). Finally, by using SCS-CN model runoff depth has been calculated.

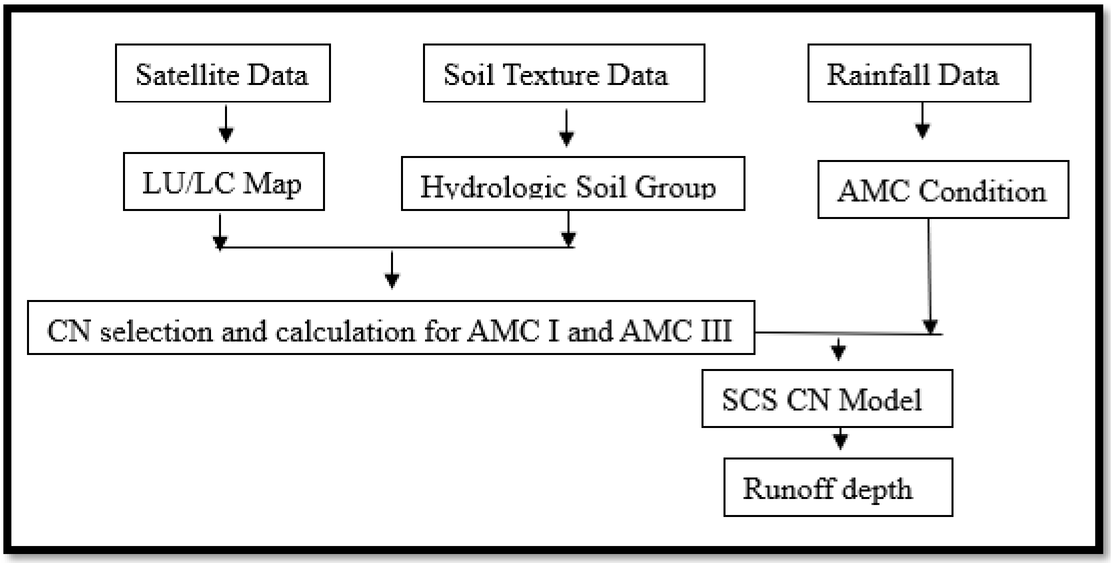

Fig 3.3 Flow chart of runoff estimation using SCS CN method

3.6 To locate suitable sites for Soil and Water conservation Measures:

Water harvesting is the technique which is used to effectively collect the surface runoff. In technical terms, water harvesting is a system that collects rainwater from where it falls around its periphery rather than allowing it to go as runoff. By constructing water harvesting structures in appropriate sites, it is possible to increase the ground water recharge and level of water table, so that we can effectively use this water for irrigation and drinking purpose in the off-monsoon season, The high spatial variability in rainfall and runoff potential shows the needs for adoption of site-specific structures for the area. Proper selection of suitable sites for water harvesting structures are important factor for effective erosion control, harvesting the runoff, moisture conversion. In this study the suitable sites for constructing water harvesting structures in Kadivali watershed is identified using QGIS. For the selection of suitable sites many guidelines put forward by various agencies are available such as IMSD, INCOH, FAO etc. In this study, selection of water harvesting structure is done on the basis of IMSD (Integrated Mission for Sustainable Development) guidelines presented by NRSA (National Remote Sensing Agency, Hyderabad).

3.6.1 Site suitability analysis

Site suitability analysis is a type of analysis used in GIS to determine the best place or site for something. Weighted overlay site selection analysis permit users to rank raster cells and allot value to each layer. For performing site selection analysis various criteria from GIS software will rate the best ideal sites. Site selection analysis can be performed with vector or raster data but weighted overlay site selection is most widely used raster data. Weighted site selection is a significant site selection method because it includes options for viewing next best slides.

3.6.2 Preparation of Thematic Maps using GIS

A thematic map is a specialized map made to focuses on the spatial variability of a specific distribution or theme about a geographic area. It is also called a special purpose, single topic or statistical map.

3.6.2.1 Slope Map

Slope map of study area has been generated by using Digital Elevation Model (DEM) from the CartoDEM of 30 m resolution data from Bhuvan. The high value of slope represents high runoff and vice versa. The higher value of slope indicates the steeper terrain and lower value of slope indictaes the flatter terrain. For identification of suitable sites for water conservation measures, slope factor is vital parameter. In present research work slope map has been prepared by using QGIS 3.18.3 software. The derived slope map has been classified based on slope in degree into 5 categories as per IMSD Guidelines.

3.6.2.2 Stream Order Map

Stream order map has been generated from DEM data in QGIS 3.18.3. It is done by choosing "channel network and drainage basin" option from "Terrain analysis Tools". After generating the stream network, identify the stream order of basin. It can be done by allocating the order of the stream in attribute table.

3.6.2.3 Geomorphology Map

Geomorphology includes the study of landforms that are found on the Earth. In the present study, the geomorphology map has been prepared by using data downloaded from the Bhukosh geological survey of India portal (http://bhukosh.gsi.gov.in/Bhukosh/Public).

3.6.2.4 Lithology Map

Lithology is the study general physical properties of rocks as well as chemical, mineral composition of rock. It shows the properties of unit rock. Sedimentary rock, igneous rock and metamorphic rock are the three main types of rocks. In the present study, the lithology map has been prepared by using data downloaded from the Bhukosh geological Survey of India portal (http://bhukosh.gsi.gov.in/Bhukosh/Public).

3.6.2.5 Geology Map

Geology is defined as the branch of science which study the composition and the process of formation of rock and change in rock over time. Geologic formations act as aquifers. Geology affects the groundwater potential, as the geologic formations changes. In the present study the Geology Map was prepared by using data downloaded from the Bhukosh geological Survey of India portal (http://bhukosh.gsi.gov.in/Bhukosh/Public).

3.6.2.6 Drainage density Map

Drainage density of watershed used to give the information related to runoff, relief, infiltration and permeability. Characteristics of surface and subsurface formations are reflected by the drainage network. The drainage density map has been prepared in QGIS 3.18.3 from drainage/stream network.

3.6.3 Weighted overlay analysis

Weighted overlay is a method of modelling suitability. QGIS uses the following process for this analysis. Each raster layer is assigned a weight in the suitability analysis, weights are assigned as different percentages that will sum up to 100%. Values in the raster's are reclassified to a common suitability scale. The suitable values in between 1 and 9 for all parameters are to be given by considering hydrogeological importance based on literatures reviewed. the highly impact parameters will be assigned 9 and least impact parameters will be assigned the value 1. The middle values are to be given accordingly. Raster layers are overlayed, multiplying each raster cell's suitability value by its layer weight and totalling the values to derive a suitability value. These values are written to new cells in an output layer. The symbology in the output layer is based on these values. Assigning a weight to each raster in the overlay process permit you to control the impact of different criteria in the suitability model. Multiplying each layer's weight by each cell's suitability value gives a weighted suitability value. Weighted suitability values are totalled for each overlaying cell and then written to an output layer. Then the suitability area in the watershed map will be obtained.

3.6.4 Suitable sites for soil and water conservation structures

The multi-layer integration of Thematic maps such as land use/land cover, slope, geology, geomorphology, drainage density and lithology gave the suitability units for identifying sites for Water conservation structure. Factor layers were comprised in QGIS, using weighted overlay function in the raster calculator of QGIS and providing final suitability map. This map was used to find potential sites for different water harvesting structures in study area. Technical guidelines put forwarded by IMSD (1995) were used for selecting suitable sites for conservation structures. Methodology of site suitability analysis (Lohar *et al*. 2018) is given in Fig 3.4 and criteria for selection of Soil and Water conservation structures is shown in Table 3.9

3.6.5 Soil and water conservation measures

Soil and water conservation measures are broadly classified into three groups:

3.6.5.1. Area treatment

1. Continuous Contour Trenches

Continuous Contour Trenches are series of broad channel or embankments constructed at suitable spacing along the graded contours of gentle slopes. They are suitable for high annual rainfall areas. This type of trenches are long trenches (as long as 50 m) and have fixed interval (15 -30 meter). In this type of trenches, horizontal intervals are fixed but vertical intervals are varied. These trenches are easy to construct but there is a problem of inconsistent deposition of soil in the trenches due to varied vertical interval and hence it is difficult to maintain.

2. Staggered Trenches

The staggered trenching includes the excavation of trenches of shorter length in a row along the contour with interspace between them. These trenches are arranged in straight line (staggered form). Suitable vertical intervals between the rows are avoided to impound the runoff without overflow. In the alternate row, the trenches are located directly below one another.

3. Compartment Bund

Compartmental bunding conserves the rainwater in situ, recharges soil uniformly, reduces runoff, soil and nutrient losses and increases crop yields on a sustainable basis. This technology is simple and low cost and can be adopted by the farmers easily in the medium to deep black soils in the region.

3.6.5.2 Drainage line treatment

1. Earthen Nala Bund (ENB)

Earthen Nala Bund (ENB) is a drainage line treatment. Due to construction of ENB, water gets stored. It will percolate water which will increase surrounding water level in wells and bore well.

2. Cement Nala Bund (CNB)

A cement nala bund (CNB) is a bund/obstruction across the nala or stream constructed by using cement concrete to obstruct and store the flowing water. Cement nala bund impounds water, and in turn can also control the speed (in local regions) of water flow through a nala during the monsoon season. The stored water is a critical surface water resource for several irrigation-based livelihood activities, for domestic needs and for livestock.

3. Gabion Bund

Gabion is a welded wire cage or box filled with materials such as stone, concrete, sand, or soil. So, gabion is a partially flexible block construction used for slope stability and erosion protection in construction

4. Loose Stone Boulder Structure

The design and construction of loose boulder structures is similar to that of gully plugs. The loose boulder structures are larger than gully plugs. These are proposed on the sub streams of our project area which will reduce the erosion of nallah banks and bed.

3.6.5.3 Storage Structures

1. Farm Pond

Farm Pond is a dug-out structure with definite shape and size having proper inlet and outlet structures for collecting the surface runoff flowing from the farm area. It is one of the most important rain water harvesting structures constructed at the lowest portion of the farm area.

2. Check Dam

A check dam is a small dam constructed across a drainage ditch, swale, or channel to lower the velocity of flow. Reduced runoff velocity reduces erosion and gullying in the channel and allows sediments to settle out. A check dam may be built from stone, sandbags filled with pea gravel, or logs.

3. Kokan Vijay Bandhara

Kokan Vijay Bandhara was founded by Soil and Water conservation department of Dr. Balasaheb Sawant Kokan Krishi university, Dapoli. We can construct it by using small-medium stones from Naala by placing plastic on bund’s upper side we can obstruct water available for 2 - 3 months.

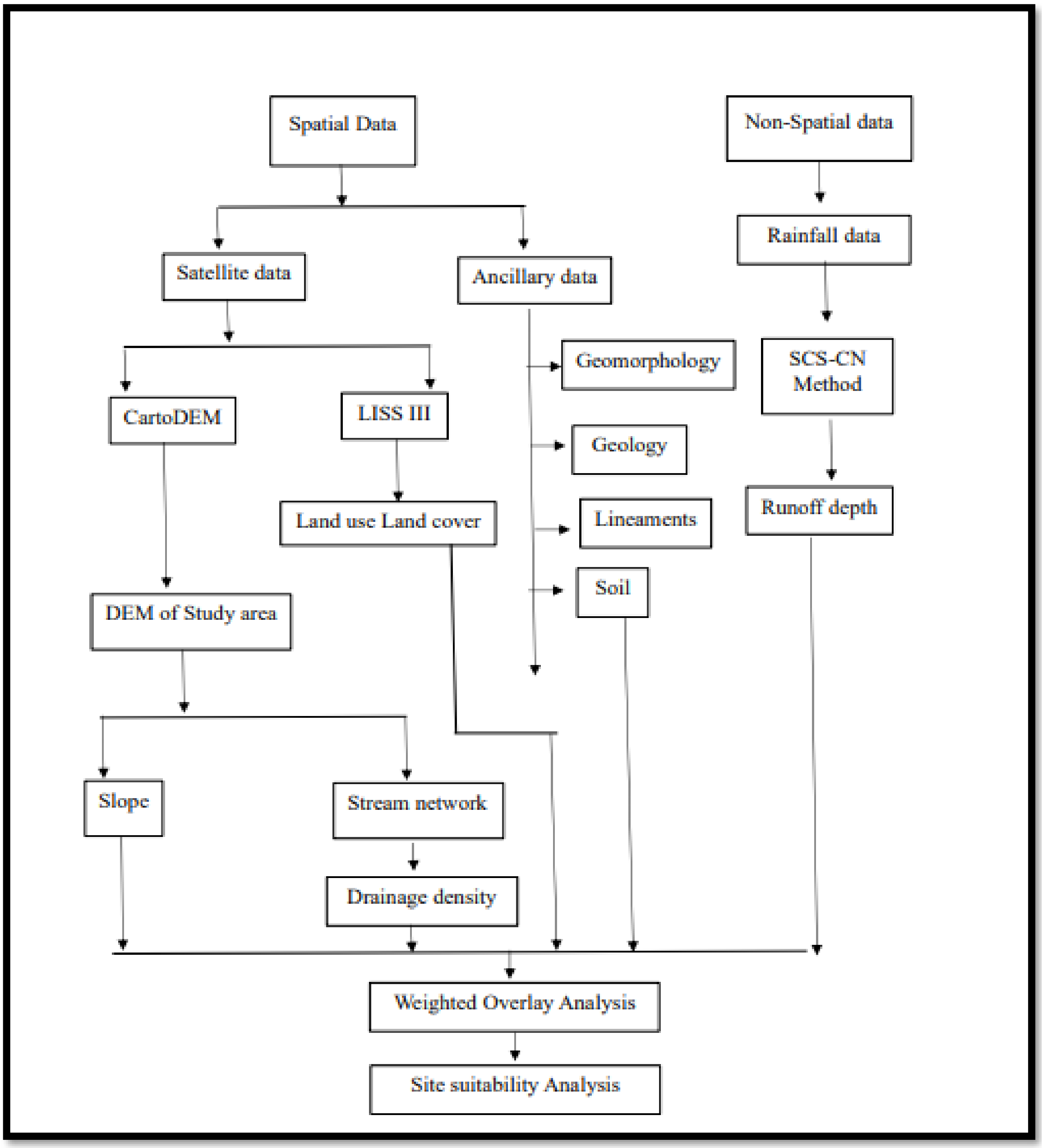

Fig 3.4 Flow chart of methodology adopted for site suitability of Soil and Water conservation structures

Table 3.9 Criteria for selection of different soil and water conservation measures

Structure	Slope (%)	Rainfall (mm)	Permeability	Runoff	Catchment area (ha)
Farm pond	0-5	> 500	Low	Medium / High	1-2
Check dam	< 15	< 1000	Low	Medium / High	>25
Kokan Vijay bandhara	< 3	3000 - 3500	High	Medium / High	25-40
Percolation Pond	< 10	<1000	High	Low	>25
Earthen Naala bund	< 3	<1000	Medium to highly permeable soil	Medium / High	> 40
Cement nala bund	< 3	<1000	Medium to highly permeable soil	Medium / High	> 40

Source: (IMSD Guidelines, 1995)

CHAPTER IV: RESULTS AND DISCUSSION

This chapter deals with results and discussion conducted in the present study. The study was undertaken on "site suitability analysis of soil and water conservation structures in Kadivali watershed using Remote Sensing and GIS." In this dissertation of consists of three parts. In first part, the watershed was delineated and morphometric parameters were analysed using remote sensing and GIS; In second part, runoff of the watershed from rainfall was estimated using SCS curve number method and in third part, site suitability of different water harvesting structures was carried out by using QGIS 3.18.3 software and results are discussed in this chapter.

4.1 Digital Delineation of Watershed

A digital elevation model (DEM) provides us a raster dataset including a range of values which is used to show the elevation (above sea level) at a specific point. In remote sensing digital elevation model (DEM) plays an important role and can be used for the extraction of terrain parameters, the creation of relief maps and for modelling water flow in a watershed. In this study, the digital elevation model (DEM) was downloaded from ISRO's geoportal 'Bhuvan' which is captured by Cartosat-1 satellite having spatial resolution 2.5 m. The DEM of the study area was clipped out from the DEM downloaded from Bhuvan in QGIS 3.18.3. The procedure of watershed delineation is illustrated in section 3.3 of material and methods chapter. Fig 4.1 shows the delineated watershed from the digital elevation model using QGIS 3.18.3. Total area of watershed is 16.49 km^2.

4.2 Contour Map of Watershed

A topographic map is a two-dimensional representation of portion of the three-dimensional surface of the earth. Contour lines are the lines joining the points of same elevation. Contour map of Kadivali watershed has been prepared in QGIS 3.18.3 taking 10 m interval. The highest contour of Kadivali watershed is 200 m and lowest contour is 10 m. The contour map of Kadivali watershed using QGIS software is shown in Fig 4.2.

4.3 Analysis of Morphometric characteristics of watershed

The morphometric analysis of the watershed was accomplished to discover the various geomorphic parameters. Morphometric analysis was carried out using formulae given in chapter III material and methods, for structured description of watershed geometry and its stream channel system to measure linear, areal and relief parameters of channel network. Linear aspect in morphometry is distinguished by basin length, stream length, stream number, stream order and bifurcation ratio. Areal aspect represents the characteristics of basin area and illustrate how catchment area controls and regulates the hydrological behaviour. Relief aspect shows terrain setup of the catchment and elevation distinctness between reference points in watershed. The various drainage morphological parameters were extracted and calculated with a combination of geoprocessing tools available in QGIS 3.18.3. As discussed in section 3.4 of chapter III material and methods the values of different morphometric parameters were calculated and presented here.

4.3.1 Basic parameters

Basic morphometric parameters are calculated and shown in Table 4.1.

4.3.1.1 Perimeter of watershed (P)

Perimeter is calculated along the ridge line that separates one watershed from the other. It is estimated in QGIS 3.18.3 software. The perimeter of Kadivali watershed was 25.30 km.

4.3.1.2 Area of watershed (A)

The total Area of Kadivali Watershed is found 1649.04 ha using QGIS 3.18.3 software.

4.3.1.3 Length of watershed (L_b)

Length of watershed is defined as the length of the straight line from the mouth of the stream to the farthest point of drainage divide. It is estimated in QGIS 3.18.3 software which is 6.44 km.

4.3.1.4 Stream Order (U)

Stream order is an important feature for drainage basin assessment. This is described as a measurement of the location of the streams in the stream hierarchy (Soni, 2017). In the present study, ranking of streams has been carried out based on the method suggested by Strahler (1964). The total number of streams are 46. QGIS 3.18.3 software gave the total number of stream segments of each stream order. There are 32 streams of order I, 10 streams of order II, 3 streams of order III and 1 stream of order IV over the area of 1649 ha. Study area has undulating land as the number of streams of order I is more. Fig 4.3 shows the drainage pattern map of the watershed and Fig 4.4 shows the Stream order map of the watershed.

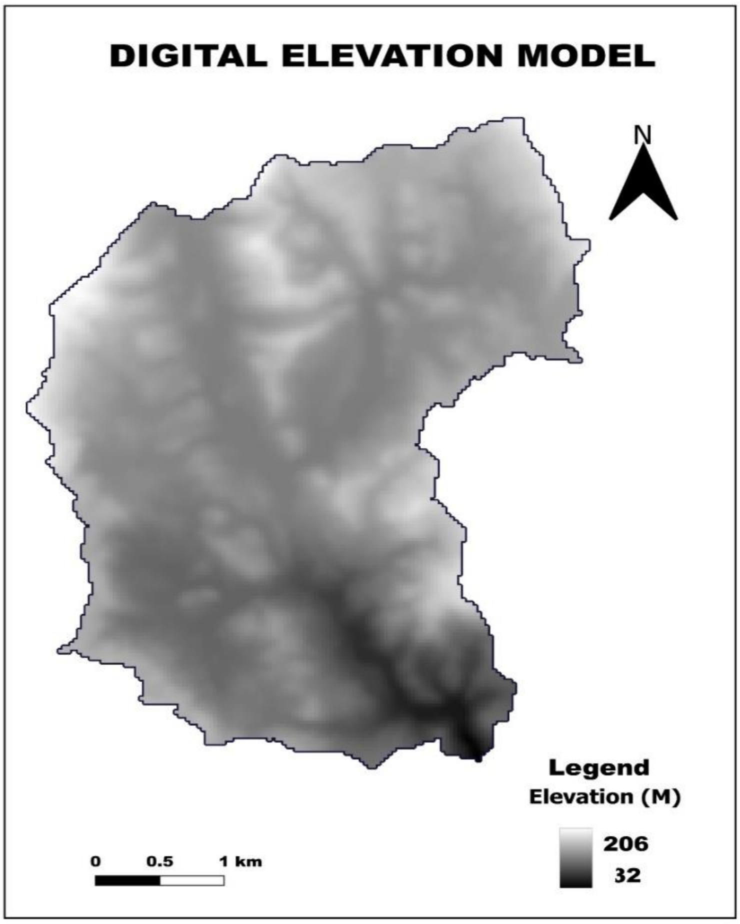

Fig 4.1 Digital Delineation of Kadivali Watershed from DEM

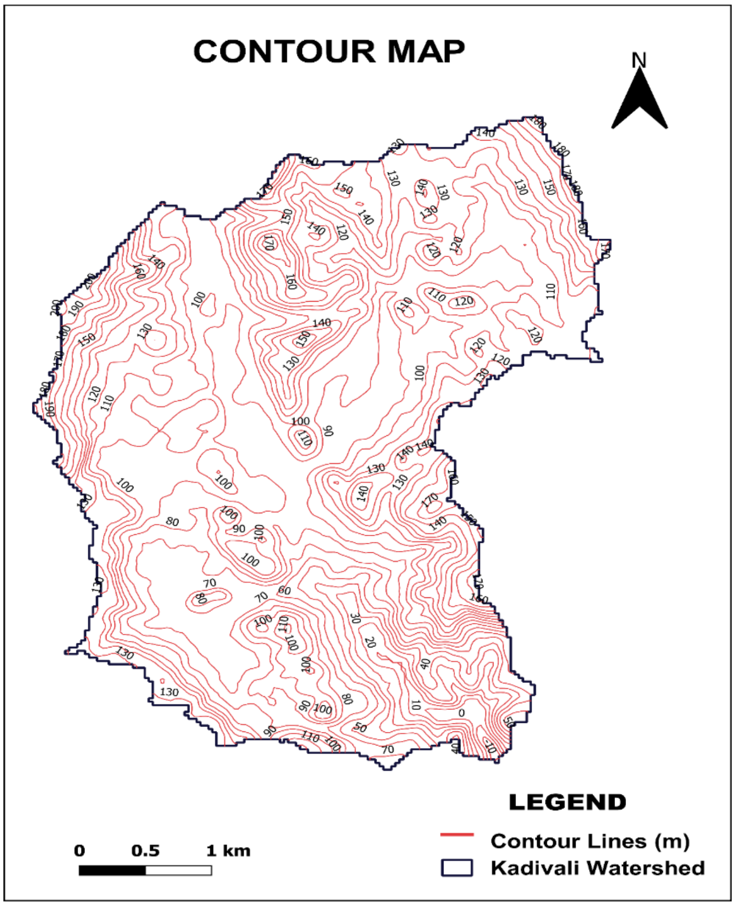

Fig 4.2 Contour Map of Kadivali Watershed

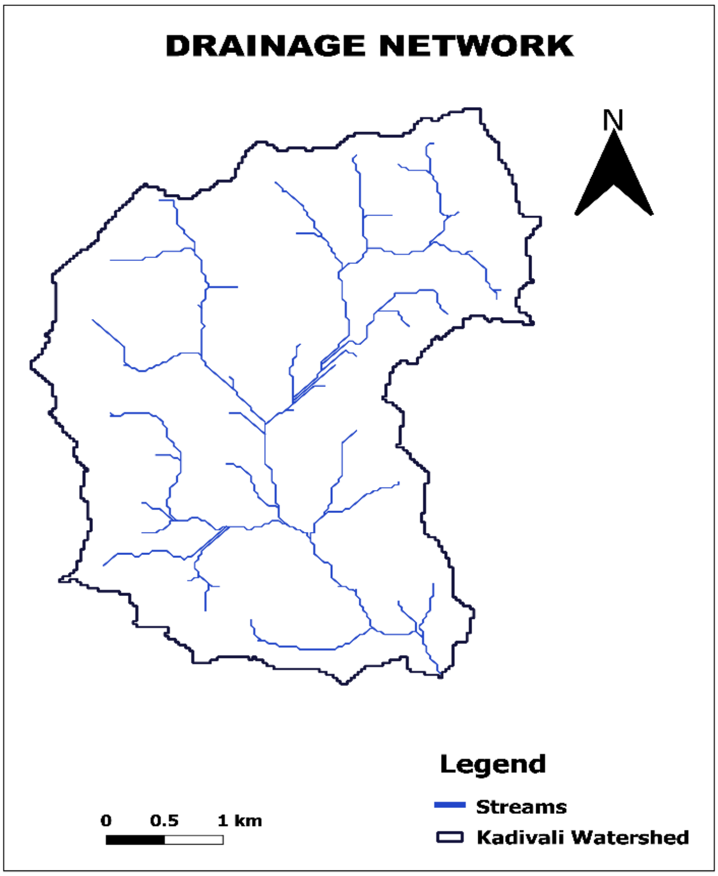

Fig 4.3 Drainage network Map of Kadivali Watershed

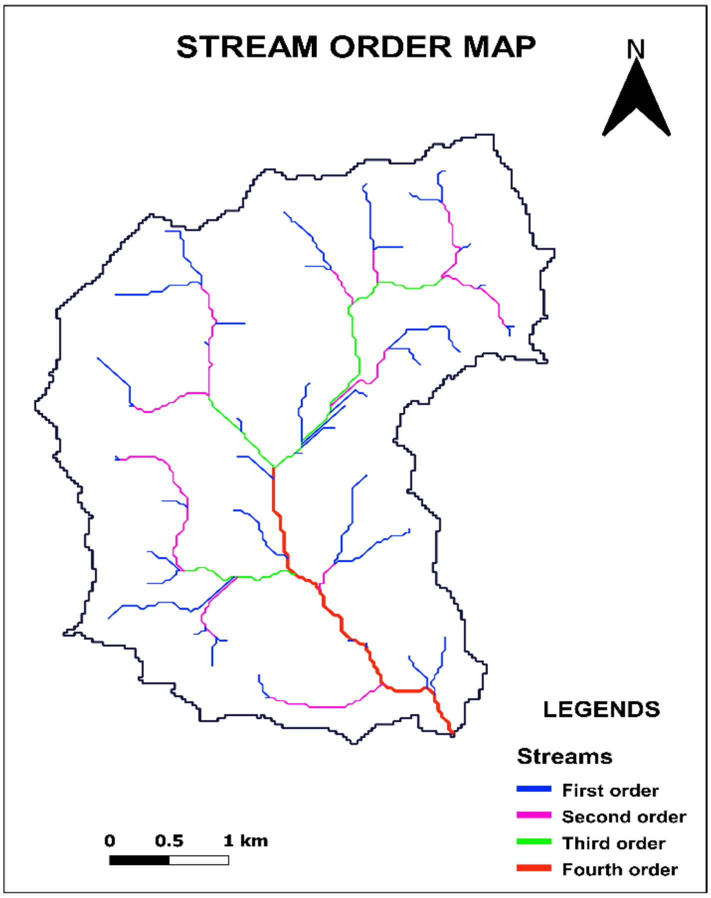

Fig 4.4 Stream order Map of Kadivali Watershed

4.3.1.5 Maximum elevation (H)

The maximum elevation is found 206 m using QGIS 3.18.3 software

4.3.1.6 Minimum elevation (h)

The minimum elevation is found 32 m using QGIS 3.18.3 software.

Table 4.1 Basic morphometric Characteristics of Kadivali Watershed

Sr. No.	Characteristics	Estimated Value
1	Watershed perimeter (P)	25.30 km
2	Watershed area (A)	16.49 km^2
3	Watershed length (L_b)	6.44 km
4	Maximum elevation (H)	206 m
5	Minimum elevation (h)	32 m
6	Stream Order (U)	Number of Streams in given Order
	I	32
	II	10
	III	3
	IV	1

4.3.2 Linear Aspects of watershed

Linear aspects of Kadivali Watershed are shown in Table 4.2.

4.3.2.1 Stream Length (L_u)

The mean stream length and total stream length of each stream order is measured using QGIS 3.18.3 software. The total length of all streams in the study area is 32.84 km. Streams having relatively smaller lengths indicate that the area is with high slopes. Longer stream lengths are indicative of flatter gradient. The total length of first order streams is 15.56 km, second order is 8.95 km, third order is 4.86 km and fourth order is 3.44 km. Stream length decreases as the order number increases.

4.3.2.2 Bifurcation Ratio (R_b)

Bifurcation ratio is the basic parameter to explain the stream patterns of the basin as the patterns are highly connected with the watershed topography and climate condition. The value of bifurcation ratio ranges between 3.0 to 5.0. The bifurcation ratio of watershed is 3.4, it shows the drainage pattern is less affected by geological structures. If the bifurcation ratio is low, flooding will be high. In the present study, 2^{nd} order streams have the maximum bifurcation ratio, it shows the highest overland flow exist here and 3^{rd} order streams has the minimum.

4.3.2.3 Stream Length Ratio (R_L)

The stream length ratio reveals an idea about the relative permeability of the rock formation. The stream length ratios for first and second, second and third, third and fourth are 1.84, 2.71, 1.41 respectively. These differences in stream length ratio between streams of different order due to variation in slope and topography.

Table 4.2 Linear aspects of Kadivali Watershed

Sr. No.	Characteristics	Estimated Value
1.	Stream length (Lu)	
	Stream Order	Sum of length of streams of given order
	I	15561.02 m
	II	8951.42 m
	III	4860.96 m
	IV	3449.14 m
2.	Mean Stream Length (Lsm)	
	Stream Order	Mean Stream Length
	I	486.28 m
	II	895.14 m
	III	2430.48 m
	IV	3449.14 m
3.	Stream Length Ratio (R_L)	
	RL1	1.84
	RL2	2.71
	RL3	1.41
4.	Bifurcation Ratio (R_b)	
	Stream Order	Bifurcation Ratio
	I	3.2
	II	5
	III	2
5.	Mean bifurcation Ratio (R_{bm})	3.4

4.3.3 Areal Aspects of Watershed

Areal aspects of Kadivali Watershed is shown in Table 4.3

4.3.3.1 Drainage density (D_d)

The drainage density indicates the groundwater potential of an area, due to its relation with surface runoff and permeability. Low drainage density generally in the areas of permeable subsoil material, dense vegetation and low relief. While high drainage density is the resultant of impermeable subsurface material, less vegetation and mountainous relief (Soni, 2017). The drainage density for Kadivali watershed is 1.99 km/km^2, which indicates gentle to steep slope terrain, medium dense vegetation, and less permeable subsoil material.

4.3.3.2 Form Factor (F_f)

Form factor describes the shape of basin and flow intensity (Horton, 1932). The value of form factor varies from zero (highly elongated shape) to 1 (perfect circular shape). The form factor for Kadivali watershed is 0.39 which indicates that watershed is less elongated.

4.3.3.3 Circulatory Ratio (R_c)

Circulatory ratio indicates the shape of basin. The value of circulatory ratio varies from 0 to 1. The value close to 1 implies more circularity of the basin. Circulatory ratio deals with the length and frequency of streams, geologic structures, climate, relief of the basin, land use land cover, with increase in the Rc value, there is a rise in the flood level and chances of flood hazards at pick time at the outlet of the watershed. The circulatory ratio of Kadivali watershed is 0.32. Suggesting that the study area has attained maturity in topographical condition. Kadivali watershed has moderate elongation.

4.3.3.4 Elongation Ratio (Re)

Elongation ratio is an important index for the analysis of basin shape. higher elongation ratio indicates high infiltration capacity and low runoff. An elongated basin is less efficient in the discharge of runoff than circular basin. The elongation ratio for Kadivali watershed is 0.71, which shows that watershed has less elongation, steep slope and high relief.

4.3.3.5 Stream Frequency (Fs)

Stream frequency is the total number of stream segments per unit area of the basin. Lower value of stream frequency causes low rate of surface runoff and higher value causes high rate of surface runoff. Stream frequency has positive correlation with drainage density. High value of stream frequency represents impermeable sub surface material, sparse vegetation, high relief conditions and low infiltration capacity. Stream frequency for Micro-watersheds ranges from 1.77 to 3.26 (Chetan and Vishnu, 2018). The stream frequency of the Kadivali watershed is 2.72, It shows watershed has moderate rate of runoff.

4.3.3.6 Length of the overland flow (L_g)

Length of the overland flow is one of the most important factors affecting both physiographical and hydrological development of watershed (Horton, 1945). Low value of overland flow (< 0.2) shows the short flow length, high relief and high runoff generation, which leads to susceptibility of flood, while high value (> 0.3) indicates mild slope and long flow length, less runoff generation and maximum infiltration. The computed value of Length of the overland flow is 0.25 km which is moderate value shows moderate relief and moderate runoff generation.

4.3.3.7 Constant of channel maintenance (C)

Constant of channel maintenance is defined as the area required for maintaining 1 km of a stream. Constant of channel maintenance of Kadivali watershed is 0.50, which shows watershed has moderate infiltration and permeability of the surface material, moderate vegetation, moderate resistant rocks.

4.3.3.8 Compactness coefficient (C_c)

Compactness coefficient represents the relationship of a basin with that of a circular basin having the same area. The compactness coefficient of Kadivali watershed is 1.75, which indicates watershed has the deviation from the circular nature (Potter and Faulkner, 1987).

Table 4.3 Areal aspects of Kadivali Watershed

Sr. No.	Characteristics	Estimated Value
1	Form Factor (F_f)	0.39
2	Circularity Ratio (Rc)	0.32
3	Elongation Ratio (Re)	0.71
4	Drainage Density (D_d)	1.99 km/km^2
5	Stream Frequency (Fs)	2.72
6	Compactness coefficient (Cc)	1.75
7	Length of overland flow (Lg)	0.25 km
8	Constant of channel maintenance (C)	0.50

4.4.4 Relief Aspects of watershed

Relief aspects of Kadivali Watershed is shown in Table 4.4.

4.4.4.1 Relief (B_h)

Basin relief is accountable for the stream gradient also, it influences flood pattern and sediment volume that can be transported. The relief of Kadivali watershed is 174.19 m which indicates low relief of the area.

4.3.4.2 Relief Ratio (Rr)

Relief ratio indicates overall steepness of a drainage basin. It is a main indicator of the intensity of erosion process operating on the slope of the watershed. The relief ratio of Kadivali watershed is 0.027 which is relatively low (< 0.1) indicates watershed has moderate to gentle slope and moderate relief.

4.3.4.3 Relative Relief (R_R)

It is an indicator of the regular elevation of the basin from peak to the outlet point. Kadivali watershed has relative relief of 0.68.

4.3.4.4 Ruggedness Number (R_n)

The ruggedness number is used to compute the surface unevenness or roughness. It is the combination of drainage density and maximum catchment relief. It also indicates the susceptibility of erosion to the watershed. The ruggedness number for Kadivali watershed is 0.34. The ruggedness number is relatively low which shows watershed is less prone to soil erosion and have intrinsic structural complexity in association with relief and drainage density (Paretha and Paretha, 2012).

Table 4.4 Relief aspects of Kadivali Watershed

Sr. No.	Characteristics	Estimated Value
1	Relief (B_h)	174 m
2	Relief Ratio (Rr)	0.027
3	Relative Relief (R_R)	0.68
4	Ruggedness Number (R_n)	0.34

4.4 Estimation of runoff by using SCS Curve Number Method.

In the present study estimation of runoff was done by SCS Curve number method as it is productive and more precise than any other method of runoff estimation**.** The different parameters needed to estimate the runoff were computed and presented in this section. Rainfall data was used to calculate the antecedent moisture condition (AMC) for the study period. Soil map was transformed into hydrological soil group map and the land use land cover map was derived in QGIS from the satellite data was combined with it to bring out the curve number value.

4.4.1 Determination of Hydrologic Soil Group (HSG)

The soil data of the study area was acquired from National Bureau of Soil Survey and

Land Use Planning (NBSS- LUP), Nagpur and it was used in QGIS to make soil map of the Kadivali watershed. Soil map was used to find the hydrological soil group by giving appropriate values for different types of soil. Natural resource conservation service classified soil into four hydrological soil groups based on soil's runoff potential which was mentioned in chapter III Material and methods. Table 3.5 represent Soil conservation service classification (USDA, 1974). The study area consisted sandy Loam texture soil all over the watershed which comes under Hydrologic Soil group C. Fig 4.8 represents the soil map of Kadivali watershed.

4.4.2 Land Use Land Cover map of the Watershed

Land use land cover map of Kadivali watershed was estimated in QGIS software. The LISS III satellite imagery dated 11/02/2019 was downloaded from ISRO's geoportal Bhuvan, which was used to make land use land cover map in QGIS. The watershed was divided into 5 classes such as agriculture land, forest land, Vegetation, barren land and settlement. study area shows that maximum portion of land use is covering forest area 637.61 ha. agriculture land covering area 382.62 ha. Vegetation covering area 296.72 ha. barren land covering area 283.05 ha. and settlement covering area 49.04 ha. Infiltration would be more and runoff would be less in the agriculture and forest areas, whereas in settlement infiltration rate may decrease. Fig 4.9 represents the land use land cover map of Kadivali watershed. Table 4.5 shows the area covered by each land use land cover class.

Table 4.5 Distribution of land use land cover in Kadivali Watershed

Sr. No.	LULC class	Area (ha)	Area percent
1	Forest land	637.61	38.68%
2	Vegetation	296.72	17.99 %
3	Agriculture land	382.62	23.20 %
4	Barren land	283.05	17.16 %
5	Settlement	49.04	2.97 %
	Total	**1649.04**	**100%**

4.4.3 Computation of curve number using NRSC tables

Curve numbers are selected based on hydrological soil group and land use land cover from Table 3.4 given in chapter III material and methods. The curve number for different LULC class is shown in Table 4.6. Curve number values, considering land use land cover and hydrological soil group are given for AMC II, equations 3.7 and 3.8 are used to convert CN from AMC II (Normal condition) to AMC I (dry condition) and AMC III (wet condition). The calculated curve numbers are as follows, CN (I) is 60.8, CN (II) is 77.90 and CN (III) is 89.25. Low runoff is represented by minimum value, while CN value approaching 100, represent high runoff.

Table 4.6 Curve number for different LULC class

LULC class	Area percent	Hydrologic Soil Group (HSG)	Curve number
Forest land	38.68%	C	71
Vegetation	17.99 %	C	73
Agriculture land	23.20 %	C	82
Barren land	17.16 %	C	91
Settlement	2.97 %	C	90

(Source: Murty and Jha, 2009)

4.4.4 Estimation of Runoff

Daily rainfall data for past 32 years (1990-2022) has been collected from Department of Agronomy, College of Agriculture, Dapoli. This data was used for runoff estimation. The highest yearly rainfall recorded was 5421.2 mm in the year 2021. The lowest yearly rainfall recorded was 2330.6 mm in the year 2015. The rainfall shows fluctuating nature during 32 years. Runoff was estimated using SCS CN method. Table 4.7 represents estimated annual runoff values from year 1990-2022 and Fig 4.5 shows annual rainfall runoff variation graph. The minimum runoff observed is 716.63 mm i.e., 29.81% of the annual rainfall in the year 2001. The maximum runoff observed is 2492.47 mm i.e., 48.57% of the annual rainfall in the year 2019.

The SCS CN method is efficiently better method, which consumes less time and gives facility to handle extensive data. The rainfall- runoff are strongly correlated with a correlation coefficient (r) value being 0.93 and coefficient of determination value is 0.87. Scatter plot between the rainfall and calculated runoff is shown in fig. 4.6. From the table 4.7, it is observed that, the average annual runoff calculated is 1560.43 mm i.e., 41.83% of rainfall.

Table 4.7 Annual Runoff Depth of Kadivali watershed (1990-2022)

Sr. No.	**Year**	**Rainfall (mm)**	**Runoff (mm)**	**% Runoff**
1	1990	5290.8	2435.40	46.03
2	1991	3772.5	1784.96	47.31
3	1992	2992.7	1128.24	37.6
4	1993	3848	863.87	22.4
5	1994	2918.5	942.32	32.28
6	1995	3140.1	1070.87	34.1
7	1996	3112.5	1019.30	32.74
8	1997	3843.1	1774.22	46.16
9	1998	3829.6	1556.30	40.63
10	1999	4226.2	1777.36	42.05
11	2000	4619.05	2394.82	**51.87**
12	2001	2403.4	716.63	29.81
13	2002	2739.5	928.06	33.87
14	2003	3004	1116.97	37.01
15	2004	3535.6	1396.44	39.49
16	2005	3654.2	1492.78	40.85
17	2006	3558.8	1204.74	33.85
18	2007	4261.9	1885.47	44.25
19	2008	3011.4	1204.58	40
20	2009	2697.3	1356.88	50.30
21	2010	4721.1	2172.62	46.01
22	2011	4932.2	2486.48	50.41
23	2012	3654	1422.48	38.92

Sr. No.	Year	Rainfall (mm)	Runoff (mm)	% Runoff
24	2013	4748	2282.96	47.97
25	2014	3370.2	1612.98	48.02
26	2015	2330.6	762.52	32.71
27	2016	4504.1	2038.20	45.25
28	2017	3633.5	1444.93	39.75
29	2018	3071.8	1146.36	37.31
30	2019	5130.9	2492.47	48.57
31	2020	4145.4	1885.47	45.48
32	2021	5421.2	2428.13	44.07
33	2022	2989.1	1168.43	39.08
Average		**3730.37**	**1560.43**	**41.83**

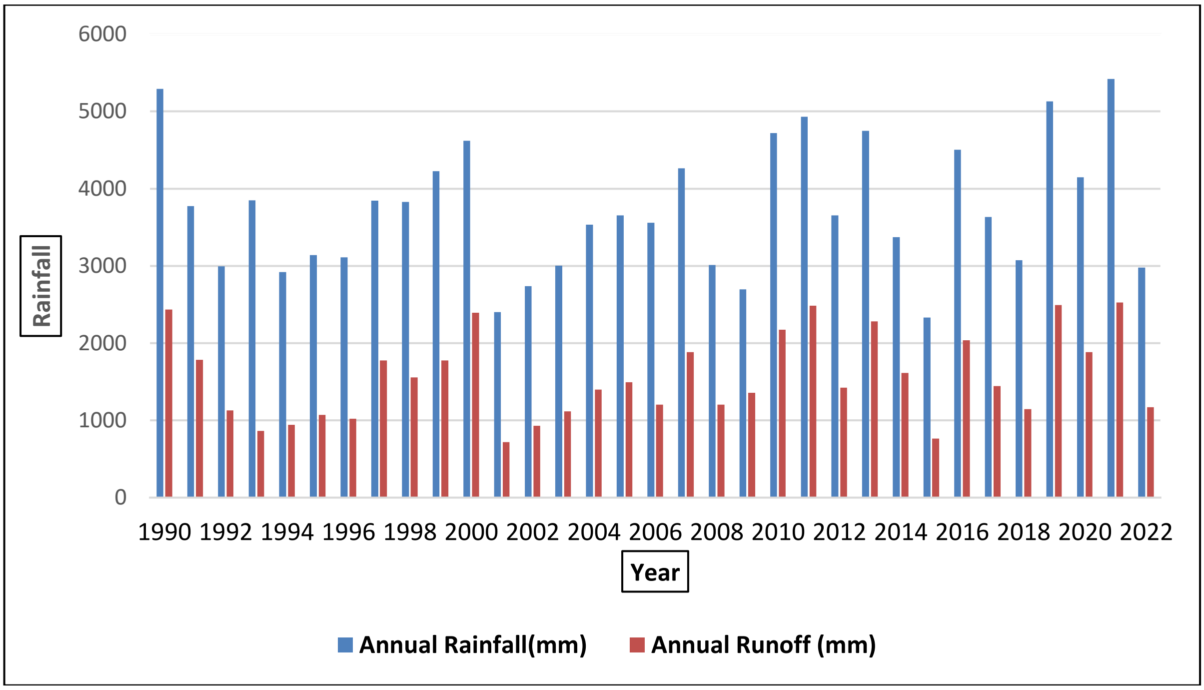

Fig 4.5 Annual Rainfall Runoff variation graph

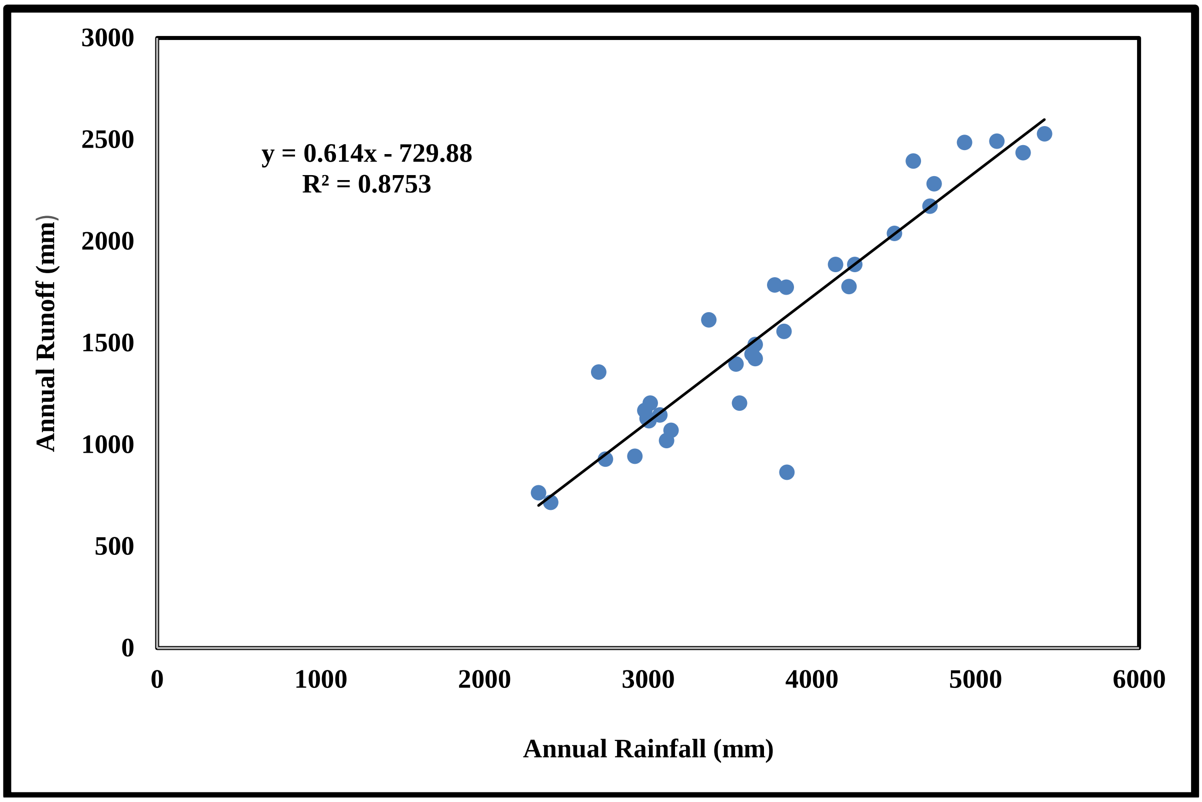

Fig 4.6 Scatter plot between the rainfall and calculated runoff

4.5 Site suitability analysis of Soil and Water Conservation Measures

After delineation the watershed, the morphometric characteristics has been determined and runoff has been estimated. In kadivali watershed Runoff is 41% of rainfall. The reduction of surface runoff can be achieved by constructing suitable structures in the area. In order to identify suitable sites for soil and water conservation structures in Kadivali watershed, a multi parametric dataset comprising satellite data and other thematic maps such as Land use land cover map, Soil map, Slope map, Geomorphology map, Lithology map, Geology map, stream order map and Drainage density map were prepared. After preparing thematic maps, different classes of each thematic layer were identified by giving weightage to them using "Reclassify by table tool" from "Raster analysis" in QGIS. These thematic layers used to derive suitable sites harvesting structure by overlaying. Weighted overlaying of these maps is done by using "Raster calculator" from "Raster" option of "Analysis Tools" in QGIS.

4.5.1 Thematic layers

4.5.1.1 Slope map

Slope is an important factor for site selection of water harvesting structures. The slope map was derived from elevation map extracted from Digital Elevation Model (DEM) by using Raster analysis in QGIS 3.18.3. The runoff, movement of surface water and recharge rely on slope of the area. The slope map of study area was classified into five classes to identify suitable sites for water harvesting structures such as gentle slope (0-5%), moderately gentle slope (5-10%), steep slope (10-15%), moderately steep slope (15-20%) and very steep slope (>20%).

Table 4.8 shows area distribution of slope classes and the slope map of Kadivali watershed using QGIS 3.18.3 is shown in Fig 4.7.

Table 4.8 Area contribution of slope classes

Sr. No.	Class	Slope category	Area (ha)	Area percent (%)
1	0-5%	Gentle slope	284.48	17.25 %
2	5-10%	Moderately gentle slope	405.88	24.61 %
3	10-15%	Steep slope	349.89	21.23 %
4	15-20%	Moderately steep slope	272.18	16.50 %
5	>20%	very steep slope	336.61	20.41 %
	-	**Total**	**1649.04**	**100 %**

4.5.1.2 Lithology Map

The study of physical properties of rocks is called as lithology. Lithology map was derived from the data collected from Bhukosh website by using toposheets 47G1 and 47G5 downloaded from survey of India (SOI). Kadivali watershed divided into two types of lithological class as basalt and laterite. The Kadivali watershed has laterite 869.88 ha (52.76%), followed by basalt 779.16 ha (47.24%). Laterite rock formation which is 870 ha of total area has very low water holding capacity therefore infiltration will be less and runoff generated will be more. Around 779.16 ha of total area is covered by basalt rock formation which has moderate infiltration capacity. Table 4.9 shows area covered by different lithology classes in Kadivali watershed and the lithology map of Kadivali watershed using QGIS is shown in Fig 4.10.

Table 4.9 Area covered by different lithology classes in Kadivali watershed

Sr. No.	Lithologic unit	Area (ha)	Area percent (%)
1	Laterite	869.88	52.76 %
2	Basalt	779.16	47.24 %
	Total	**1649.04**	**100 %**

4.5.1.3 Drainage Density Map

The drainage density of study area is created using channel network of study area, which gives idea about infiltration capacity of soil. Line density tool from Interpolation used to create drainage density in QGIS. The drainage density has association with surface runoff and permeability. High drainage density implies the surface runoff due to the underlying less permeable layer. The study area has been classified into five classes. The classes of drainage density have been assigned to ‘Excellent’ (0 - 5.9 km/km^2), ‘Very good’ (5.9 - 11.9 km/km^2), ‘Good’ (11.9 - 17.8 km/km^2), ‘Moderate’ (17.8 – 23.7 km/km^2) and ‘Poor’ (> 23.7 km/km^2). Table 4.10 shows area distribution of Drainage density classes in Kadivali watershed and the drainage density Map of Kadivali watershed shown in the figure 4.11.

Table 4.10 Area distribution of Drainage density classes in Kadivali watershed.

Sr. No.	Drainage density (km/km^2)	Category
1	0 - 5.9	Excellent
2	5.9 - 11.9	Very good
3	11.9 - 17.8	Good
4	17.8 – 23.7	Moderate
5	> 23.7	Poor

4.5.1.4 Geomorphology Map

Geomorphology is the study of various land form and structural features. Geomorphology map was prepared from the data obtained from Bhukosh website by using toposheets 47G1 and 47G5 downloaded from survey of India (SOI). the most part of study area is dominated by moderately dissected lower plateau covering area 1631.49 ha. followed by waterbodies covering area 16.66 ha and pediment-pediplain complex covering area 0.89 ha. Table 4.11 shows area covered by different geomorphology classes in Kadivali watershed and the geomorphology map of Kadivali watershed using QGIS is shown in Fig 4.12.

Table 4.11 Area covered by different geomorphology classes in Kadivali watershed.

Sr. No.	Geomorphic units	Area (ha)	Area percent (%)
1	Moderately dissected lower plateau	1631.49	98.93 %
2	Pediment-pediplain complex	0.89	0.053 %
3	Waterbodies	16.66	1.017 %
	Total	**1649.04**	**100 %**

4.5.1.5 Geology Map

Geology map was derived from the data acquired from Bhukosh website by using toposheets 47G1 and 47G5 downloaded from survey of India (SOI). There are two geology features found in the study area namely deccan trap and basalt/laterite. Table 4.12 shows area covered by different geology classes in Kadivali watershed and the geology map of kadivali watershed shown in the figure 4.13.

Table 4.12 Area covered by different geology classes in Kadivali watershed

Sr. No.	Geology unit	Area (ha)	Area percent (%)
1	Deccan trap	795.54	48.22 %
2	Laterite / bauxite	853.50	51.78 %
	Total	**1649.04**	**100 %**

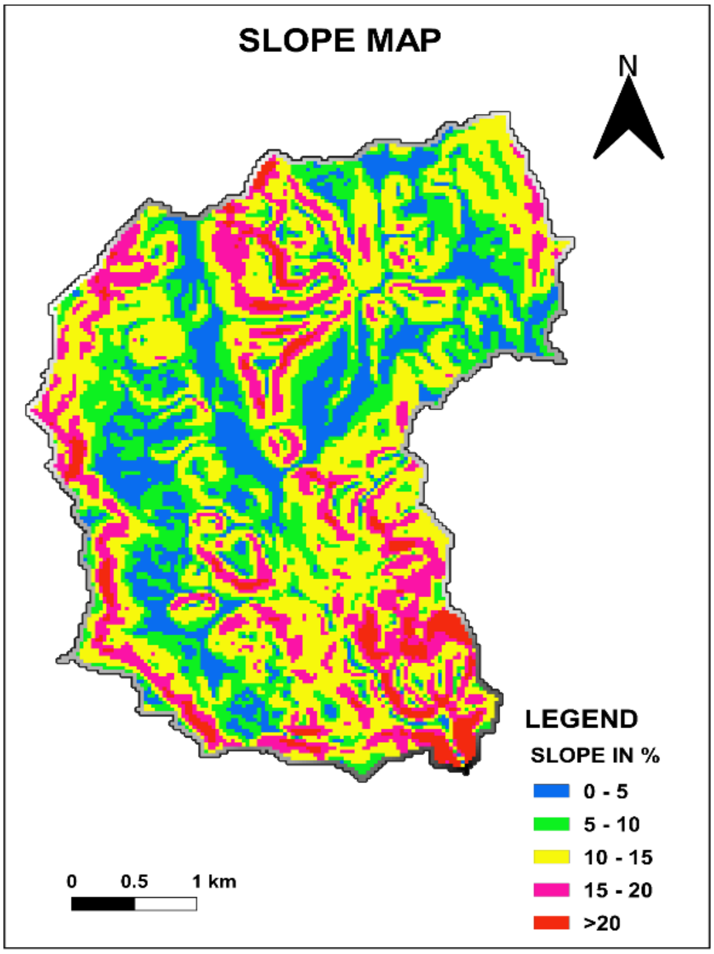

Fig 4.7 Slope Map of Kadivali Watershed

Fig 4.8 Soil Map of Kadivali Watershed

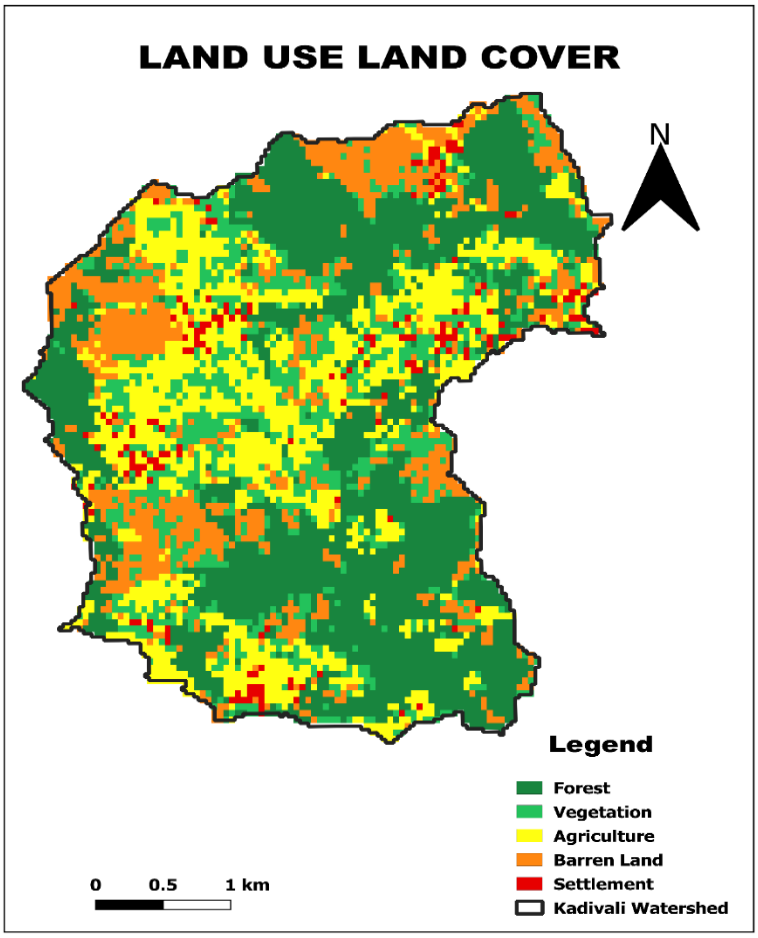

Fig 4.9 Land Use Land Cover Map of Kadivali Watershed

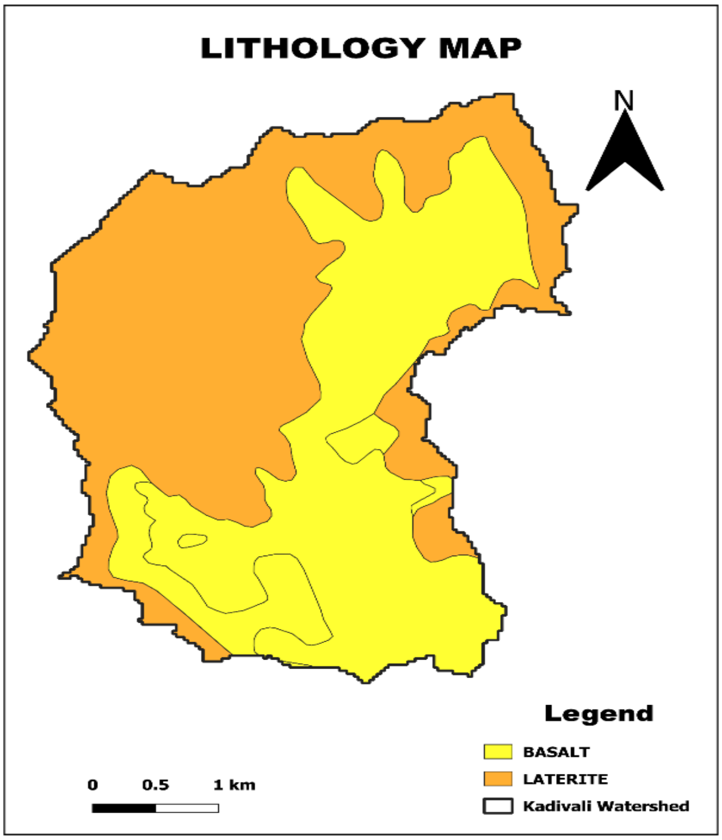

Fig 4.10 Lithology Map of Kadivali Watershed

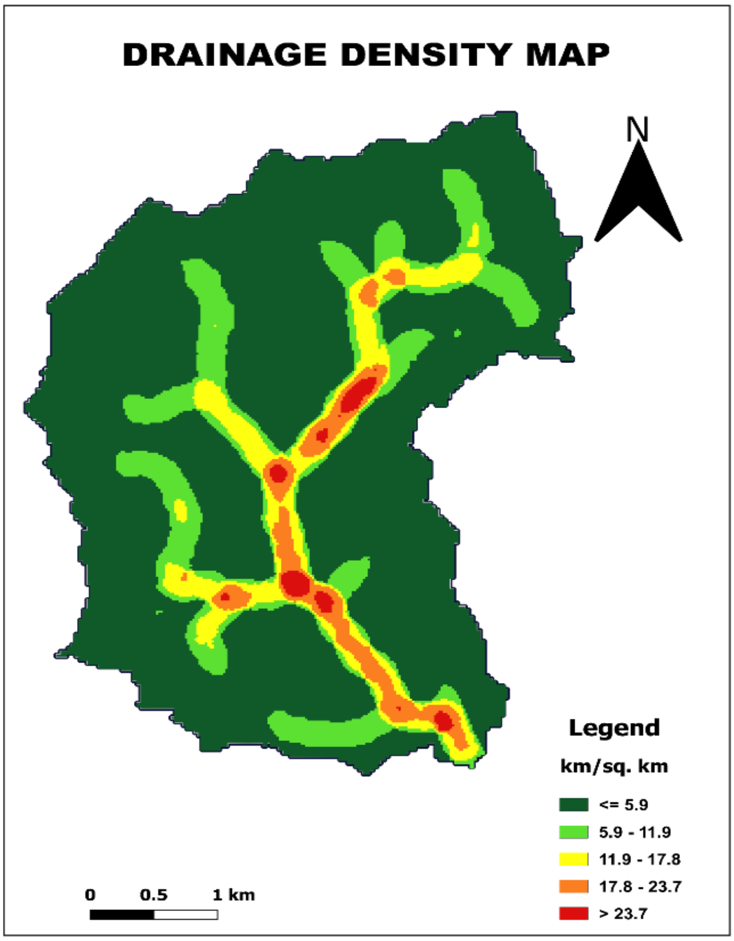

Fig 4.11 Drainage density Map of Kadivali Watershed

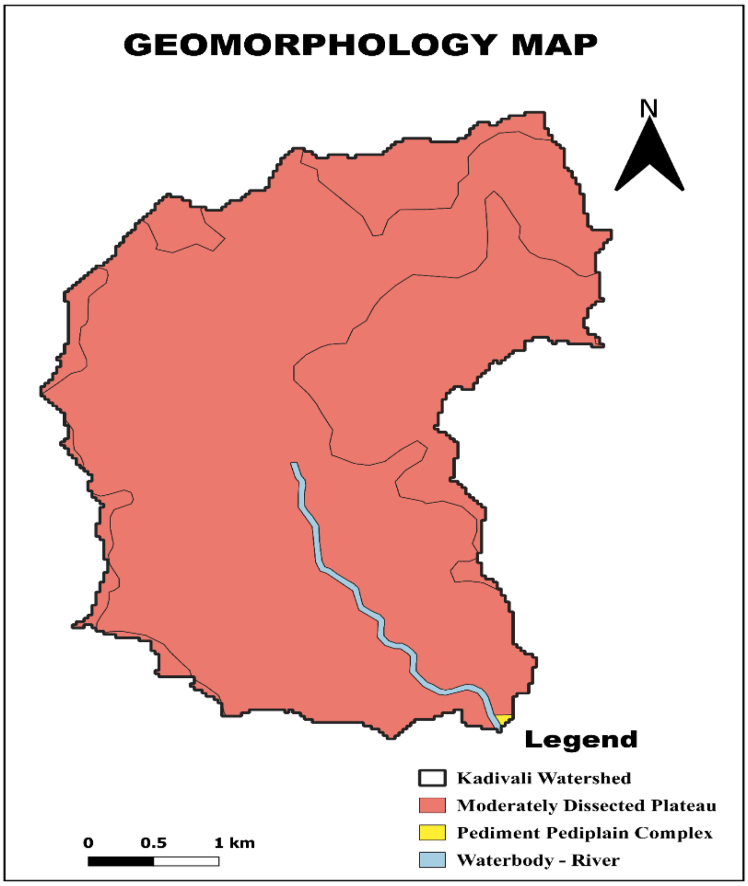

Fig 4.12 Geomorphology Map of Kadivali Watershed

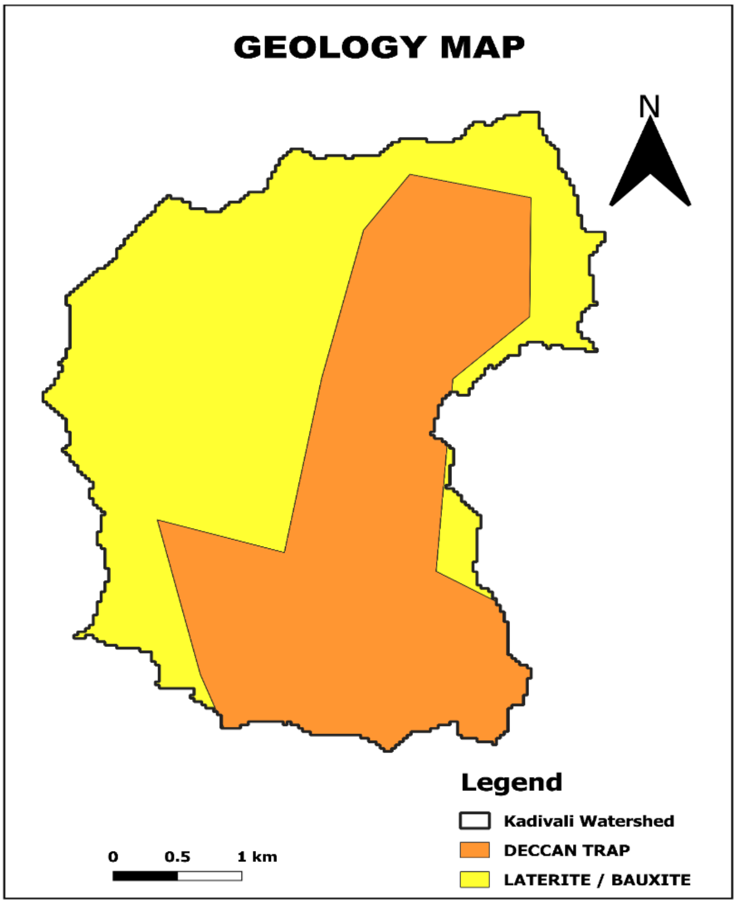

Fig 4.13 Geology Map of Kadivali Watershed

4.5.2 Weighted overlay analysis

The weighted overlay is performed to find out suitable area for soil and water conservation structures. In QGIS, reclassify by table tool from Raster analysis is used for assigning weightages to different classes of thematic layers and Raster calculator is used for assigning weightages to different thematic layers. The weightages are assigned as given in table (Waikar, 2014 and Bhange *et al*. 2016). The value assigned to each parameter is shown in Table 4.13.

Table 4.13 Weightages assigned for different thematic layers

Layer	Weight assigned (%)	Feature classes	Rank
Geomorphology	30	Moderately dissected lower plateau	5
		Pediment-pediplain complex	2
		Waterbodies	3
Drainage density	20	0 - 5.9	5
		5.9 - 11.9	4
		11.9 - 17.8	3
		17.8 – 23.7	2
		> 23.7	1
Lithology	15	Basalt	5
		Laterite	3
Geology	10	Deccan trap	5
		Laterite / bauxite	3
Land use land cover	10	Forest	4
		Vegetation	3
		Agriculture	5
		Barren land	2
		Settlement	1
Slope	10	0-5%	5
		5-10%	4
		10-15%	3
		15-20%	2
		>20%	1
Soil	5	Sandy Loam	5

4.5.3 Site suitability analysis

In this study, soil and water conservation structures sites were selected on the basis of integration of thematic maps. The suitability of study area suitable for water harvesting structures was achieved on the basis of ranking assigned. The Rank 2 was assigned for suitable area and Rank 1 for non-suitable area. After overlay and integration of all the thematic layers 875.78 ha

(53.10%) area found suitable for soil and water conservation structures construction and 773.26 ha (46.89%) area of watershed not suitable for water harvesting structures. Not suitable area should be treated properly. Fig 4.14 shows the site suitability for soil and water conservation structures in Kadivali watershed.

4.5.4 Potential sites for soil and water conservation measures

According to Integrated Mission for Sustainable Development (IMSD) guidelines the location of suitable sites for soil and water conservation structures suggested by considering slope, Drainage density, land use land cover and Site suitability map of the Kadivali watershed. QGIS software helped in selection of suitable structures. Total 45 sites found suitable for various soil and water conservation structure. The structures suitable for the area are check dams, percolation tanks, Cement Nala bunds, Earthen Nala bund, Kokan Vijay bandhara and farm ponds. 26 places are found suitable for construction of farm ponds. 5 sites for Check dams, 6 sites found suitable for percolation tanks, 2 for cement nala bunds, 1 for earthen Nala bunds, and 5 sites for Kokan Vijay bandhara were suggested. Table 4.14 shows Number of soil and water harvesting structures suggested in Kadivali watershed and Fig 4.15 shows site suitability map of soil and water conservation structures for Kadivali watershed using QGIS 3.18.3.

Table 4.14 Total number of different soil and water conservation structure suggested in Kadivali watershed

Sr. No.	Soil and Water conservation structures	Total number
1	Farm Pond	26
2	Check Dam	5
3	Kokan Vijay Bandhara	5
4	Percolation Pond	6
5	Cement Nala Bund	2
6	Earthen Nala Bund	1
	Total	**45**

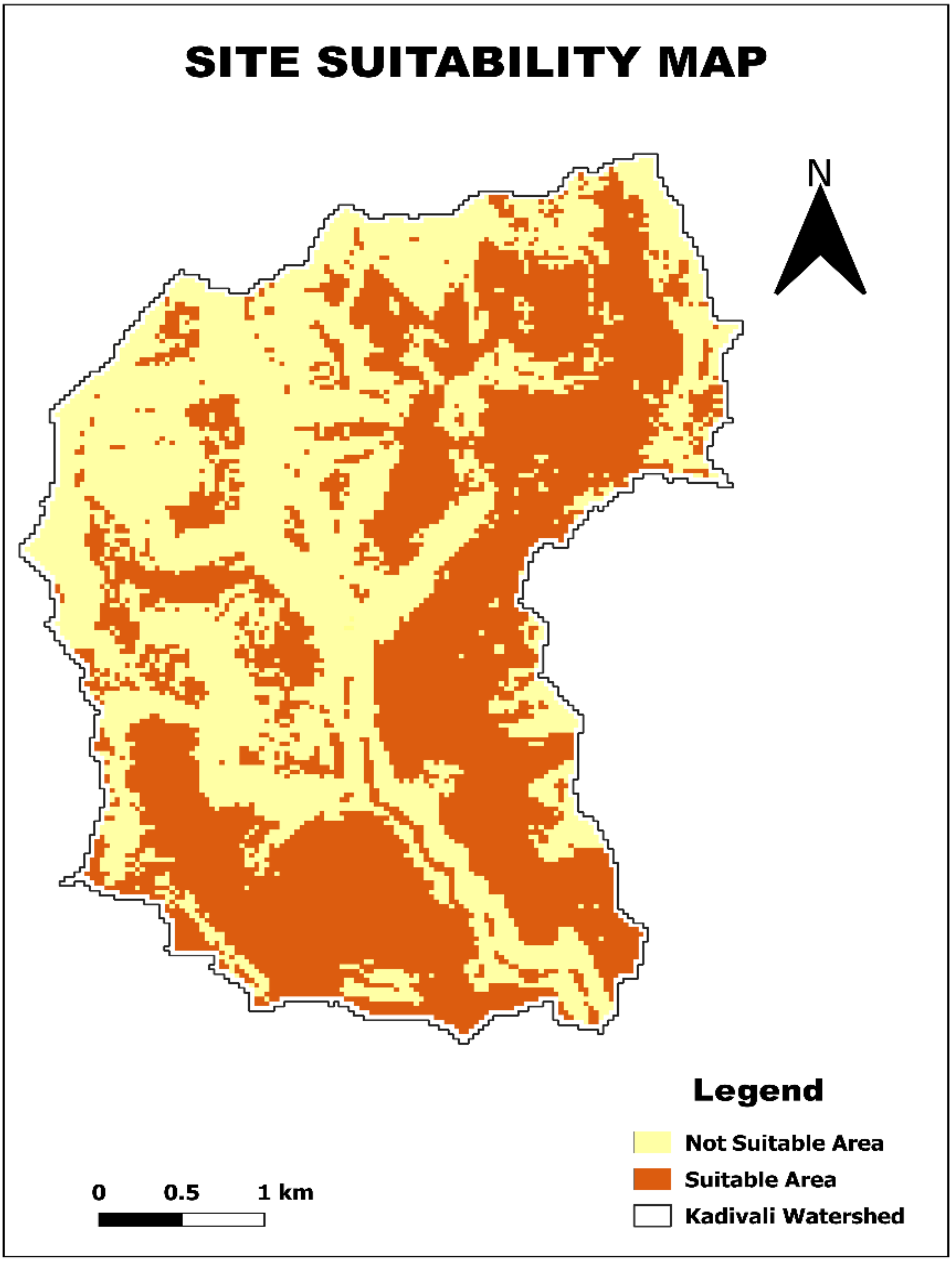

Fig 4.14 Site suitability map for implementing Soil and Water conservation structure in Kadivali watershed

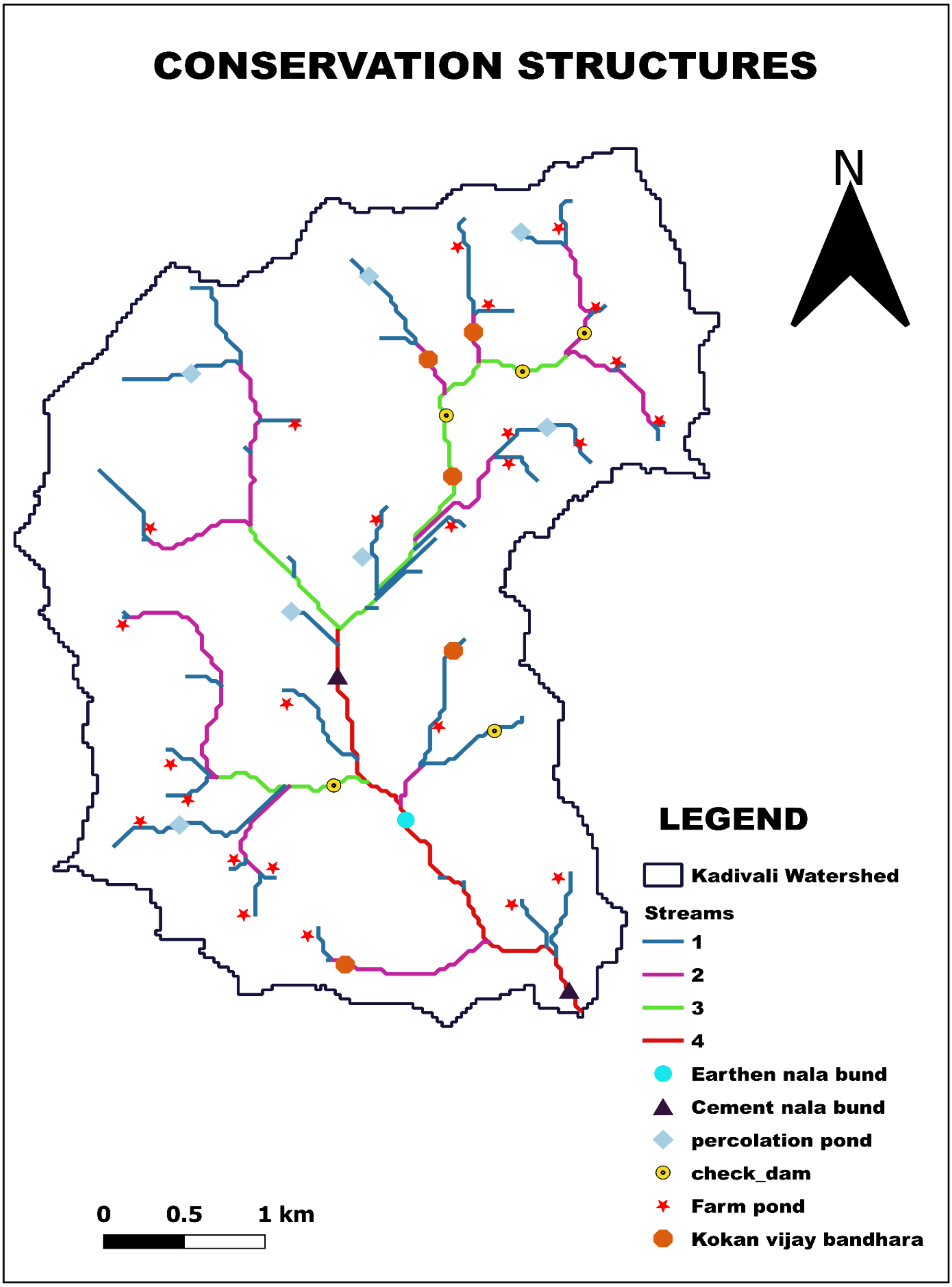

Fig 4.15 Site suitability map of soil and water conservation structures for Kadivali watershed

Table 4.15 Locations obtained in QGIS for soil and water conservation structures sites

Sr. No.	Name of structure	Locations obtained in QGIS software	
1.	**Farm Pond**		
	1	73° 23’38’’ E	17°85’06” N
	2	73° 23’11” E	17°84’90” N
	3	73° 21’91” E	17°84’70” N
	4	73° 21’71” E	17°85’11” N
	5	73° 21’54” E	17°84’83” N
	6	73° 21’48” E	17°85’15” N
	7	73° 20’93” E	17°85’37” N
	8	73° 22’67” E	17°85’96” N
	9	73° 21’78” E	17°86’08” N
	10	73° 20’81” E	17°86’54” N
	11	73° 20’97” E	17°87’12” N
	12	73° 22’73” E	17°87’15” N
	13	73° 22’29” E	17°87’18” N
	14	73° 21’81” E	17°87’75” N
	15	73° 23’48” E	17°87’65” N
	16	73° 23’94” E	17°87’79” N
	17	73° 23’69” E	17°88’14” N
	18	73° 23’57” E	17°88’46” N
	19	73° 23’34” E	17°88’93” N
	20	73° 22’75” E	17°88’81” N
	21	73° 22’94” E	17°88’47” N
	22	73° 21’10” E	17°85’72” N
	23	73° 21’20” E	17°85’50” N
	24	73° 23’06” E	17°87’71” N
	25	73° 23’06” E	17°87’52” N
2.	**Check Dam**		
	1	73°22’06” E	17°85’60” N
	2	73°23’00” E	17°85’93” N
	2	73°22’70” E	17°87’81” N
	4	73°23’14” E	17°88’07” N
	5	73°23’50” E	17°88’31” N
3.	**Percolation Pond**		
	1	73° 21’16” E	17° 85’36” N
	2	73° 21’80” E	17° 86’63” N
	3	73° 22’21” E	17° 86’96” N
	4	73° 23’29” E	17° 87’74” N
	5	73° 23’12” E	17° 88’90” N
	6	73° 21’20” E	17° 88’04” N
4.	**Kokan Vijay Bandhara**		
	1	73° 22’14” E	17° 84’53” N
	2	73° 22’75” E	17° 86’41” N
	3	73° 22’59” E	17° 88’14” N
	4	73° 22’85” E	17° 88’31” N
	5	73° 22’74” E	17° 87’45” N
5.	**Cement Nala Bund**		
	1	73° 23’45” E	17° 84’39” N
	2	73° 22’07” E	17° 86’25” N
6.	**Earthen Nala Bund**		
	1	73° 22’48” E	17° 85’40” N

CHAPTER V : SUMMARY AND CONCLUSION

This chapter deals with the summary and conclusion of the results obtained during the site suitability analysis of soil and water conservation measures for Kadivali watershed using remote sensing and GIS.

5.1 Summary

India has abundant natural resources. Land and water are the two most important natural resources. Rivers are primary sources for surface water. Because of climate change and growing demand of water for agriculture and urban development, the pressure on water resources is increasing. In fact, every kind of activity is linked with land and profitability of nation depends on the quality of its land resources. Soil and water conservation structures includes waterways, bunds and terraces, grade stabilization and gully control structures, water harvesting structures etc. are important to prevent soil erosion and improve water harvesting.

Remote sensing and Geographic Information System (GIS) has proved to be more accurate and efficient tools in the analysis of watershed and site suitability analysis of water conservation structures. Geographic information system (GIS) is a computer-based system which used to design, capture, store, manipulate, analyse, manage and present spatial data. The spatial information includes patterns of soil, land use land covers, geomorphology, ground water, topography, etc. QGIS software is free and open-source cross platform and capable of storing all kind of spatial and non-spatial data.

A study was undertaken for site suitability analysis of soil and water conservation structures in Kadivali village, Dapoli tehsil, Ratnagiri district, Maharashtra. The total area it covers is about 1649.4 ha. Kadivali village is located in between 17°82 N Latitudes and 73°24 E Longitude having average annual rainfall is 3500 mm received mostly during monsoon months of July to September.

In the present study, an effort has been made to analyze the morphometric characteristics and the digital elevation model (DEM) of Kadivali watershed. The digital elevation model (DEM) has been downloaded from ISRO's geoportal 'Bhuvan' which is captured by Cartosat-1 satellite having spatial resolution 2.5m. The delineation of Kadivali watershed was performed in QGIS 3.18.3 software by using digital elevation model (DEM). It demarcated boundary of watershed depending upon the rainfall and runoff which contributes in the area. Digital delineation saves time, labour and money as well as it is an easy method.

The geomorphological characteristics includes basic parameters such as area, perimeter, length of watershed, Stream order, Maximum and minimum elevation has been determined using QGIS software. The result showed that, study area covers 1649 ha area having perimeter 25.30 km and length 6.44 km, also maximum and minimum elevation is 206 m and 32 m respectively. There were 45 streams present in the watershed with order IV as the highest stream order. The linear aspect includes stream length, Stream length ratio, bifurcation ratio, etc. The average stream length ratio and average bifurcation ratio were found as 0.60 and 3.4 respectively.

The areal aspects of watershed were two-dimensional components which includes drainage density, form factor, elongation ratio, circulatory ratio. The drainage density for Kadivali watershed is 1.99 km/km2, belongs in its medium category which shows gentle to steep slope terrain, medium dense vegetation, and less permeable with medium precipitation. The form factor is 0.39 which implies that watershed is less elongated. The circulatory ratio and elongation ratio are 0.32 and 0.71 respectively. The relief aspects are three dimensional components which involves relief, relative relief, relief ratio and ruggedness number. The relief of Kadivali watershed is 174 m which shows low relief of the area. The relief ratio is 0.027 which is relatively low (<0.1) indicates gentle slope. The ruggedness number is 0.34. The Rn value is relatively low which indicates less prone to soil erosion.

Runoff is one of the important hydrologic variables used in the water resources management. In the site suitability analysis of soil and water conservation structures in small watersheds, it is mandatory to know the relationship between rainfall and runoff. For estimation of runoff SCS- Curve number method was selected as it is less time consuming and more accurate than any other method of runoff estimation. It involves determination of hydrologic soil group (HSG), land use land cover (LULC), antecedent moisture condition (AMC) and curve number. The study area consisted sandy loam texture soil all over the watershed which comes under Hydrologic soil group C. The land use land cover map was prepared in QGIS 3.18.3 using LISS III satellite imagery. It shows that Kadivali watershed contains 38.68% forest land, 17.99 % vegetation, 23.20% Agriculture land, 17.16 % barren land and 2.97% settlement. The CN value further calculated for AMC I, II and III. CN I is 60.8, CN II is 77.90 and CN III is 89.25. The Minimum runoff observed is 716.63 mm i.e., 29.81% of the annual rainfall in the year 2001. The maximum runoff observed is 2492.47 mm i.e., 48.57 % of the annual rainfall in the year 2019.

Estimation of runoff shows, in study area 41.83% of rainfall contributed in runoff. In order to reduce the runoff, construction of soil and water conservation structures is necessary. Site suitability analysis of soil and water conservation structures is an important step towards maximizing water availability and land productivity. The sites were selected using QGIS 3.18.3 software by overlaying different thematic maps like slope map, lithology map, geology map, geomorphology map, soil texture map, drainage density map and land use land cover map. The suitable conservation structures were located according to the criteria discussed in Chapter III in Table 3.7. The ground truthing was performed to check suitability and accessibility of the selected sites.

In the present study, total 45 sites found suitable for various soil and water conservation structures. The structures suitable for the area are check dams, percolation tanks, cement nala bunds, Earthen Nala bund, Kokan Vijay bandhara and farm ponds, around 45 sites in which, 26 places are found suitable for construction of farm ponds; 5 sites for check dams; 6 sites found suitable for percolation tanks; 2 for cement nala bunds; 1 for earthen nala bunds and 5 sites for Kokan Vijay bandhara structures in the Kadivali watershed.

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5.2 Conclusions

After completing the research work entitled 'Site suitability analysis of soil and water conservation structures for Kadivali watershed using remote sensing and GIS' following conclusions have been drawn from the study.

1. From the study, it is concluded that digital delineation of watershed using DEM in QGIS 3.18.3 software is the appropriate, simple and easy method for delineation of any watershed.

2. Morphometric characteristics of the watershed have been analysed. The study shows that morphometric analysis can be carried out accurately & conveniently with the help of Carto DEM data and remote sensing and GIS technology.

3. The maximum stream water frequency was observed in case of first order stream and then second order stream. Hence, it is noticed that, there is decrease in stream frequency as stream order increase and vice-versa.

4. The bifurcation ratio of watershed is 3.4, which shows that, drainage pattern is less affected by structural differences. The elongation ratio of watershed is 0.71, which shows that, the watershed has less elongation, steep slope and high relief.

5. The relief ratio of Kadivali watershed is 0.027, which is relatively low (< 0.1) which indicates watershed has moderate to gentle slope and moderate relief. The ruggedness number of Kadivali watershed is 0.34, which is relatively low, it shows that, the watershed is less prone to soil erosion. The antecedent moisture condition (AMC) of soil, plays an important role, because curve numbers vary according to soil and that is essential while estimation of runoff.

6. The SCS – Curve number method is proven to be suitable method, which consumes less time and less data. The average annual runoff calculated from Kadivali watershed is 1560 mm i.e., 41.83% of rainfall for 32-year period.

7. The weighted overlay analysis of thematic maps provided 45 suitable sites for soil and water conservation structures in Kadivali watershed.

8. The structures suitable for the study area are check dams, percolation tanks, cement nala bunds, earthen nala bund, Kokan vijay bandhara and farm ponds.

9. The use of remote sensing and GIS helped for site suitability analysis in the study area to create thematic maps like slope, geology, geomorphology, land use land cover, soil, drainage density, stream order etc. Thus, it is apparent that QGIS 3.18.3 software is highly beneficial for site suitability analysis of soil and water conservation structures as it is less time consuming compared to conventional methods as it reduces time of field study.

CHAPTER VI : BIBLIOGRAPHY

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THESIS ABSTRACT

Soil and water are the most important natural resources and physical base for all life supporting system as water sustains life where soil acts as a medium. Remote sensing and Geographic Information System (GIS) have become easier and efficient tools in the watershed analysis and planning conservation measures. Therefore, the attempts have been made for site suitability analysis of soil and water conservation measures for Kadivali watershed using remote sensing and GIS. The watershed has been delineated using Cartosat- 1 digital elevation model downloaded from Bhuvan in QGIS 3.18.3. The analysis of morphometric characteristics showed that there were 45 streams present in Kadivali watershed having fourth order as the highest stream order. The values of form factor, elongation ratio and circulatory ratio were found 0.39, 0.71 and 0.32 respectively. It indicated that shape of Kadivali watershed is less elongated. The study used SCS curve number method to estimate the runoff from the study area. It was necessary to analyze the land use land cover (LULC), hydrologic soil group (HSG), antecedent moisture condition (AMC) and curve number (CN) of the study area to locate sites for soil and water conservation structures. The study found that the area under agricultural land, forest land, barren land and residential area was 23.20 %, 38.68 %, 17.16 % and 2.97 %, respectively. It was also observed that the value of curve number for AMC I, II and III was 60.8, 77.90 and 89.25 respectively. The study area consisted sandy Loam texture soil all over the watershed which comes under Hydrologic Soil group C.

The rainfall data of 32 years (1990-2022) was analyzed to estimate runoff of Kadivali watershed. The average runoff of watershed was found to be 1560.43 mm i.e., 41.83 % of total rainfall. The study was found useful for suitable sites selection of various soil and water conservation structures. In the present study, total 45 sites found suitable for various soil and water conservation structure. The structures suitable for the area are check dams, percolation tanks, Cement Nala bunds, Earthen Nala bund, Kokan Vijay bandhara and farm ponds. 26 places are found suitable for construction of farm ponds. 5 sites for Check dams, 6 sites found suitable for percolation tanks, 2 for cement nala bunds, 1 for earthen Nala bunds, and 5 sites for Kokan Vijay bandhara were suggested in the Kadivali watershed using QGIS 3.18.3 software. The selected sites were validated by ground truthing.

Keywords: RS and GIS, LULC, AMC, Soil and water conservation structures, SCS-CN.

THESIS ABSTRACT

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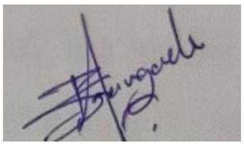
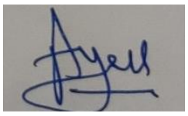
i)	Signature of student	
j)	Signature, Name and address of forwarding authority	: 

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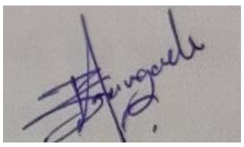

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