

**Land Resource Inventory for 14 Selected Watersheds of
Maharashtra for Land Use Planning Using Geo-spatial Techniques
(PMKSY 2.0)**

(WDC-2.0)3/2021-22: Chiplun, Dist - Ratnagiri



**ICAR-National Bureau of Soil Survey and Land Use Planning
Nagpur, Maharashtra**



**Vasundhara Watershed Development Agency
Pune, Maharashtra**

About the ICAR-NBSS&LUP

The ICAR-National Bureau of Soil Survey and Land Use Planning (ICAR-NBSS&LUP), Nagpur was set up in the year 1976 with the objective to prepare soil resource maps at the national, regional, state and district levels, to provide research inputs for land evaluation, land use planning, land resource management and database management using GIS, and to impart training on soil survey and land use planning. The Bureau has the mandate to correlate and classify soils of the country and maintain a National Register of all the established soil series.

During the past decades, ICAR-NBSS&LUP provided the country with the first comprehensive soil resource maps of India and her states on 1:1 million and 1:250000 scales, respectively. The Bureau generated land resource inventories (LRIs) on different scales (1: 50,000 or larger) at watershed, block and district levels to aid planning agencies in the formulation and implementation of agricultural land use plans. Other landmark data products generated by the Bureau include the land degradation map of India, potential soil loss maps of different states, and agro-ecological region and sub-region maps of the country. The Institute has received commendable mention by the NITI Aayog for providing land use plans in respect of 27 Aspirational districts of India. Taking cognizance of the demands of various agencies to develop regional land use plans in the shortest possible time, the Bureau has recently developed a revised standard operating protocol (SOP) by combining traditional knowledge with GIS and machine learning tools. The revamped SOP was successfully adopted for bringing out the Land Resource Inventory of Bundelkhand, Vidarbha, Bikaner, Kachchh and South Gujarat regions of India. The Bureau has also released the first soil depth map and the National Soil Spectral Library of the country and is in the process of bringing out the digital soil map of Maharashtra state. ICAR-NBSS&LUP has also assisted several state governments in watershed planning through LRI under the PMKSY 2.0.

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PREFACE

Watershed development requires the systematic and integrated planning of social and technological interventions based on its socio-economic and bio-physical characteristics. Activities related to conservation/management of natural resources, enhancement of systems' productivity, livelihood support through micro-enterprises and businesses, are all planned in a holistic manner for ensuring sustainable gains from the watershed programme. Implementation of watershed plans follows the preparation of detailed project report (DPR), which in turn is based on comprehensive information obtained through on- and off-field surveys. While the data requirement for DPR preparation is substantial, adoption of a minimum data set covering major aspects of the watershed through use of advanced RS, GIS and machine learning tools could significantly reduce time taken for the same, while making it more pragmatic and user-friendly.

Comprehensive land use planning of any area begins with large-scale land resource inventory, which provides valuable data for crop and nutrient management planning, and supports scientific decision-making. Generation of Land Resource Inventory (LRI) by the ICAR-NBSS&LUP during the last two decades has been a proven critical input for planned agricultural development. Encouraged by the success of LRI based watershed programmes in Karnataka, many states have started using soil/land data for rural development. It is essential that LRI based development is extended to other parts of India through spreading awareness of its benefits. Administrators at national and state level(s) have recognized it and instructed that at least 10% area of the watersheds be covered under LRI in the plateau and upland region under the section 19.1.2 (b) of WDC-PMKSY 2.0 guidelines.

Being a frontrunner on several aspects of agricultural development, the Government of Maharashtra, through the Vasundhara Watershed Development Agency (VWDA), proactively entrusted the Bureau with the generation of LRI for 14 selected watersheds across different agro-ecological sub regions of Maharashtra for formulation of scientific land use plans using geo-spatial techniques. This report presents a comprehensive understanding of soils of the watershed in terms of their physical and chemical characteristics, nutrient status, crop suitability and soil and water conservation requirements. It is expected that this report will serve as a valuable resource for land users, watershed planners, researchers and policy developers in rationalizing land use and for implementing ongoing agricultural development schemes.



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We are grateful to the Deputy Director General (NRM), Indian Council of Agricultural Research for his continuous support and guidance in successful completion of this project. We also sincerely thank the Assistant Director General (S&WM), NRM Division for his timely efforts and encouragement while implementing the project.

We place on record our deep sense of gratitude to the Chief Executive Officer(s), Deputy Chief Executive Officer(s), technical and administrative staff of the VWDA for entrusting us with this important project and for their financial and logistic support from the beginning to the completion of the project.

The authors express their sincere gratitude to all the scientists and technical staff, the I/c PME Cell, I/c Library, Chief Administrative Officer, Chief Finance and Accounts Officer, Administrative Officer, Assistant Administrative Officers and all other administration, accounts and audit sections of ICAR-NBSS&LUP, Nagpur, who ensured that the project continued smoothly. Their valuable help and cooperation in all respects are gratefully acknowledged.

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EXECUTIVE SUMMARY

The Pradhan Mantri Krishi Sinchayee Yojana - Watershed Development Component (PMKSY-WDC 2.0) requires a scientific and collaborative approach to watershed development through systematic evaluation of land and water resources. For effective planning, the Land Resource Inventory (LRI) provides a critical technical input for informed planning, prioritization of interventions, and sustainable management of natural resources. In accordance with the programme guidelines, the ICAR-National Bureau of Soil Survey and Land Use Planning (ICAR-NBSS&LUP) conducted the LRI and offered technical assistance for preparing watershed development plans.

ICAR-NBSS&LUP conducted the watershed assessment for Chiplun (WDC-2.0) Village Cluster-watershed. It is situated within the Vashishti River, specifically located in Chiplun Taluka, Ratnagiri District, Maharashtra. Agriculture is the primary land use in this watershed, heavily relying on monsoon rainfall. The primary objectives of the study were to systematically characterize soil and land resources at watershed level, assess land capability and crop-site suitability, support watershed-based land use planning, and evaluate groundwater potential to aid sustainable watershed development under PMKSY-WDC 2.0.

The assessment was carried out following standard methodologies and procedures prescribed by ICAR-NBSS&LUP. Pre-field analysis, detailed soil survey, laboratory analysis, and GIS-based interpretation were undertaken to generate spatial and thematic datasets. Base maps were prepared using authenticated sources. Soils were characterized through field observations and laboratory analysis and classified using established soil classification systems.

The watershed exhibits variability in landforms, slope, soils, and land use, which governs runoff generation, soil erosion, moisture availability, and groundwater occurrence. Soils show variations in depth, texture, drainage, and fertility status, reflecting differences in terrain position and land management practices. Hydrological assessment and groundwater potential evaluation were carried out using integrated thematic analysis to support identification of suitable areas for soil and water conservation and groundwater recharge interventions.

The outcomes of the Land Resource Inventory provide a scientific basis for watershed-level planning, identification of resource constraints, and prioritization of soil and water conservation measures. The technical inputs generated by ICAR-NBSS&LUP are intended to support implementing agencies in designing location-specific interventions and promoting sustainable management of land and water resources under PMKSY-WDC 2.0.

In conclusion, the Land Resource Inventory and watershed assessment carried out by ICAR-NBSS&LUP for the Chiplun sub-watershed constitutes an essential technical framework for watershed development planning and implementation, in accordance with the objectives and guidelines of PMKSY-WDC 2.0.

CHAPTER 1

INTRODUCTION

A region, block, district, or village's Land Resource Inventory (LRI) has proven to be an essential component of planned agricultural development. This inventory provides critical baseline data for effective watershed management and sustainable land use planning, particularly through the application of advanced geospatial technologies. Encouraged by the success of LRI-based watershed programs in Karnataka, many states have started using soil/land data for rural development.

Administrators at the national and state level(s) have recognized the significance of LRI and documented in the PMKSY 2.0 document that at least 10% area of the watersheds be covered under LRI in the plateau and upland region of the country. In addition to LRI, the agro-ecological zone approach is deemed to be most effective for regeneration of *in-situ* resources for sustaining the biological growth and, in turn, soil health. Agro-ecological regions and subregions delineated by the ICAR-National Bureau of Soil Survey and Land Use Planning (ICAR-NBSS&LUP) therefore form the ideal base for selection and planning of watershed development, as our understanding of soil-crop and weather interactions is greatly enhanced under this approach.

The Government of Maharashtra directed the Bureau to conduct a Land Resource Inventory (LRI) in 14 watersheds located in different agro-ecological zones of the state. The objective is to measure improvements and ensure the long-term health of farming and related activities in rainfed areas, which will benefit the local farmers.

The process for selecting these watersheds was designed to fairly represent where existing projects were located across Maharashtra's distinct regions. As a result, four watersheds were selected for both the Vidarbha and Konkan regions, as they had a high number of ongoing projects. Western Maharashtra, Marathwada, and Northern Maharashtra were each assigned two watersheds, reflecting a lower concentration of implemented projects.

The project, planned for 48626 ha was implemented with the following objectives:

1. To characterize and map the soil and water resources of the watersheds.
2. To assess the soil-site suitability of the crops based on land evaluation at the watershed level.
3. To develop watershed-based alternate land use options and soil and water conservation plans.
4. To assess and characterize the groundwater potential of the watersheds.

This report presents the Land Resource Inventory (LRI) conducted in the Ratnagiri (WDC-2.0)/3/2021-22 sub-watershed of Chiplun taluka under the Pradhan Mantri Krishi Sinchayee Yojana - Watershed Development Component (PMKSY-WDC 2.0). The study involved detailed field visits, soil observations, mapping, and assessment of local hydrological conditions. The information collected was carefully analyzed to understand land capability, soil suitability, drainage patterns and groundwater potential. These findings provide a

practical foundation for planning watershed development and soil and water conservation measures suited to local conditions.

List of micro watersheds (MWS) earmarked for LRI studies by the ICAR-NBSS&LUP

District	Project name	Block	No. of MWS	No. of villages	Area (ha)
Akola	Akola (WDC-2.0)1/2021-22	Barshitakli	11	8	4898.0
Buldhana	Buldhana (WDC-2.0)3/2021-22	Lonar	21	4	2498.5
Nandurbar	Nandurbar (WDC-2.0)4/2021-22	Nandurbar	5	14	3533.2
Nashik	Nashik (WDC-2.0)3/2021-22	Malegaon	7	7	2760.4
Osmanabad	Osmanabad (WDC-2.0)3/2021-22	Tuljapur	25	10	3380.0
Palghar	Palghar (WDC-2.0) 6/2021-22	Dahanu	7	23	3926.2
Parbhani	Parbhani (WDC-2.0)3/2021-22	Gangakhed	8	9	3791.0
Raigad	Raigad (WDC-2.0)2/2021-22	Roha	3	11	3825.0
Ratnagiri	Ratnagiri (WDC-2.0)3/2021-22	Chiplun	13	9	2548.0
Sangli	Sangli (WDC-2.0)3/2021-22	Jath	23	5	3200.0
Sindhudurg	Sindhudurg (WDC-2.0)3/2021-22	Dodamarga	5	5	3604.4
Solapur	Solapur (WDC-2.0)2/2021-22	Mangalwedha	31	7	4198.1
Wardha	Wardha (WDC-2.0)3/2021-22	Seloo	12	7	2657.5
Washim	Washim (WDC-2.0)5/2021-22	Malegaon	21	8	3806.1
Total			192		48626.9

CHAPTER 2

CHIPLUN WATERSHED AT A GLANCE

2.1 Location and Extent

The watershed (Fig. 2.1) is situated in Chiplun Taluka which is one of the administrative subdivisions of Ratnagiri district, located in the central-western part of the district within the Konkan region of Maharashtra. Geographically, the cluster area falls in taluka between 17.32° to 17.44° N latitude and 73.44° to 73.61° E longitude. The region is marked by rugged hills and receives high annual rainfall, with rural settlements spread across a landscape dominated mainly by forest cover, along with patches of degraded forest. Administratively, Chiplun comes under the Konkan revenue division and is predominantly rural in nature, characterized by forested slopes and narrow river valleys. The Vashishti River, rising from the Sahyadri ranges, is the major river running through the taluka and serves as a vital source of water for irrigation, domestic consumption, and industrial needs.

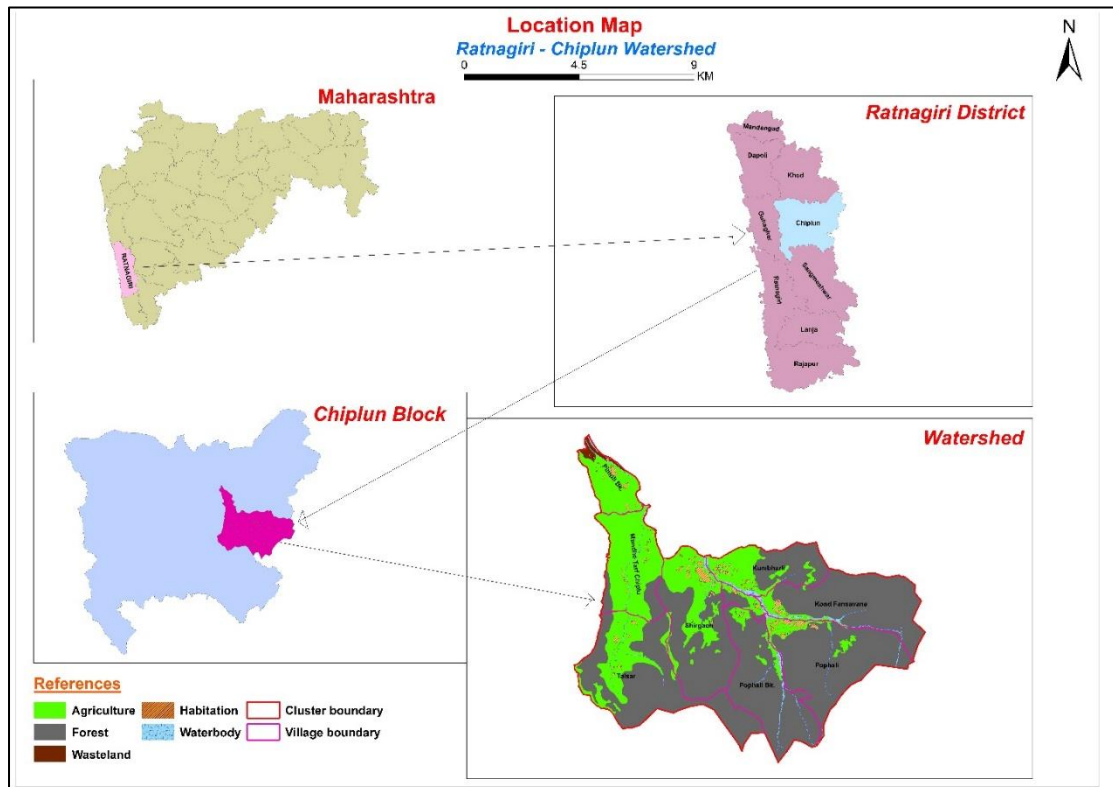


Fig. 2.1: Location map of the Chiplun watershed

Chiplun Taluka cluster villages watershed are mostly hilly, rainfed, and dependent on agriculture as the primary source of livelihood. Despite heavy rainfall during the monsoon, the region frequently faces high surface runoff, soil erosion, and declining groundwater availability, leading to water scarcity in the months following the monsoon. These recurring conditions form the basis for selecting the area for watershed-based natural resource development. Table 2.1 provides the general profile in respect of the watershed. The

selected villages are situated within the Vashishti river basin and are intersected by multiple seasonal streams flowing through valleys and slopes. These streams are active during monsoon (June to October) and significantly reduce or dry up by December in most years. Elevation varies from low-lying plains to higher slopes of the Western Ghats, forming several micro-watersheds within a compact area. This topographical setting is suitable for ridge-to-valley watershed treatment, enabling opportunities for water conservation, soil stabilization, and improved groundwater recharge.

Table 2.1: Geographical and Administrative Profile

S. No.	Particulars	Details
1	District	Ratnagiri
2	Taluka	Chiplun
3	Revenue Division	Konkan
4	Total sub-watershed Area	Approx. 8,325 hectares
5	Villages	09 (Akuskhan Nagar, Kond Fansavane, Kumbharli, Mundhe Tarf Chiplun, Pimpli Bk., Pophali, Pophali Bk., Shirgaon, and Talsar)
6	Major River	Vashishti River
7	Climate	Tropical, Hot, and Humid
8	Average annual Rainfall	1851 mm

2.2 Geology

The geology of the Chiplun watershed in Ratnagiri district is mainly dominated by Deccan Trap basaltic lava flows belonging to the Upper Cretaceous to Lower Eocene period. These basalt flows occur in horizontal layers and form the basic rock formation of the area. In many parts of the watershed, especially on hilltops and elevated surfaces, the basalt is covered by lateritic formations that have developed due to long-term weathering under the humid climatic conditions of the Konkan region. This laterite often forms a hard crust and is commonly found over upland areas. In contrast, the valley portions and low-lying areas contain recent alluvial deposits made up of sand, silt and clay. Together, the occurrence of basalt, laterite and alluvium influences the soil development, drainage pattern and groundwater conditions within the watershed.

2.3 Geomorphology

The geomorphology of the Chiplun watershed in Ratnagiri district reflects the typical landscape of the Konkan region and the Western Ghats. The area is characterized by rugged terrain consisting of hills, ridges and narrow valleys formed due to prolonged weathering and erosion of the basaltic rocks. The western part of the district is influenced by the steep slopes of the Western Ghats, while the terrain gradually descends towards the coastal plains. River valleys and low-lying areas are associated with depositional surfaces where alluvial materials have accumulated. These geomorphic features have developed over time under the influence of heavy rainfall, active drainage systems and tropical weathering

processes. The geomorphological setting of the watershed influences soil development, drainage characteristics and land use patterns within the area.

2.4 Physiography and Soil

The physiography of the study area is predominantly hilly, with undulating terrain extending from low-lying valleys to steep uplands. Elevation within the watershed ranges between 6 to 1073 m above mean sea level, creating distinct micro-watersheds and varied slope conditions. Slopes vary widely from 0% in valley plains to more than 255% rise on steep escarpments and ridge zones. These topographic differences strongly influence runoff behaviour, soil erosion, and the distribution of land use across the landscape. The region also contains well-defined drainage channels and numerous seasonal streams, which remain active during the monsoon months and gradually dry up toward the winter season.

Basalt forms the dominant lithology of the area, reflecting its geological setting within the Deccan Traps. The soils developed over these basaltic formations are primarily clay loam & clay in texture, followed by silty clay, and silty clay loam occurring in smaller patches. The soils show moderate to high moisture-holding capacity and support seasonal agriculture in flatter zones, while the upper hill slopes remain more vulnerable to erosion due to higher runoff intensity.

2.5 Climate

The climate of Chiplun in Ratnagiri district is tropical humid and strongly influenced by the southwest monsoon. The region receives very heavy rainfall, with average annual rainfall of 1851 mm, most of which occurs during the monsoon months from June to September, with July being the wettest month. Temperatures remain moderate throughout the year due to the coastal influence of the Arabian Sea, with maximum temperatures generally ranging between 29°C and 35°C, while minimum temperatures during winter may fall to about 15 to 17°C. The region experiences high humidity throughout the year, and moderate monsoon winds prevail during the rainy season.

2.6 Drainage

The drainage of the Chiplun area in Ratnagiri district is mainly controlled by the Vashishti River, which flows through the region and ultimately drains into the Arabian Sea. The river originates in the Western Ghats and flows westward across the Konkan region. A number of small streams and nalas join the main river along its course, especially during the monsoon season. Most of these streams are seasonal in nature and carry significant runoff during periods of heavy rainfall. The overall drainage pattern is mainly dendritic and is influenced by the basaltic terrain and undulating topography of the region.

2.7 Cropping Patterns, and Demography and Socioeconomics

2.7.1 Cropping Pattern

The cropping pattern in Chiplun Taluka, farming is closely linked to the monsoon, with most cultivation occurring during the Kharif season. Paddy is the dominant crop, grown across low-lying fields and valley floors where rainfall provides sufficient moisture. In addition to paddy, horticultural crops such as mango and cashew are commonly cultivated, particularly on upland slopes and terraces, taking advantage of the region's fertile soils and favorable climate. In some areas with adequate residual moisture or access to small-scale irrigation, farmers also grow Rabi crops, including pulses and vegetables, during the post-monsoon season. Overall, the cropping pattern in the taluka reflects a balance between staple food production and perennial horticulture, shaped by rainfall, soil characteristics, and topography.

2.7.2 Demographic and Socioeconomic Status

The Chiplun Taluka, situated within the Ratnagiri district is predominantly characterized by its rural population. The cluster exhibits outward migration of the local population to Mumbai in search of employment. Consequentially, this migratory pattern has yielded a highly advantageous sex ratio of 1,071 females per 1,000 males, a figure notably surpassing the state average for Maharashtra. Culturally, the taluka exhibits diversity, with the Hindu, Muslim, and Buddhist communities constituting the primary religious groups. Educationally, the area is well-resourced, recording an aggregate literacy rate of approximately 76.7%.

2.8 Water Resources

2.8.1 Surface Water

The Vashishti River serves as the main surface water source. During the monsoon, it carries a substantial volume of water, but most of it is lost because storage and water-harvesting facilities are minimal. Numerous seasonal streams and small nalas drain rapidly into the river, with little intervention to retain or regulate flow. The taluka lacks a major canal system, and surface water use is mostly confined to small check dams, farm ponds, and percolation tanks, many of which are partially silted or not fully functional.

2.8.2 Groundwater

Groundwater occurs mostly in weathered and fractured zones of basalt rock. According to the Dynamic Ground Water Resources of Ratnagiri District (CGWB), 2024, annual extractable ground water resources place the region under the "safe" category, with the groundwater extraction level is 12.5%.

2.8.3 Irrigation and Water Management

Irrigation and water resource management within the region are facilitated through a strategic synthesis of traditional agrarian practices and formal infrastructural frameworks, specifically adapted to the undulating topography and high precipitation levels. In the montane terrains, cultivators implement step farming by engineering level terraces into the

hillsides to optimize moisture retention and effectively capture downhill runoff. Individual agricultural plots are historically demarcated by stone bunds, known as bandhs, which incorporate deliberate apertures to facilitate the safe overflow of rainwater to lower-tier fields.

2.9 Constraints

The following key issues were observed in the cluster villages, both through field surveys (2024-2025) and community consultations:

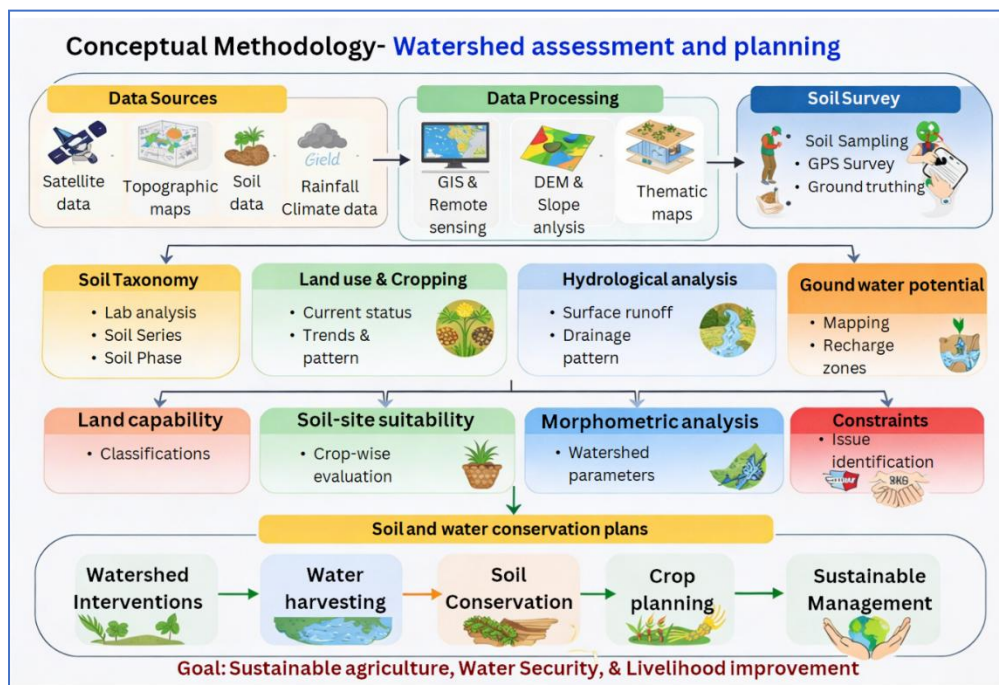
- a. Soil erosion and runoff losses: Heavy monsoon rainfall combined with hilly terrain leads to significant topsoil loss and increased surface runoff.
- b. Seasonal water scarcity: Despite high annual rainfall, limited storage and recharge infrastructure result in water shortage during the dry season.
- c. Declining groundwater levels: Groundwater in the basaltic terrain shows a decreasing trend, impacting availability for irrigation and domestic use.
- d. Flooding and inundation during monsoon: The Vashishti River overflows during heavy rains, submerging settlements, roads, and agricultural lands.
- e. Forest degradation and watershed instability: Deforestation and land-use changes contribute to slope instability and higher erosion risk, affecting watershed health and sustainability.

CHAPTER 3

METHODOLOGY

3.1 Overview of activities

The following figure depicts the overall flow of activities adopted for the project:



The various activities involved in the generation of land resource data and maps can be broadly grouped under pre-field, soil survey, post-field and post-LRI activities, as listed below:

A. Pre-field

- Procurement of high-resolution satellite imageries, cadastral maps, geology/physical maps
- Image interpretation for physiography/landforms/land use
- Finalization of physiography/landform map with legend as base maps.

B. Soil Survey

- Selection of transects (cutting across as many physiographic units as possible)
- Digging of soil profile pits up to 1.5 m depth or hard rock, whichever is earlier
- Examination and description of soil profiles in transects
- Study and record of soil-site characteristics
- Collection of soil samples from the pedons of each soil series
- Field review (preliminary, progressive and final) for soil correlation
- Grouping of soil profiles studied at each transect into soil series
- Development of progressive soil legend
- Mapping of soil phases (management units)
- Mapping of current land use/land cover, existing soil and water conservation structures etc.

C. Post-field phase

- Processing of soil samples, and laboratory analysis for physical, physico-chemical properties
- Compilation and interpretation of data
- Generation of thematic maps (slope, erosion, soil depth, drainage, pH, SOC, N, P, K and micronutrients, etc.)
- Land evaluation for various suitability classes for different crops and irrigation
- Preparation of soil and water conservation maps
- Developing soil mapping unit wise alternate land use options
- LRI Report write-up

3.2 Preparation of Base Maps

Spatial data preparation began by georeferencing Survey of India (SOI) toposheets at a 1:50,000 scale, utilizing the WGS 84 datum and UTM projection supported by field - verified Ground Control Points (GCPs). Landform delineation was executed within a GIS environment, integrating 30 m resolution SRTM Digital Elevation Models (DEM) with systematic on-screen visual interpretation. This geomorphic analysis relied on fundamental image elements - including shape, tone, colour, pattern, shadow and texture - to identify land features. To enhance interpretation, False Colour Composites (FCC) were generated through various satellite band combinations. Final mapping of land use/land cover (LULC) and landform units was conducted using ArcGIS software.

3.3 Ground-truth Verification

The area was traversed to identify different landform units, slope and present land use/land-cover (LULC) classes, and correlated with image interpretation units. The boundaries that were originally derived during the base map preparation were verified and corrected wherever necessary. To understand the soil variability in the study area, representative sites on each landform unit were selected, located using handheld Global Positioning System (GPS) and 30 profiles observations were taken and studied for morphological properties in the field following the guidelines for field soil descriptions (Soil Survey Division Staff 2000) and were recorded in the standard format.

3.4 Soil Sampling and Analysis

Soil samples from each horizon of all of the representative soil series were collected for laboratory studies. The soil samples collected during the fieldwork were initially air dried in the laboratory at room temperature, ground using a wooden pestle and mortar, screened through a 2 mm sieve, properly labelled, and stored in polythene bags for laboratory analysis. The soil samples were analysed in the laboratory for physical and chemical parameters using standard procedures. The particle size analysis was done by international pipette method. A combined glass-calomel electrode was used to determine the pH measured (1:2.5 soil/solution ratio). Soil organic carbon (SOC) was determined using the wet digestion method of Walkley and Black (1934). Available nitrogen (N) was measured by the alkaline permanganate method as described by Subbiah and Asija (1956). Available phosphorus (P) was determined by the Bray II method (Bray and Kurtz 1945). Cation

exchange capacity (CEC) of soil was measured as per the procedure outlined by Jackson (1976). Exchangeable cations [calcium (Ca), potassium (K), and magnesium (Mg)] were extracted with 1 M ammonium acetate (NH₄Oac) (pH 7.0). Potassium content was determined by flame photometry (Rich 1965), while Ca and Mg were determined in ethylene diamine tetra acetic acid (EDTA) titration. Exchangeable Al was extracted with 1 N potassium chloride (KCl) solution and titrated with 0.1 N sodium hydroxide (NaOH) solution. Available micronutrient content [copper (Cu), manganese (Mn), iron (Fe), and zinc (Zn)] were determined by diethylene triamine penta-acetic acid (DTPA) extraction (Lindsay and Norvell 1978), followed by atomic absorption spectrophotometry. Soils were classified according to Keys to Soil Taxonomy (Soil Survey Staff 2010).

3.5 Development of Soil Mapping Legend

In the present study, soil series phases were used as the basic mapping units. A soil series refers to a group of soils or polypedons that exhibit similar horizon sequences and share closely related properties within a narrow range of variation (Soil Survey Division Staff, 2000). The phases considered in this study included soil depth, surface texture, slope, erosion status and flooding conditions.

Soil profiles were examined and correlated within each major landform and soil series were identified accordingly. The identified soil series information was then extended to the sub-units of major landforms based on diagnostic soil characteristics observed from soil profile descriptions and auger observations.

A detailed soil map depicting soil series and their respective phases was prepared at a scale of 1:10,000. The soil legend code developed for the map represents the soil series name followed by surface texture, slope class, erosion status and soil depth, as described by Singh et al. (2016).

3.6 Surface Runoff Estimation

Direct surface runoff occurring in the Chiplun watershed was estimated using the Soil Conservation Service Curve Number (SCS-CN) method, employing daily rainfall data from 2014 to 2024. The SCS-CN method is widely used for estimating surface runoff as it establishes a functional relationship between rainfall, land use, soil conditions, and the physical characteristics of the landscape. The method is based on the Curve Number (CN), a dimensionless parameter that reflects the runoff potential of an area depending on land use, soil type, and hydrologic condition. The CN plays a decisive role in determining the proportion of rainfall that contributes to direct runoff.

The watershed area was delineated into individual spatial polygons representing homogeneous units of land use, soil, and slope characteristics to capture spatial variability across the landscape. For each polygon, the appropriate Hydrologic Soil Group (HSG) was assigned based on soil infiltration capacity and other physical characteristics. The Curve Number (CN) for each polygon was determined according to its corresponding land use and soil group combination. This polygon-based approach enabled a more spatially refined estimation of runoff, as runoff potential varies across different parts of the watershed.

The Antecedent Moisture Condition (AMC), a measure of soil moisture based on the previous rainfall events, was computed daily. The AMC plays an important role in adjusting the CN because soils that are already saturated are more likely to produce runoff than those that are dry. The AMC was computed using the rainfall data from the previous five days, and based on the resulting moisture condition, the CN for the day was adjusted accordingly. This adjustment helps account for variations in runoff potential that result from antecedent moisture conditions.

After calculating the CN for each unit, the weighted average CN for the entire study area was computed, considering the area of each polygon. The initial abstraction (S), which represents the portion of rainfall that does not contribute to runoff (e.g., water that is stored in depressions, infiltrates into the soil, or evaporates), was also estimated using CN values. The runoff for each month and year was then calculated, with data from 2014 to 2024 providing insights into seasonal and yearly runoff patterns within the watershed.

3.7 Groundwater Potential Zone Mapping

The groundwater potential of the watershed was determined using a comprehensive approach that integrates eight thematic layers to provide valuable insights for the sustainable management of this critical resource. Each of the thematic layer represents a factor influencing groundwater availability, and include soil, slope, drainage density, elevation, land use/land cover (LULC), rainfall, geomorphological landform units, and lithology. A multi-criteria decision-making (MCDM) approach was adopted to integrate these layers for assessing the groundwater potential across the region. Each thematic layer contributes uniquely to the understanding of groundwater potential. For instance, the type and permeability of soil play a vital role in groundwater recharge and storage capacity. The slope of the land influences the infiltration rate and surface runoff, with steeper slopes typically having lower groundwater recharge potential. Drainage density, which refers to the network of streams or rivers in the area, affects groundwater recharge by facilitating water flow into the ground. Elevation is another important factor, as it dictates the direction of water flow, with lower areas often being more favorable for groundwater accumulation. The land use/land cover type also has a direct impact, with urban areas typically having lower groundwater potential due to impervious surfaces, while agricultural and forested areas are generally more conducive to recharge. Rainfall is a key driver of groundwater replenishment, as it is the primary source of recharge, with the quantity, distribution, and seasonality of rainfall significantly influencing groundwater availability. The geomorphological landforms also play an essential role in shaping groundwater potential, as different landforms, such as valleys and plateaus, influence the movement and storage of groundwater. Lastly, lithology, or the geological composition of the region, determines the porosity and permeability of rocks, which in turn affects groundwater storage and movement.

The relative importance of each of these factors was assessed by employing the Analytical Hierarchy Process (AHP), a decision-making tool that allows the integration of expert opinions and subjective judgment in a structured manner. AHP assigns weights to each thematic layer based on its significance in influencing groundwater potential. Expert

opinions, along with a thorough review of existing literature, guide the determination of these weights, ensuring that all relevant factors are carefully considered. The weight assigned to each layer reflects its relative contribution to groundwater availability in the watershed. This step is crucial for ensuring that the final groundwater potential map accurately reflects the different factors that affect groundwater in the region. Once the weights are assigned, the study applies the Weighted Sum Method (WSM) to integrate the normalized thematic layers into a composite groundwater potential index. The normalization process ensures that each thematic layer contributes appropriately to the overall assessment, regardless of its numerical scale. The WSM method allows for a systematic integration of the layers, combining them in a way that reflects their relative importance and generating a comprehensive map of groundwater potential zones in the Chiplun watershed. This composite groundwater potential index is then used to classify the region into five distinct categories: very poor, poor, moderate, good, and very good potential. These categories represent the varying levels of groundwater availability across the region, helping to identify areas where groundwater resources are abundant, as well as those where availability is limited.

3.8 Land Evaluation

The evaluation of soil-site suitability was carried out to understand how well the land resources of the watershed can support sustainable crop production under existing environmental conditions. The approach combines information on soil properties, terrain features, and climate to assess the capability of different land units to meet the growth requirements of various crops, thereby supporting scientific land-use planning.

The assessment was conducted using the maximum likelihood method based on the guidelines proposed by Sys et al. (1993) and Naidu et al. (2006). Detailed field surveys, laboratory analysis of soil samples, and interpretation of spatial datasets were used to generate a comprehensive soil and site database. Since the watershed area is relatively small, temperature and rainfall were considered uniform across the entire area and treated as constant climatic inputs for the suitability evaluation.

Soil wetness conditions, including drainage status and the possibility of flooding, were examined to understand soil aeration and moisture availability. Physical soil characteristics such as surface texture and effective soil depth were assessed to evaluate their influence on root growth, water retention, and nutrient uptake. Soil fertility indicators, including pH, soil organic carbon, apparent cation exchange capacity, base saturation, and exchangeable cations, were analyzed to determine the nutrient-supplying capacity of soils. In addition, terrain features such as slope and erosion risk were considered to understand their impact on runoff, soil loss, and field operations.

Each soil and site factor was rated according to its degree of limitation to crop growth, and the combined effect of these limitations was used to determine overall land suitability. Based on this integrated analysis, soils were grouped into five suitability classes: highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and not suitable (N). This classification helps in identifying suitable crops, planning appropriate

management practices, and promoting sustainable agricultural development within the watershed.

3.9 Identification of Soil and Water Conservation Measures

The identification and spatial allocation of soil and water conservation (SWC) measures within the village cluster watershed of Chiplun Taluka were carried out through an integrated geospatial and land resource assessment approach. A comprehensive spatial database was prepared using high-resolution satellite imagery, digital elevation models (DEM), soil resource maps, land use/land cover data, and drainage network information. From the DEM, slope classes, flow accumulation, and drainage patterns were derived to understand runoff movement and erosion-prone areas within the watershed. Soil resource information, including soil depth, texture, and drainage characteristics, was integrated with land use data to assess land capability and constraints affecting agricultural productivity.

Based on these datasets, land capability assessment and terrain analysis were performed to delineate management units within the watershed. Each unit was evaluated for its suitability for specific conservation interventions by considering parameters such as soil depth, slope gradient, existing land use, runoff potential, and proximity to drainage lines. Decision rules commonly used in watershed planning were applied to assign appropriate measures. For example, field bunding and strengthening of existing bunds were recommended in cultivated lands with gentle slopes to reduce runoff and enhance in situ moisture conservation, while conservation bench terraces were proposed in unbundled agricultural areas with moderate slopes where soil depth permitted terracing. The Broad Bed and Furrow (BBF) system was identified for agricultural fields, particularly in medium to deep soils, to improve surface drainage and soil moisture distribution under rainfed conditions.

Water harvesting interventions were identified based on runoff contributing areas, drainage density, and storage potential. Farm ponds were proposed in agricultural fields with suitable catchment areas, while lined farm ponds were recommended in locations with higher seepage potential. Structural measures such as cement nala bunds (CNB) and earthen nala bunds (ENB) were proposed along drainage lines after evaluating channel characteristics, contributing catchment area, and groundwater recharge potential. Renovation and desilting of existing water bodies and farm ponds were suggested based on field observations and spatial identification of existing structures.

Vegetative interventions were planned in areas characterized by scrubland, degraded lands, or drainage margins, where afforestation and stream bank plantations could help stabilize soil and reduce erosion. Horticultural plantations supported with in situ moisture conservation practices were proposed in suitable land parcels to enhance land productivity. Additional measures such as rooftop rainwater harvesting in built-up areas and road-side drainage protection works were identified to capture and safely manage runoff from non-agricultural surfaces. Through the integration of terrain analysis, soil resource information, land use assessment, and hydrological considerations, site-specific conservation measures were systematically identified and spatially allocated within the watershed. This approach ensured that the proposed interventions are technically suitable, hydrologically effective, and aligned with the existing land resource conditions of the watershed.

CHAPTER 4

RESULTS AND INTERPRETATIONS

4.1 Irrigation, Cropping Patterns, and Demography and Socioeconomics

A field survey was conducted to document the availability of water resources, cropping patterns, and the demographic and socio-economic characteristics of farmers in the watershed. The results obtained from this survey are presented in the following sub-sections.

4.1.1 Irrigation and water management

The irrigation pattern of the Chiplun watershed is presented in Table 4.1. Rainfed agriculture accounts for the majority of the cultivated land, with no irrigation support available for these areas. The heavy dependence of farmers on monsoon rainfall for crop cultivation, making agricultural production highly vulnerable to rainfall variability.

The irrigation pattern of the cluster shows extremely limited irrigation infrastructure, with borewells providing minimal irrigation support while the majority of agricultural land remains rainfed.

Table 4.1 Seasonal Distribution of Irrigation Sources in the Chiplun Watershed

Sr. No.	Number of Farmers Interviewed (n)	Irrigation Source	Seasonal Water Availability	Contribution to Season's Total Irrigation (%)
1	23	Borewell	Kharif	100.0
2	214	Rainfed	Kharif	0.0

4.1.2 Cropping Pattern

The cropping pattern of the Chiplun watershed is presented in Table 4.2. The gross cropped area was 185.62 ha, while the net sown area was 129.20 ha.

$$\text{Cropping intensity}(\%) = \frac{\text{Gross cropped area}}{\text{Net sown area}} \times 100$$

$$\text{Cropping intensity}(\%) = \frac{185.75}{129.20} \times 100 = 143.7\%$$

The cropping intensity of the area is calculated as 143.7%, indicating that the agricultural land is cultivated more than once during the year despite the predominance of rainfed agriculture.

In the Kharif season, Rice was found to be the major crop, occupying 65.98% of the cropped area with a productivity of 2512.46 kg/ha, making it the principal staple crop of the region. Rice cultivation forms the backbone of the cropping system and is primarily dependent on monsoon rainfall.

Perennial horticultural crops also contribute significantly to the cropping pattern. Mango occupies 14.49% of the total cropped area with a productivity of 411.31 kg/ha, while Cashew covers 2.81% of the total cropped area with a productivity of 7791.75 kg/ha, indicating the importance of horticulture in the farming system. The cropping pattern of the

cluster is characterized by the dominant Kharif Rice cultivation along with perennial horticultural crops such as Mango and Cashew, which together support agricultural production and livelihood security under rainfed conditions. The high cropping intensity reflects the integration of seasonal crops with perennial plantations, contributing to improved land utilization.

Table 4.2 Crop-wise Distribution in the Chiplun watershed

Sr. No.	Season	Crop	No. of Farmers Interviewed (n)	Irrigation Type	Total Cropped Area (%)	Productivity (kg/ha)
1	Kharif	Rice	218	Rainfed	66.0	2512.5
2	Perennial	Mango	63	Rainfed	14.5	411.3
3	Perennial	Cashew	17	Rainfed	2.8	7791.8

4.1.3 Socioeconomic Status

4.1.3.1 Land holding pattern

The landholding pattern of farmers in the Chiplun watershed is presented in Table 4.3. From the table, it was observed that marginal farmers (<1 ha) have the highest population, 48.26% of the total farmers, having an average landholding of 0.49 ha, followed by small farmers (1–2 ha) accounting for 25.58% with an average landholding of 1.4 ha.

Semi-medium farmers (2-4 ha) have 19.19% of the total farmers with an average landholding of 2.59 ha, while medium farmers (4-10 ha) account for 6.98% with an average landholding of 4.29 ha. No farmers were recorded under the large farmer category (>10 ha).

Average landholding size was found to be 1.39 ha, indicating that agriculture is characterized by small and marginal landholdings. Such small farm sizes may limit farm mechanization, capital investment capacity, irrigation development and adoption of improved agricultural technologies.

Table 4.3 Land holding pattern in Chiplun watershed

Category	Criteria Land (ha)	No. of Farmers Interviewed (n)	Farmers (%)	Average Land Holding (ha)
Marginal Farmers	<1	83	48.26%	0.5
Small Farmers	1-2	44	25.58%	1.4
Semi-Medium Farmers	2-4	33	19.19%	2.6
Medium Farmers	4-10	12	6.98%	4.3
Large Farmers	>10	0	0.0%	0.0
Average land holding				1.39

4.1.3.2 Income distribution

The income pattern from different crops in the Chiplun watershed is presented in the Table 4.4. Rice occupies the largest cropped area 68.17% with an average income of 40,669 Rs, indicating a major crop and an earning source.

Mango occupies 18.26% of the cropped area with an average income of 27,438 Rs, indicate supplemental farmers income. Cashew covers 5.96% of the cropped area with an average income of 10,350 Rs.

The results indicate that rice dominates the cropping pattern and income structure of the study area, while horticultural crops such as mango and cashew provide additional income. This cropping pattern highlights the importance of staple crop cultivation along with limited diversification into horticultural crops in the watershed area.

Table 4.4 Average annual income of farmers in Chiplun watershed.

Name of Crops	No. of Farmers Interviewed (n)	Crop Area (%)	Average Income (Rs.)
Rice	43	68.17%	40669
Mango	16	18.26%	27438
Cashew	6	5.96%	10350

4.1.3.3 Education

The educational profile of the population in the villages of the Chiplun watershed is presented in the Table 4.5. Pophali Bk recorded the highest illiteracy rate (100%), where the respondents reported no formal education, indicating extremely poor educational status in the village. Very high levels of illiteracy were also observed in Akunsan Nagar (89%), Pophali (84%), Munde Turf Chiplu (81%), and Kondfansawane (79%). Similarly, Pimpli Bk (74%), Talsar (69%), and Kumbharli (62%) showed a large population without formal education.

Primary education levels remain low in the villages, with the highest population recorded in Talsar (14%), followed by Kumbharli (12%) and Sirgaon (10%). With respect to secondary education, Sirgaon recorded the highest population (27%), followed by Kumbharli (22%) and Talsar (13%).

The respondents with higher secondary education is extremely low across all villages, generally ranging between 1–2%. With respect to higher studies, Pimpli Bk recorded the highest proportion (26%), followed by Kondfansawane (21%) and Akunsan Nagar (11%), whereas Pophali Bk recorded no population with higher studies.

The results indicate that the watershed is characterized by very high levels of illiteracy with limited access to higher levels of education. This educational scenario may significantly influence awareness levels, decision-making ability and adoption of improved agricultural practices and developmental programs.

Table 4.5 Education profile of villages in Chiplun watershed by population

Village	No Education (%)	Primary (%)	Secondary (%)	Higher Secondary (%)	Higher Studies (%)
Akunsan Nagar	89	0	0	0	11
Kumbharli	62	12	22	2	2
Kondfansawane	79	0	0	0	21
Munde Turf Chiplu	81	7	10	1	1
Pimpli Bk	74	0	0	0	26
Pophali	84	6	7	1	2
Pophali Bk	100	0	0	0	0
Sirgaon	58	10	27	2	3
Talsar	69	14	13	1	3

4.2 Land-use/Land-cover

LULC classification is undertaken to quantify how the watershed area is distributed among different land use categories. This helps in identifying the dominance of agriculture, the extent of wastelands, and the presence of water bodies and built-up areas. Such classification provides a scientific basis for watershed planning, resource management, and prioritization of conservation measures. The classification of the area reveals that two-thirds of the watershed is dominated by forests, occupying 5548 ha, while agriculture is practiced in about 30% of the area (Table 4.6 and Fig. 4.1). Waterbodies occupy 2% of the total area, reflecting the presence of limited surface water resources.

Table 4.6 Land-use/land-cover statistics of Chiplun watershed

Land use	Area(ha)	Percent (%)
Forest	5547.7	66.6
Agriculture	2425.4	29.1
Waterbody	167.2	2.0
Habitation	146.6	1.8
Wasteland	37.9	0.5
Total	8324.8	100.0

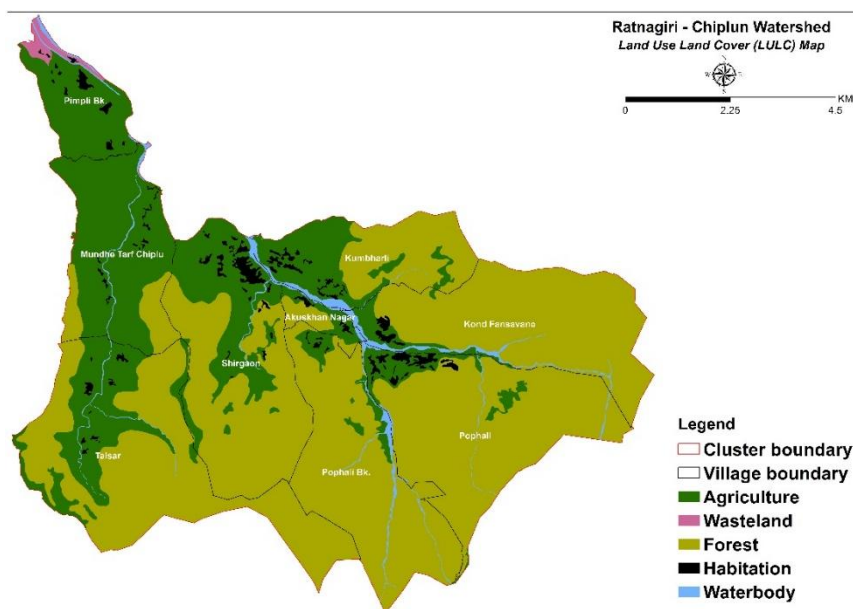


Fig. 4.1: Land-use/land-cover map

4.3 Landform Delineation

Chiplun watershed, Ratnagiri district represents a predominantly hilly terrain with noticeable variation in surface form and relief. Pediments and alluvial plain comprise one-fifth of the watershed area on which cultivation is mostly taken up. Two-thirds of the watershed area is defined by rugged hills and undulating ridges. The upland areas represent higher ground with gentle to moderate undulations. Overall, the watershed presents a diverse mix of landforms, reflecting a naturally varied geomorphic setting. The landform map of the watershed is presented in Fig. 4.2. The descriptions of each landform are presented in Table 4.7.

Table 4.7: Landform features existing in Chiplun watershed

Landform	Area(ha)	Percent (%)
Plateau	25.8	0.3
Hills & Ridges	5550.4	66.7
Escarpment	587.7	7.1
Valley	78.1	0.9
Pediment	1453.5	17.5
Alluvial Plain	315.5	3.8
Habitation	146.6	1.8
Waterbody	167.2	2.0
Total	8324.8	100.0

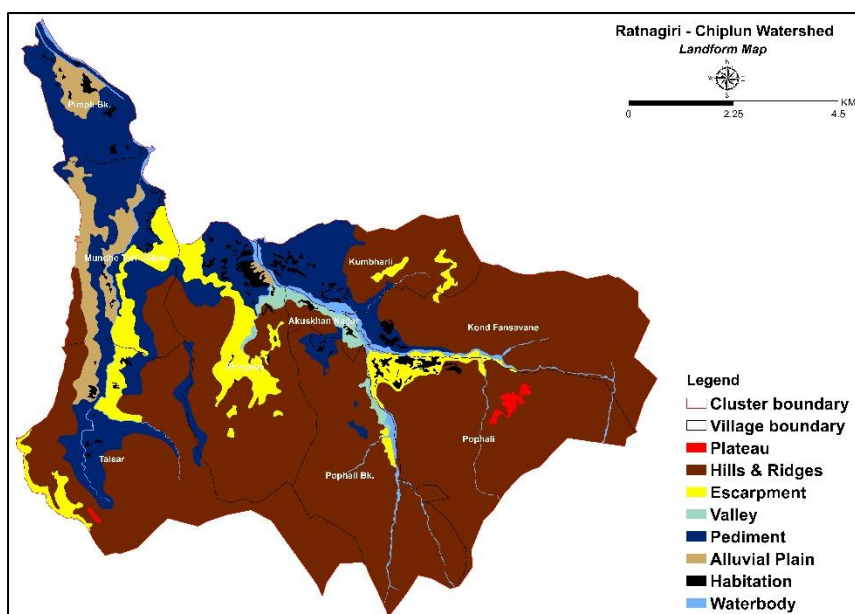


Fig. 4.2: Landform map of Chiplun watershed

4.4 Soil series and phases

Nine soil series have been identified and mapped with 28 soil mapping units (phases of series) (Fig 4.3). The taxonomic classification and mapping legend of the soil series are shown in Table 4.8. The detailed descriptions of each phase is provided in Table 4.9.

Table 4.8. Dominant soil series identified in the watershed

Sr. No.	Series	Area (ha)	Percent (%)
1	Kumbharli	173.9	2.1
2	Kumbharli1	1021.4	12.3
3	Mundhe	131.4	1.6
4	Pimpli Bk.	138.9	1.7
5	Pophali Bk.	149.4	1.8
6	Pophali Bk.1	40.2	0.5
7	Shirgaon	211.3	2.5
8	Talsar	358.3	4.3
9	Talsar1	5786.3	69.5
10	Habitation	146.6	1.8
11	Waterbody	167.2	2.0
	Total	8324.8	100.0

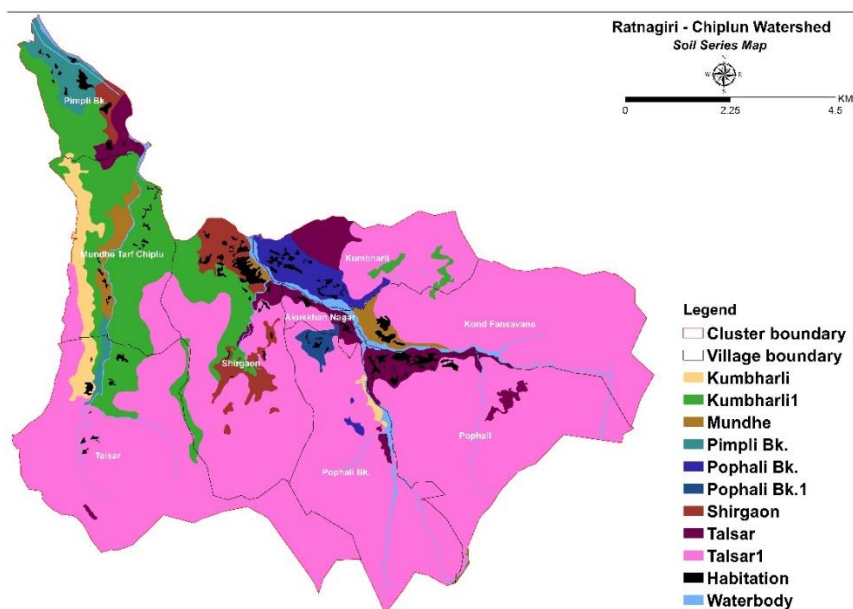


Fig. 4.3: Soil series map of Chiplun watershed

Table 4.9. Soil phases existing in Chiplun watershed

Sr. No.	Phase	Area (ha)	Percent (%)
1	Kub2kF4	32.1	0.4
2	Kub2mB1	651.1	7.8
3	Kub2mD1	310.2	3.7
4	Kub2mD4	25.4	0.3
5	Kub2mF4	2.7	0.0
6	Kum5mA1	13.2	0.2
7	Kum6mA1	160.7	1.9
8	Mun4mB1	8.3	0.1
9	Mun5mA1	123.1	1.5
10	Pim2mA1	27.9	0.3
11	Pim3mA1	73.1	0.9
12	Pim3mC1	37.9	0.5
13	Pob3mB1	40.2	0.5
14	Pop2mD2	142.0	1.7
15	Pop3mB2	7.4	0.1
16	Shi2mA1	36.9	0.4
17	Shi2mB2	48.9	0.6
18	Shi2mC1	41.4	0.5
19	Shi2mD4	84.2	1.0
20	Tal2mA1	65.0	0.8
21	Tal2mB1	25.8	0.3
22	Tal2mB3	96.7	1.2
23	Tal2mE2	64.6	0.8
24	Tal2mH4	106.2	1.3

25	Tas1fH4	5547.7	66.6
26	Tas1gD3	1.4	0.0
27	Tas1mC3	53.7	0.6
28	Tas1mD2	183.6	2.2
29	Habitation	146.6	1.8
30	Waterbody	167.2	2.0
	Total	8324.8	100.0

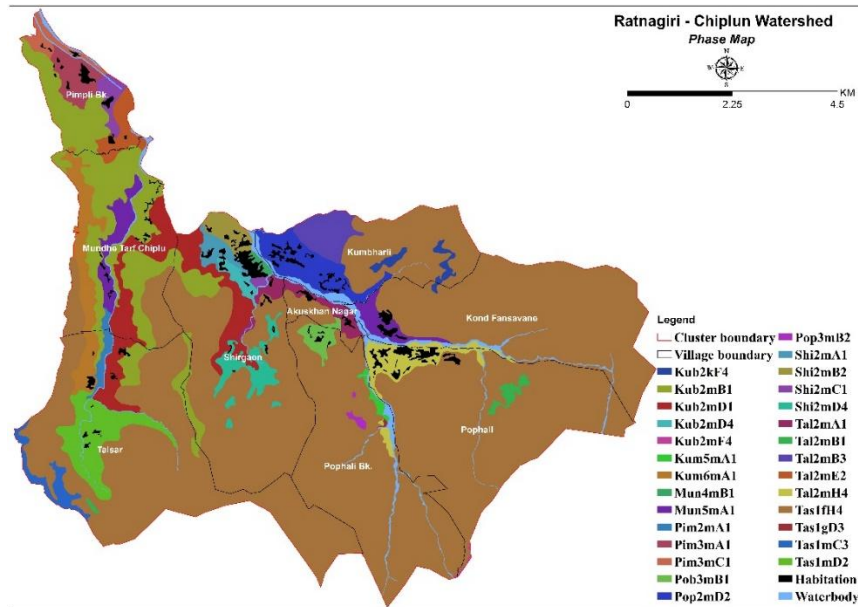


Fig. 4.4: Soil Phase map of Chiplun watershed

4.5 Soil Survey Interpretation

4.5.1 Slope

Land slope plays a crucial role in agriculture, as it affects water drainage, soil erosion, and the ease with which crops can be cultivated. Steep slopes tend to have higher rates of surface runoff, which can lead to soil erosion and loss of valuable topsoil, reduce soil fertility and compromise crop yields. On the other hand, flat or gently sloping lands allow for better water retention, easier mechanization, and more efficient irrigation practices, leading to higher productivity. The slope also influences the microclimate of the area, with sloped terrains potentially being more prone to temperature extremes or frost in certain regions. With a predominantly hilly terrain, about 70% of Chiplun watershed exhibits slope exceeding 15%. Among the other slope classes (Table 4.10, Fig. 4.5), nearly level to eight percent slope prevails in about 25% of the watershed, largely supporting agriculture.

Table: 4.10. Land slope classes in Chiplun watershed

Sr.No.	Slope Class (%)	Area (ha)	TGA (%)
1	Level to nearly level (0 - 1)	499.8	6.0
2	Very gently sloping (1 - 3)	878.3	10.6
3	Gently sloping (3 - 8)	879.7	10.6

4	Moderately sloping (8 - 15)	64.6	0.8
5	Moderately steep sloping (15 - 30)	5582.4	67.1
6	Steeply sloping (30 - 50)	106.2	1.3
7	Habitation	146.6	1.8
8	Waterbody	167.2	2.0
	Total	8324.8	100.0

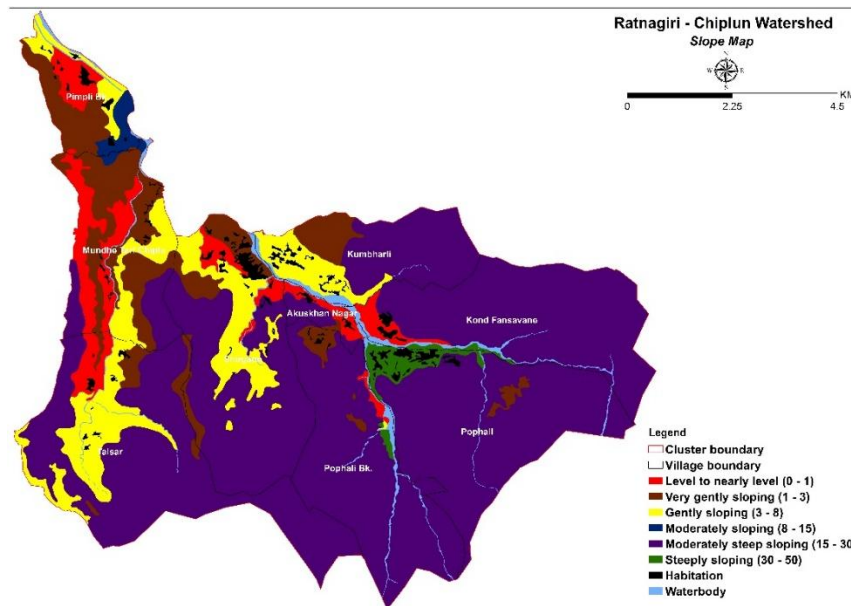


Fig. 4.5: Slope map of Chiplun watershed

4.5.2 Soil Erosion

As expected from the slope classes, nearly 70% of the watershed experiences severe soil erosion, while three-quarters of the watershed is prone to moderate to severe rates of erosion (Table 4.11, Fig. 4.6). Nearly one-fifth of the area can be managed through appropriate conservation practices.

Table 4.11: Soil erosion status in Chiplun watershed

Sr. No.	Erosion class	Area (ha)	Percent (%)
1	None	225.6	2.7
2	Very Slight	1389.0	16.7
3	Moderate	446.4	5.4
4	Severe	296.0	3.6
5	Very Severe	5654.0	67.9
6	Habitation	146.6	1.8
7	Waterbody	167.2	2.0
	Total	8324.8	100.0

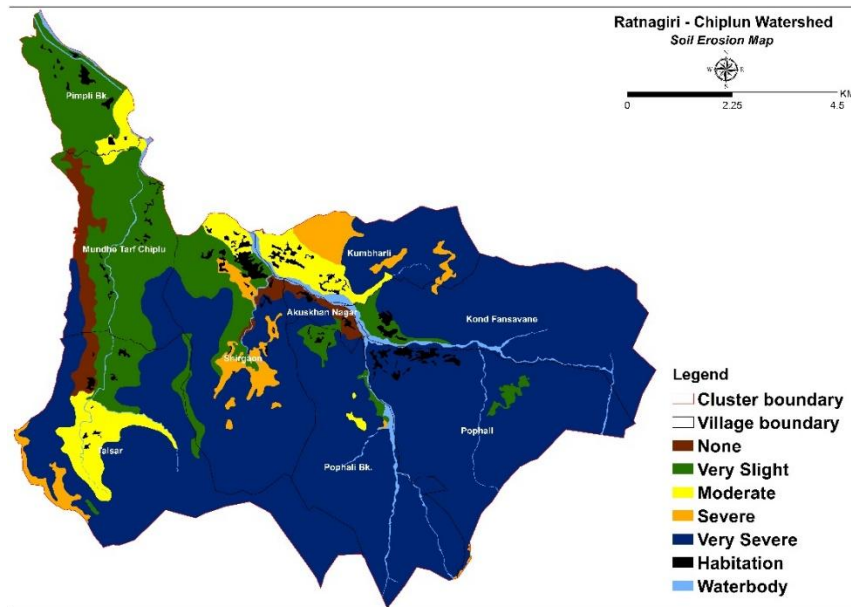


Fig. 4.6: Erosion map of Chiplun watershed

4.5.3 Soil Depth

Soil depth acts as an integrative proxy for several other soil properties and functions, including soil moisture retention, organic carbon storage, effective rooting depth, nutrient availability, and overall profile development. These properties are intrinsically linked to pedogenic processes such as weathering, translocation, erosion-deposition dynamics, and biological activity, all of which are strongly modulated by landscape position and hydrological regime. Thus, spatial variability in soil depth reflects not only physical soil thickness but also broader gradients in soil fertility, water holding capacity, and ecosystem functioning across the terrain. Deeper soils generally provide more space for roots to penetrate, access water, and take up essential nutrients, which supports healthier plant growth and higher crop yields. Shallow soils, on the other hand, can restrict root development and limit the availability of nutrients and moisture, especially during dry periods. This can result in stunted plant growth, lower productivity, and increased vulnerability to drought stress. In regions with shallow soils, farmers may need to implement practices such as deep ploughing, irrigation, or the addition of organic matter to improve soil depth and enhance crop performance. Understanding soil depth helps farmers make better decisions on crop selection, irrigation, and soil management, promoting more efficient and sustainable agricultural practices. The soil depth in the watershed (Fig. 4.7) varies from shallow (<25 cm) to very deep (>100 cm). Area wise distribution of the data (Table 4.12) shows that maximum area was under shallow (~70%) followed by moderate depth (18%) soils. Thus, it can be said that soil depth in majority of the watershed area is below 50 cm, which restricts the choice of crops.

Table 4.12. Soil depth classes in Chiplun watershed

Sr. No.	Depth Class (cm)	Area (ha)	TGA (%)
1	Shallow (< 25) cm	5908.41	70.97
2	Moderate (25 - 50) cm	1468.94	17.65
3	Moderately Deep (50 - 75)	328.44	3.95
4	Deep (75 - 100)	8.25	0.10
5	Very Deep (> 100)	297.01	3.57
6	Habitation	146.56	1.76
7	Waterbody	167.15	2.01
	Total	8324.77	100.00

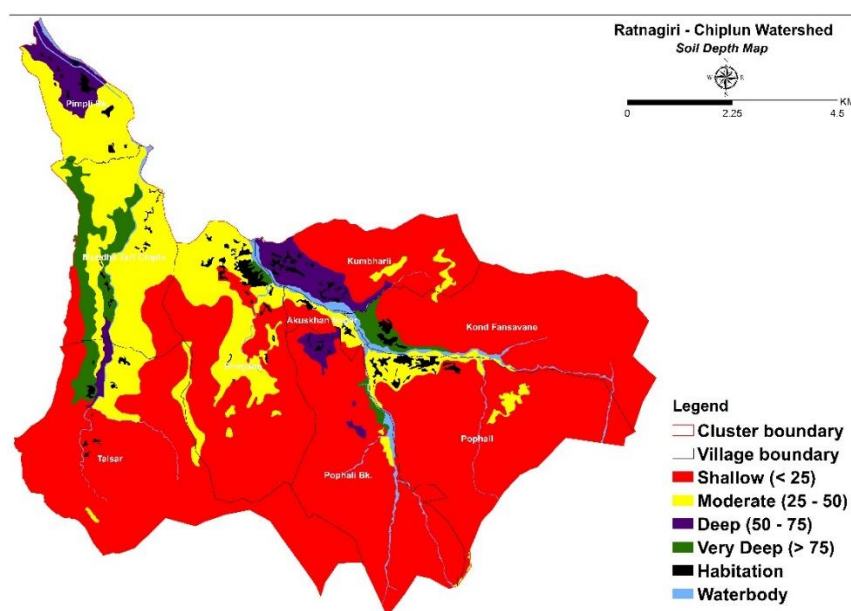


Fig. 4.7: Depth map of Chiplun watershed

4.5.4 Surface texture

Soil texture plays a vital role in agriculture by directly influencing water retention, root development, and nutrient availability to plants. Soils with a balanced texture, such as loam, provide optimal conditions for plant growth by allowing good water drainage while retaining enough moisture for the roots. Clay soils, though rich in nutrients, can become compacted and poorly drained, while sandy soils may drain too quickly and lack essential nutrients. Understanding soil texture helps farmers make informed decisions about irrigation practices, crop selection, and the appropriate use of soil amendments. The texture of the watershed area soils was predominantly clayey, with clay and clay loam together comprising 95% of the watershed soils (Table 4.13, Fig. 4.8). Based on the texture, the soils of the watershed, particularly the moderately deep soils are expected to be fertile and produce good crops.

Table 4.13. Soil texture distribution in Chiplun watershed

Sr. No.	Texture	Area (ha)	TGA (%)
1	Clay	2429.9	29.2
2	Clay Loam	5547.7	66.6
3	Silty Clay	32.1	0.4
4	Silty Clay Loam	1.4	0.0
5	Habitation	146.6	1.8
6	Waterbody	167.2	2.0
	Total	8324.8	100.0

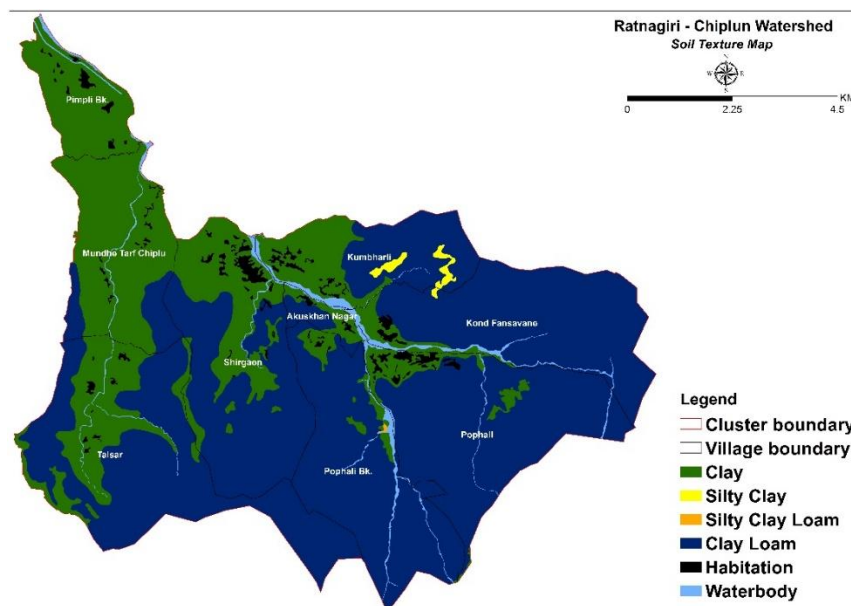


Fig. 4.8: Soil texture map of Chiplun watershed

4.5.5 Soil reaction

Soil reaction or pH, a measure of acidity or alkalinity, is crucial for plant health and growth because it directly impacts nutrient availability, microbial activity, and overall soil health, influencing crop yields and suitability. The pH value also helps to determine the quantity of various amendments to be added to the soils for ameliorating acidity or alkalinity. The soils of the watershed are acidic, with pH ranging from 5.0 to 6.5 (Table 4.14, Fig. 4.9). The acidic soils with moderate soils are expected to be fertile.

Table 4.14. Soil pH distribution in Chiplun watershed

Sr. No.	Soil pH	Area (ha)	TGA (%)
1	Moderately Acidic (5.0 - 6.0)	5841.6	70.2
2	Slightly Acidic (6.0 - 6.5)	2169.5	26.1
3	Habitation	146.6	1.8
4	Waterbody	167.2	2.0
	Total	8324.8	100.0

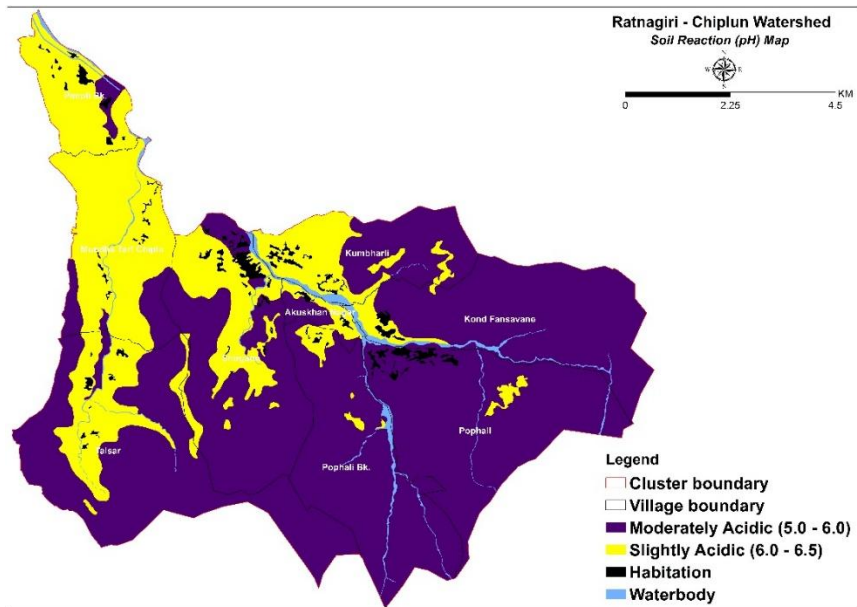


Fig. 4.9: Soil pH map of Chiplun watershed

4.5.6 Soil salinity

The EC of the soils of the watershed were well within the permissible limit of salinity (Table 4.15, Fig 4.10) and will not affect to crop growth.

Table 4.15. Soil salinity classes in Chiplun watershed

Sr. No.	Electrical conductivity (dSm ⁻¹)	Area (ha)	TGA (%)
1	Normal (0 - 1)	8011.1	96.2
2	Habitation	146.6	1.8
3	Waterbody	167.2	2.0
	Total	8324.8	100.0

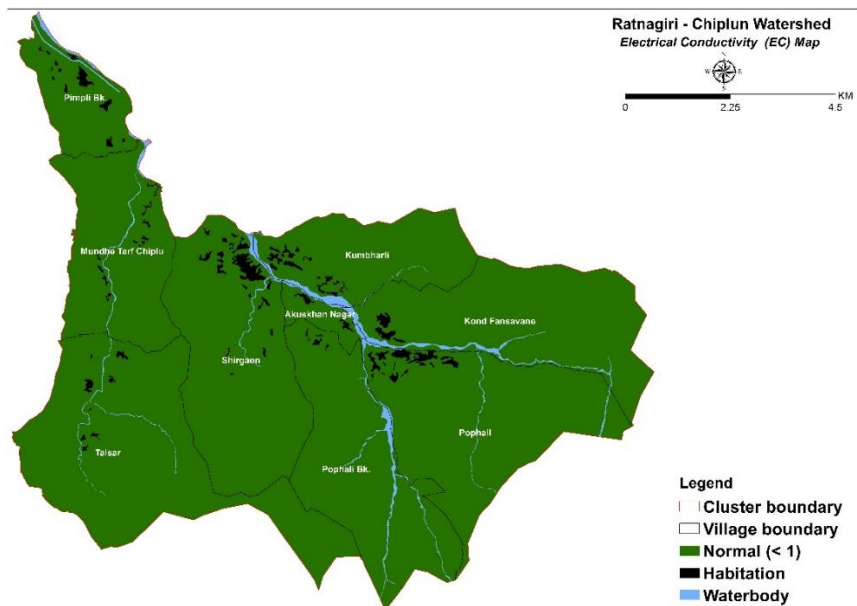


Fig. 4.10: Soil EC map of Chiplun watershed

4.5.8 Soil organic carbon

The soil organic carbon (SOC) is a critical component to several ecological processes and is primarily derived from plant decomposition and animal residues, like leaves, roots, and dead organisms. It serves as a significant indicator of soil health and fertility. The SOC influences the soil's ability to retain and release essential nutrients, regulate water-holding capacity and support microbial activity. It also acts as a reservoir for carbon sequestration, helping mitigate climate change by removing carbon dioxide from the atmosphere.

Monitoring SOC levels is crucial for sustainable land use and management. The loss of SOC through practices like deforestation and intensive agriculture can result in degraded soils leading to reduced agricultural productivity and enhanced greenhouse gas emissions. Promotion of climate-smart practices that increase SOC can ensure healthier and productive soils. Soils of Ratnagiri-Chiplun watershed exhibit very high SOC content, which can be inferred from Table 4.16 and Fig. 4.11. This is also indicated by the loamy texture prevalent in the watershed. The deep valley soils are expected to be fertile and support field crops.

Table 4.16 Soil organic carbon status of Chiplun watershed

Sr. No.	Organic carbon (%)	Area (ha)	TGA (%)
1	Moderately High (0.61 - 0.80)	106.2	1.3
2	Very High (> 1.00)	7904.8	95.0
3	Habitation	146.6	1.8
4	Waterbody	167.2	2.0
	Total	8324.8	100.0

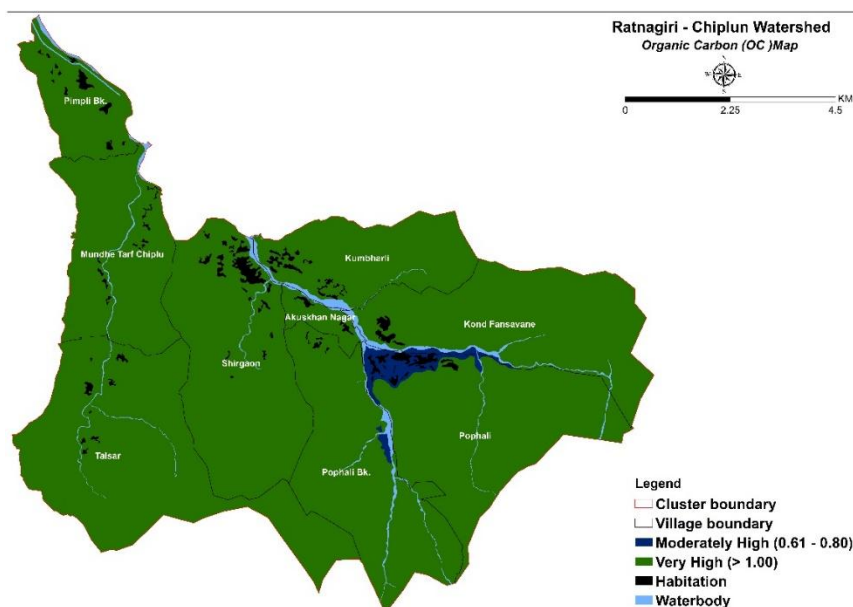


Fig. 4.11: Soil organic carbon map of Chiplun watershed

4.5.9 Available nitrogen (N)

Available nitrogen content in soils is crucial as it forms the primary building block for plant growth, is essential for producing proteins, amino acids, and chlorophyll to support photosynthesis, plant health and yield. The agricultural soils of watershed are inherently deficient in available N content. As seen from Table 4.17 and Fig. 4.12. More than 85% of the soils of Ratnagiri-Chiplun watershed area are inherently low in available N ($<280 \text{ kg ha}^{-1}$), which necessitates external application. Since, nitrogen is highly prone to leaching in high rainfall areas, it is advocated to apply the slow-release nitrogenous fertilizers as per crop needs to maximize yields in the watershed area.

Table 4.17: Available N content in soils of Chiplun watershed

Sr. No.	Available N (kg ha^{-1})	Area (ha)	TGA (%)
1	Low (141 - 280)	7459.7	89.6
2	Medium (281 - 420)	551.3	6.6
3	Habitation	146.6	1.8
4	Waterbody	167.2	2.0
	Total	8324.8	100.0

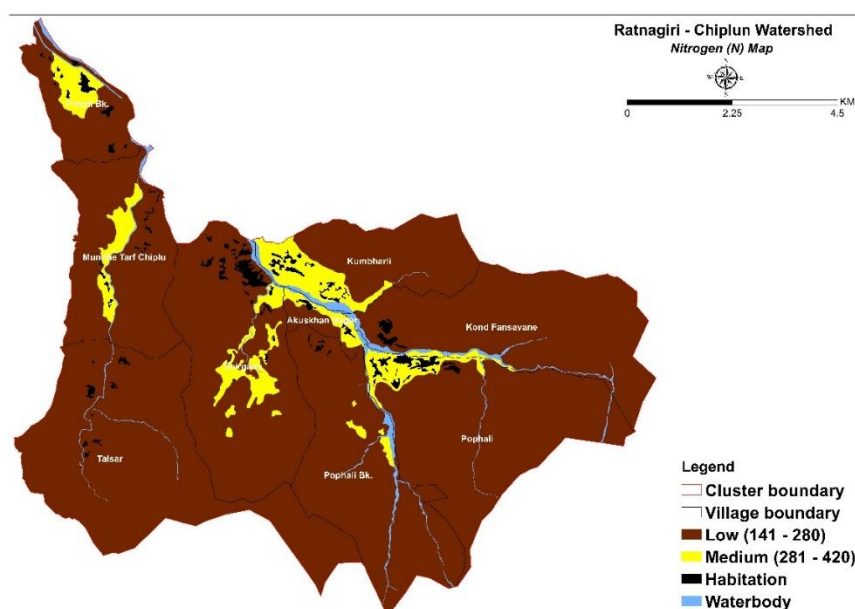


Fig. 4.12: Available soil nitrogen map of Chiplun watershed

4.5.10 Available Phosphorous (P)

Among the three major nutrients, phosphorus (P) plays an important role to complete the life cycle of a plant; its functions start right from the stimulation of root growth to proper seed filling and seed setting. It also plays a vital role in photosynthesis, carbohydrate breakdown and transfer of energy in the form of ATP and ADP compounds in various metabolic processes. Similar to nitrogen, available P content of the agricultural soils of the watershed (Table 4.18, Fig. 4.13) ranged is very low ($<15 \text{ kg ha}^{-1}$) the arable lands of the watershed, which could be attributed to the high fixation of P under low pH conditions.

Further, the very low to low status indicates that the farmers are not adequately applying phosphatic fertilizers to soils.

Table 4.18: Available P content in soils of Chiplun watershed

Sr. No.	Available P (kg ha ⁻¹)	Area (ha)	TGA (%)
1	Very Low (< 15)	8011.1	96.2
2	Habitation	146.6	1.8
3	Waterbody	167.2	2.0
	Total	8324.8	100.0

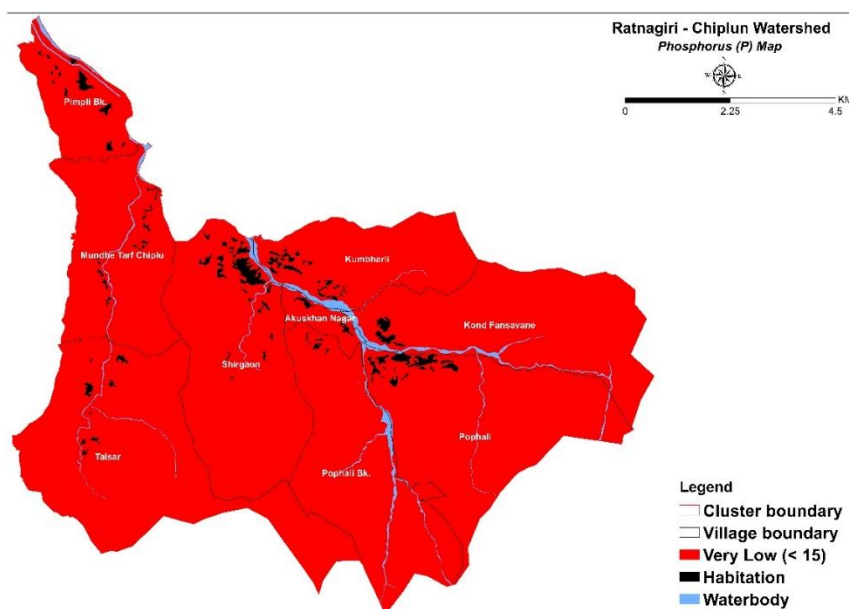


Fig.4.13: Available soil Phosphorus map of Chiplun watershed

4.5.11 Available Potassium (K)

Exchangeable or available K is widely used to evaluate the soil K status and to predict the crop K requirements. Six classes of available K (Table 4.19, Fig. 4.14) were observed in the watershed soils. About 85% of the watershed area exhibits a low K content (below 180 kg ha⁻¹ necessitating external addition through potassic fertilizers.

Table 4.19: Available K content of soils of Chiplun watershed

Sr. No.	Available K (kg ha ⁻¹)	Area (ha)	TGA (%)
1	Very Low (< 120)	1256.5	15.1
2	Low (121 - 180)	5753.9	69.1
3	Medium (181 - 240)	324.9	3.9
4	Moderately High (241 - 300)	206.6	2.5
5	High (301 - 360)	58.3	0.7
6	Very High (> 360)	410.8	4.9
7	Habitation	146.6	1.8
8	Waterbody	167.2	2.0
	Total	8324.8	100.0

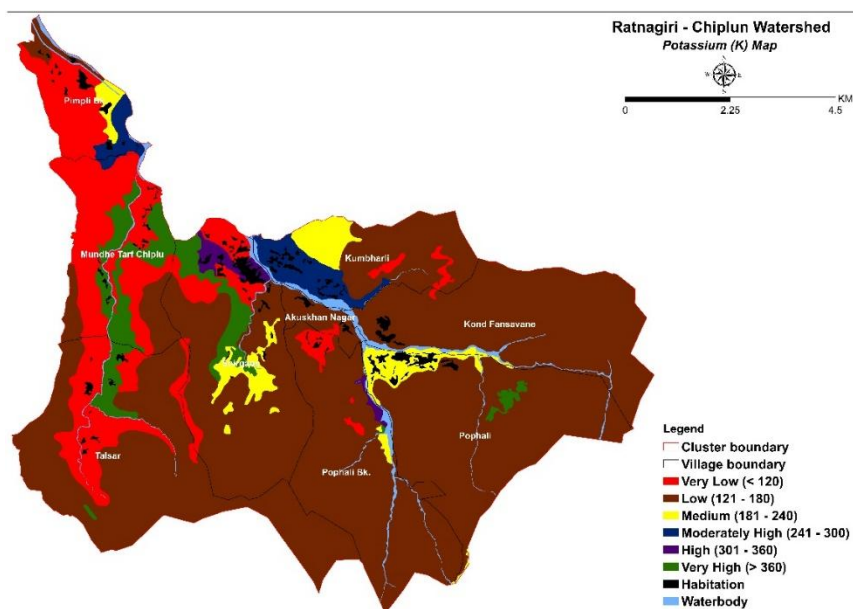


Fig. 4.14: Available soil Potassium map of Chiplun watershed

4.5.12 Micronutrient status of soils

Although required in small quantities, the DTPA-extractable micronutrients, are involved in vital plant processes like photosynthesis, enzyme activation, and nitrogen fixation. Deficiencies in any of these micronutrients can lead to poor plant development, reduced yields, and lower quality crops. Table 4.20-4.23, and Fig. 4.15- 4.18 indicate that a majority of the watershed soils are rich in bioavailable micronutrients, due to the low soil pH and also to the possible organic-micronutrient chelation in the soils. However, Zn deficiency was observed in a few pockets, and needs to be externally applied to crops.

Table 4.20: Available Fe content in the soils of Chiplun watershed

Sr. No.	Available Fe (mg kg ⁻¹)	Area (ha)	TGA (%)
1	Very High (> 10.5)	8011.1	96.2
2	Habitation	146.6	1.8
3	Waterbody	167.2	2.0
	Total	8324.8	100.0

Table 4.21: Available Mn content in the soils of Chiplun watershed

Sr. No.	Available Mn (mg kg ⁻¹)	Area (ha)	TGA (%)
1	Very High (> 9.0)	8011.1	96.2
2	Habitation	146.6	1.8
3	Waterbody	167.2	2.0
	Total	8324.8	100.0

Table 4.22: Available Cu content in the soils of Chiplun watershed

Sr. No.	Available Cu (mg kg ⁻¹)	Area (ha)	TGA (%)
1	Very High (> 1.0)	8011.1	96.2
2	Habitation	146.6	1.8
3	Waterbody	167.2	2.0
	Total	8324.8	100.0

Table 4.23: Available Zn content in the soils of Chiplun watershed

Sr. No.	Available Zn (mg kg ⁻¹)	Area (ha)	TGA (%)
1	Low (0.3 - 0.6)	619.4	7.4
2	Medium (0.6 - 0.9)	719.2	8.6
3	Moderately High (0.9 - 1.2)	5959.9	71.6
4	High (1.2 - 1.8)	712.5	8.6
5	Habitation	146.6	1.8
6	Waterbody	167.2	2.0
	Total	8324.8	100.0

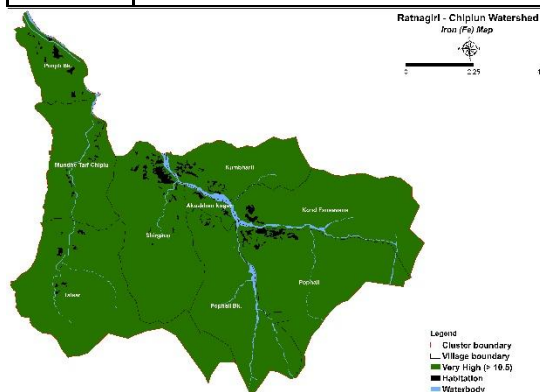


Fig. 4.15: DTPA-extractable soil Fe map of Chiplun watershed

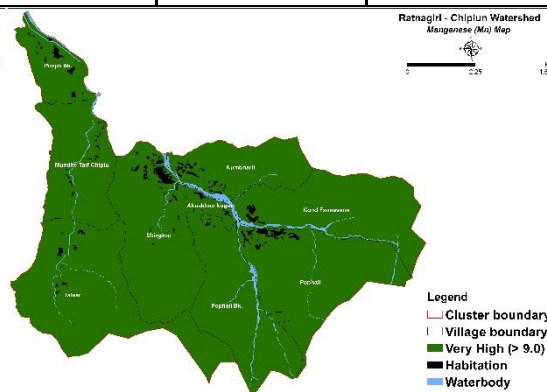


Fig. 4.16: DTPA-extractable soil Mn map of Chiplun watershed

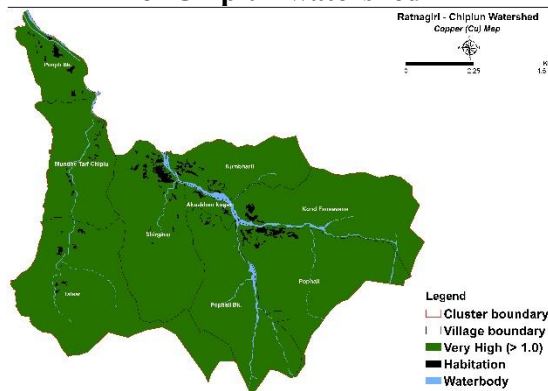


Fig. 4.17: DTPA-extractable soil Cu map of Chiplun watershed

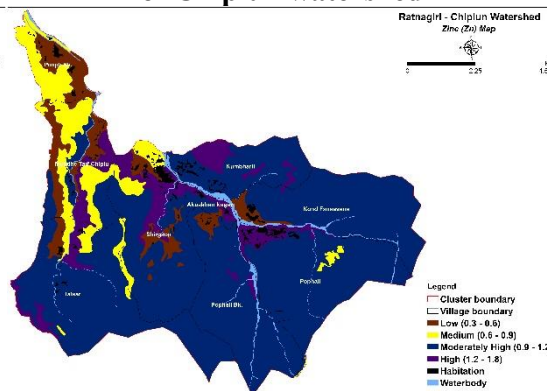


Fig. 4.18: DTPA-extractable soil Zn map of Chiplun watershed

4.6 Surface Runoff

Surface runoff is an essential component for understanding water dynamics in the Chiplun Taluka cluster watershed. The region receives an average annual rainfall of 1851.2 mm over the period 2014-2024, with precipitation concentrated mainly during the monsoon months. The watershed encompasses diverse terrain, from low-lying river valleys to steep hilly slopes. While valley areas and riverside settlements generally have sufficient water due to natural recharge and proximity to the Vashishti River, the upland and hilly regions face challenges such as rapid surface runoff, soil erosion, and limited infiltration.

To quantify these effects, surface runoff was estimated using the SCS-Curve Number (CN) method, incorporating observed rainfall data, verified land use, and field-verified soil characteristics. This method provides a potential runoff estimate, which is

critical for designing water harvesting and soil conservation interventions, and understanding how much rainfall contributes to surface flow versus infiltration.

Rainfall data for the period 2014-2024 were compiled from the IMD station. Land use and soil types were verified through field surveys, satellite imagery, and farmer consultations. CN values were assigned according to the combination of soil type, land use, and slope class. The estimated runoff for each monsoon season was adjusted for antecedent moisture conditions. Peak runoff is observed in July and August, when rainfall intensity is highest and soils are already near saturation.

Paddy cultivation dominates the gentle slopes, which contributes to relatively high surface runoff when analyzed through the SCS-Curve Number (CN) method. Paddy fields were assigned a high CN value (CN=95) because these plots are intentionally kept saturated or ponded during the crop growth period, reducing their capacity to absorb additional rainfall. According to the SCS-CN methodology, this results in a high potential runoff estimate, as the approach assumes uniform rainfall distribution and immediate response from the entire catchment, without factoring in local field practices. In reality, however, surface runoff is much lower than these theoretical estimates. Paddy plots are typically surrounded by small bunds and field boundaries that temporarily retain water, promoting gradual infiltration and percolation into the soil profile. In such landscapes, a significant portion of rainfall contributes to soil moisture replenishment and subsurface flow, rather than direct surface discharge. Additionally, a portion of rainfall is used by crops during the growing period, which further reduces the volume available as runoff. Considering that the study area consists of small, scattered agricultural catchments, complete conversion of rainfall into surface runoff is hydrologically unrealistic, even during heavy monsoon events.

The estimated runoff values therefore represent the potential maximum rather than actual flows observed in the field. Were these maximum values to occur fully, it would imply localized flooding within small cultivated patches, which does not happen under real conditions. The discrepancy arises largely due to on-site retention, soil infiltration, and temporary water storage, which together moderate the hydrological response of the landscape.

Thus, while the SCS-CN method provides a useful upper bound for assessing runoff potential and guiding the design of water conservation structures, interpretations must account for field-level practices, crop type, bunding, and soil permeability. This ensures that watershed interventions are properly scaled, economically viable, and hydrologically balanced, capturing excess runoff effectively without overdesigning storage or drainage systems.

Table 4.24: Details of Monthly (June-Oct) runoff (mm) for the period 2014-2024

Year/Month	June		July		Aug		Sept		Oct	
	Rainfall (mm)	Runoff (mm)	Rainfall (mm)	Runoff (mm)	Rainfall (mm)	Runoff (mm)	Rainfall (mm)	Runoff (mm)	Rainfall (mm)	Runoff (mm)
2014	148.0	0.0	767.1	178.5	411.6	13.7	217.1	5.4	88.0	0.0
2015	467.0	135.2	179.8	0.0	134.8	0.0	112.7	0.0	88.8	0.0
2016	218.9	0.6	744.7	175.2	586.7	149.5	198.7	7.6	27.4	0.0
2017	257.3	11.2	641.8	112.4	252.8	4.2	336.8	17.7	110.0	0.0
2018	291.3	17.2	714.0	137.6	327.1	3.6	90.6	0.0	55.1	0.0
2019	232.6	15.2	1008.8	314.8	921.8	367.7	479.3	53.2	329.0	50.8
2020	314.6	21.9	284.0	1.4	798.6	191.1	156.9	0.0	271.9	46.8
2021	545.8	113.4	947.2	382.5	128.7	0.0	257.8	3.9	109.9	0.0
2022	103.9	0.0	694.9	140.5	485.2	66.9	270.4	5.4	259.4	6.8
2023	168.8	4.8	633.2	97.6	175.6	1.2	153.5	0.0	69.1	10.0
2024	264.2	0.0	1018.5	242.6	457.8	64.4	203.5	4.9	125.1	0.1
Average	273.9	29.0	694.0	162.1	425.5	78.4	225.2	8.9	139.4	10.4

Table 4.24 presents the monthly runoff data for June to October (2014-2024) in Chiplun Taluka, showing a distinct seasonal pattern. Runoff is minimal in June (29.0 mm) and October (10.4 mm), as early and late rains are largely absorbed by dry soils or lost to evaporation. The highest runoff occurs in July (162.1 mm), remaining significant in August (78.4 mm), with these two months together contributing approximately 83% of the total seasonal runoff. This clearly highlights the importance of timely water harvesting and soil conservation measures during the peak monsoon period. Inter-annual variability is evident, with 2019 recording the highest runoff due to extreme rainfall, while 2023 experienced the lowest despite moderate precipitation, indicating that both rainfall intensity and timing strongly influence runoff dynamics.

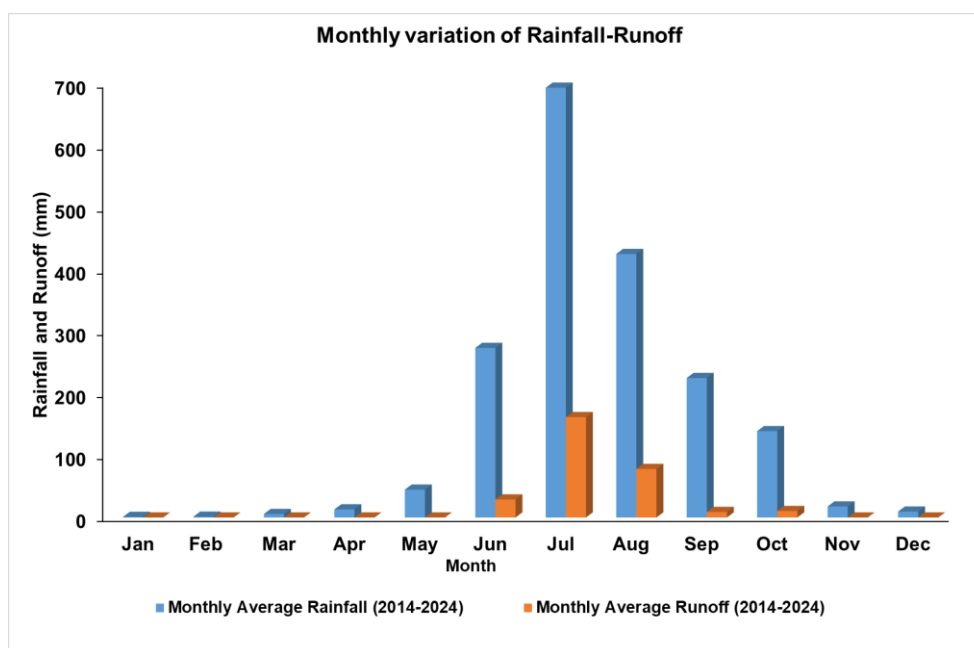


Fig. 4.19: Monthly variation of rainfall-runoff in Chiplun watershed

Table 4.25 Relationship between rainfall and runoff

Year	Rainfall (mm)	Runoff (mm)	No. of Runoff Events	Runoff (%)
2014	1796.4	197.6	24	11.0
2015	1086.8	135.2	5	12.4
2016	1792.2	332.9	26	18.6
2017	1667.9	145.4	23	8.7
2018	1546.2	158.3	21	10.2
2019	2996.7	801.8	40	26.8
2020	1893.2	261.1	21	13.8
2021	2333.9	499.9	23	21.4
2022	1835.5	219.6	25	12.0
2023	1264.3	113.5	19	9.0
2024	2149.6	312.0	29	14.5
Average	1851.2	288.8	23	15.6

Table 4.25 further elaborates the relationship between annual rainfall and runoff. The watershed receives an average of 1851.2 mm of rainfall annually, generating 288.8 mm of runoff, which is about 15.6% of total rainfall. The number of runoff events varies widely, from 5 in 2015 to 40 in 2019, showing that some years' experience frequent small runoff events, while others are dominated by fewer, high-intensity events. Years like 2019 and 2021, with high rainfall concentration, produced the highest runoff percentages (26.8% and 21.4%, respectively), whereas years with more evenly distributed or lower rainfall, such as 2017 and 2023, had the lowest runoff percentages (8.7% and 9.0%, respectively). This emphasizes that runoff is governed more by rainfall intensity and concentration than by total annual precipitation.

Overall, the analysis confirms that surface runoff in Chiplun Taluka is highly seasonal and strongly influenced by rainfall distribution. While only a portion of the rainfall averaging 288.8 mm or 15.6% is converted into surface runoff, the remainder infiltrates into the soil, supports crop water requirements, or is lost to evaporation. The concentration of runoff in July and August underscores the necessity of designing water harvesting and soil conservation measures that can effectively capture and utilize peak flows. Additionally, the inter-annual variability in runoff highlights the need for flexible and adaptive watershed interventions that can accommodate both extreme and moderate rainfall years. This information provides critical guidance for planning targeted water management structures, improving soil moisture retention, and enhancing groundwater recharge across the Chiplun Taluka watershed.

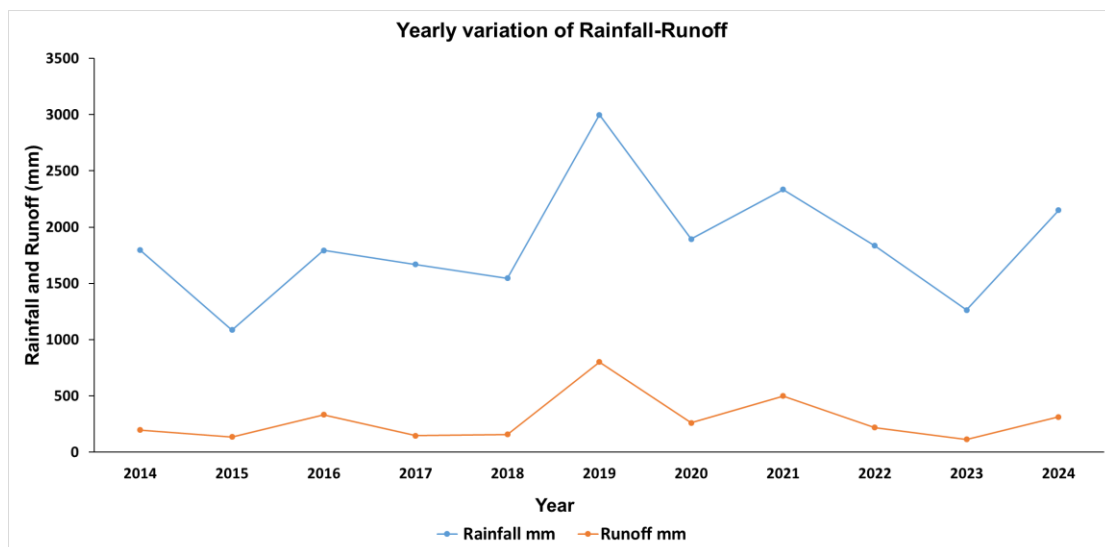


Fig. 4.20: Yearly variation of rainfall-runoff in Chiplun watershed

4.7 Mapping of Groundwater Potential Zones

Groundwater is a vital resource in Chiplun Taluka, supporting drinking water, domestic needs, and irrigation, particularly in hilly areas and zones without reliable surface water. Although the region receives a high annual rainfall of 1851.2 mm, groundwater availability is highly uneven due to variations in slope, soil depth, geology, and recharge processes. These disparities make it essential to map and understand areas with different groundwater potential for sustainable watershed management.

To address this, a detailed Groundwater Potential Zonation (GWPZ) map was developed for the cluster of 9 villages in Chiplun Taluka. The GWPZ map dividing the watershed into five categories: Very Good, Good, Moderate, Poor, and Very Poor.

The results indicate that 27.5% of the watershed falls under the “Very Poor” category, representing steep, rocky slopes with minimal soil cover and low groundwater recharge potential. “Poor” zones constitute 38.8%, characterized by limited infiltration and higher surface runoff. The “Moderate” potential zone covers 17.9% of the area, corresponding to undulating terrain with average recharge capacity. Only 9% and 6.8% of the watershed are categorized as “Good” and “Very good” respectively, highlighting the limited extent of areas suitable for high groundwater yield. Overall, approximately 84.2% of the landscape ranges from moderate to very poor potential, emphasizing the necessity for focused groundwater recharge and watershed management interventions. This detailed zonation is a crucial tool for planning watershed development interventions. It guides the design and placement of groundwater recharge structures, soil and moisture conservation measures, and other natural resource management activities under programs like PMKSY-WDC 2.0. By prioritizing areas with poor and very poor potential, planners can enhance groundwater availability, improve irrigation reliability, and support sustainable agriculture. Simultaneously, zones with higher potential can be managed to optimize recharge without overexploitation. The GWPZ thus provides actionable insights for ensuring long-term

water security, supporting livelihoods, and promoting resilient watershed management in Chiplun Taluka.

Given the intricate hydrogeological conditions of the Konkan region, this integrated assessment is a crucial tool for sustainable groundwater management. It supports the effective utilization and augmentation of groundwater resources across the Chiplun Taluka cluster, ensuring long-term water security for domestic, agricultural, and ecological purposes, and contributing to the overall socio-economic development of the region.

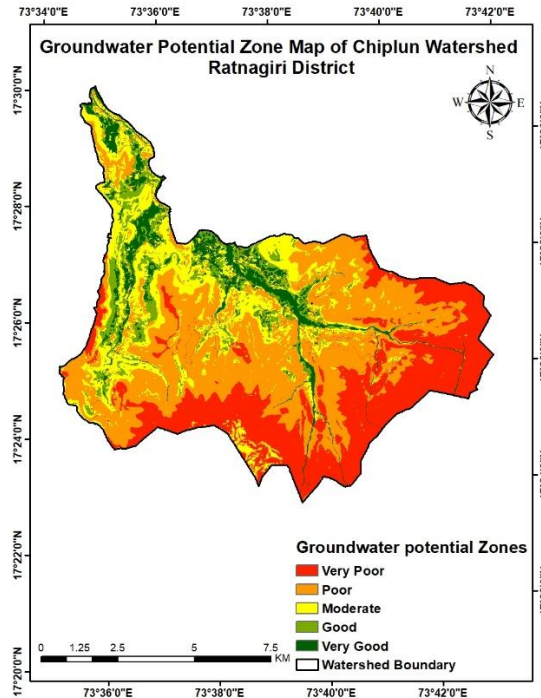


Fig. 4.21. Ground water potential zones in Chiplun watershed

4.8 Evaluation of Soil-Site Suitability for Crops

Crop growth primarily depends on soil and climate. Evaluating soil-site suitability for crops requires a careful assessment of key soil attributes including soil depth, texture, fertility status, and drainage conditions. This is important because a soil's physicochemical properties and the crop's micro-environment directly influence the availability of water and essential nutrients. The evaluation process helps in the interpretation of soil maps to assess their suitability for various field and horticultural crops, thereby supporting the development of scientific land-use plans for watershed management.

Soil-site suitability was evaluated by assessing limitations across five key categories: climate (c), topography (t), wetness (w), soil fertility (f), and physical soil constraints (s) using a grading scale from 0 to 4, where Grade 0 signifies no limitation and optimal conditions; Grade 1 denotes a slight, nearly optimal limitation; Grade 2 indicates a moderate limitation with noticeable negative effects on crop performance; Grade 3 represents a severe limitation making the land uneconomical; and Grade 4 signifies a very severe limitation where crop yields are below economically viable levels, rendering the

land unsuitable for the proposed agricultural use.

To assess the suitability of the land for agricultural crops and other uses, an evaluation was conducted considering a range of soil-site parameters grouped into several key categories: climatic variables (rainfall and temperature), topographic features (slope, landscape position, and susceptibility to erosion), wetness conditions (drainage, risk of flooding, and soil aeration), physical soil properties (texture, soil depth, structure, and available soil moisture), fertility attributes (soil pH, nutrient availability, organic matter content and cation exchange capacity). By integrating these multiple parameters, the watershed area was evaluated to determine its suitability for crops that are either commonly cultivated or possess the potential for introduction.

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The suitability of soils for crop cultivation was assessed using the criteria proposed by Naidu et al. (2006), employing a hierarchical land evaluation classification system based on land utilization types with a structure of orders, classes, subclasses, and units. This system recognizes two primary orders: Suitable (S), which is subdivided into three classes S1 (High suitability), S2 (Moderate suitability), and S3 (Marginal suitability) and Not Suitable (N),

Soil-site suitability was evaluated by assessing limitations across five key categories: climate (c), topography (t), wetness (w), soil fertility (f), and physical soil constraints (s) using a grading scale from 0 to 4, where Grade 0 signifies no limitation and optimal conditions; Grade 1 denotes a slight, nearly optimal limitation; Grade 2 indicates a moderate limitation with noticeable negative effects on crop performance; Grade 3 represents a severe limitation making the land uneconomical; and Grade 4 signifies a very severe limitation where crop yields are below economically viable levels, rendering the land unsuitable for the proposed agricultural use.

To assess the suitability of the land for agricultural crops and other uses, an evaluation was conducted considering a range of soil-site parameters grouped into several key categories: climatic variables (rainfall and temperature), topographic features (slope, landscape position, and susceptibility to erosion), wetness conditions (drainage, risk of flooding, and soil aeration), physical soil properties (texture, soil depth, structure, and available soil moisture), fertility attributes (soil pH, nutrient availability, organic matter content and cation exchange capacity). By integrating these multiple parameters, the watershed area was evaluated to determine its suitability for crops that are either commonly cultivated or possess the potential for introduction.

Due to the constraints of soil depth and low available macronutrients, choice of crops is limited in the watershed. Only a few crops, particularly fruit/plantation crops are discussed in this document.

4.8.1 Soil-Site Suitability for Rice Cultivation

The soil site suitability carried out for the paddy crop is presented in Table 4.26 and figure 4.22. It suggests that rice is highly suitable (S1) for cultivation in 283.8 ha (3.4%) of the watershed, as this region has favorable temperature and rainfall for cultivation. Moderately and marginally suitable area for cultivation constitutes another 1900 ha (23%). This area is constrained by land having a gentle slope and shallow soil. Rice is Not suitable (N) for cultivation in the highly slopy areas has shallow soil, comprising 70% of the area.

Table 4.26 Area under suitability sub-classes for Rice cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Highly Suitable (S1)	283.8	3.4
2	Moderately Suitable (S2)	142.1	1.7
3	Marginally Suitable (S3)	1798.8	21.6
4	Not Suitable (N)	5786.3	69.5
5	Habitation	146.6	1.8
6	Waterbody	167.2	2.0
	Total	8324.8	100.0

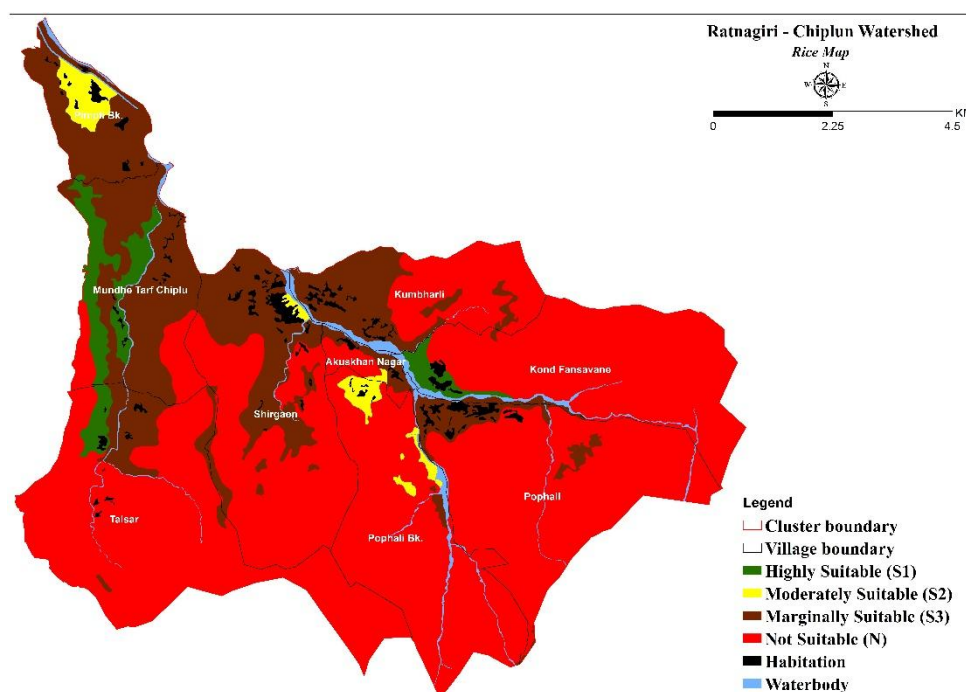


Fig. 4.22 Soil site suitability map for Rice cultivation

4.8.2 Soil-Site Suitability for Mango Cultivation

The spatial distribution of suitability classes in respect of mango is presented in Table 4.27 and Fig. 4.23. The results indicate that a major proportion of the total geographical area (TGA) is classified as not suitable (N) for mango cultivation, covering more than 7705.8

ha (92.6%) of the watershed. Approx 300 ha (4%) of the watershed area is under the moderately (S2) and marginally (S3) suitable category owing to limitations in soil depth. However, mango (var. Alphonso) is cultivated in major parts of Ratnagiri district, suggesting that mango should be cultivated with caution in limited portions of the watershed by following management practices.

Table 4.27 Area under suitability sub-classes for Mango cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Moderately Suitable (S2)	160.7	1.9
2	Marginally Suitable (S3)	144.6	1.7
3	Not Suitable (N)	7705.8	92.6
4	Habitation	146.6	1.8
5	Waterbody	167.2	2.0
	Total	8324.8	100.0

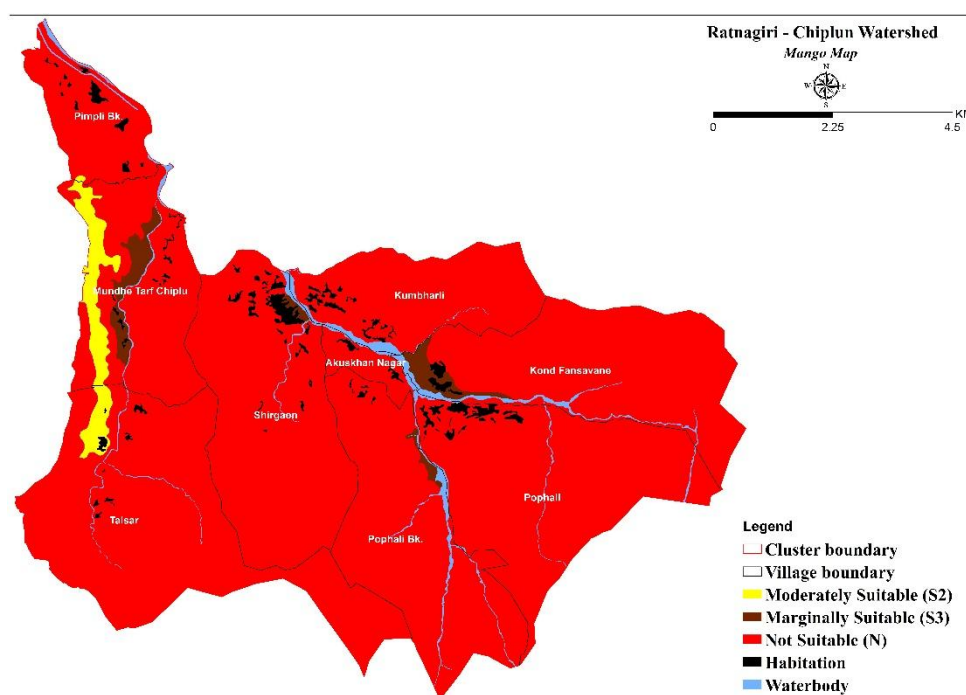


Fig. 4.23 Soil site suitability map for Mango cultivation

4.8.3 Soil-Site Suitability for Cashewnut Cultivation

The soils of the watershed were evaluated for Cashewnut cultivation based on crop-specific requirements. The distribution of suitability classes is presented in Table 4.28 and Fig. 4.24. The results indicate that about 7.5% of the watershed area provides favorable soil and site conditions for optimal crop growth and is suitable (S2 and S3) for Cashewnut due to reasonably acceptable soil texture, depth and drainage, while also indicating moderate to

severe limitations related to soil and terrain parameters that may restrict yield potential unless appropriate management practices are adopted.

Furthermore, about 88% of the watershed area is not suitable (N) for cashew cultivation due to severe soil and site constraints.

Table 4.28 Area under suitability sub-classes for Cashewnut cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Moderately Suitable (S2)	297.0	3.6
2	Marginally Suitable (S3)	336.7	4.0
3	Not Suitable (N)	7377.4	88.6
4	Habitation	146.6	1.8
5	Waterbody	167.2	2.0
	Total	8324.8	100.0

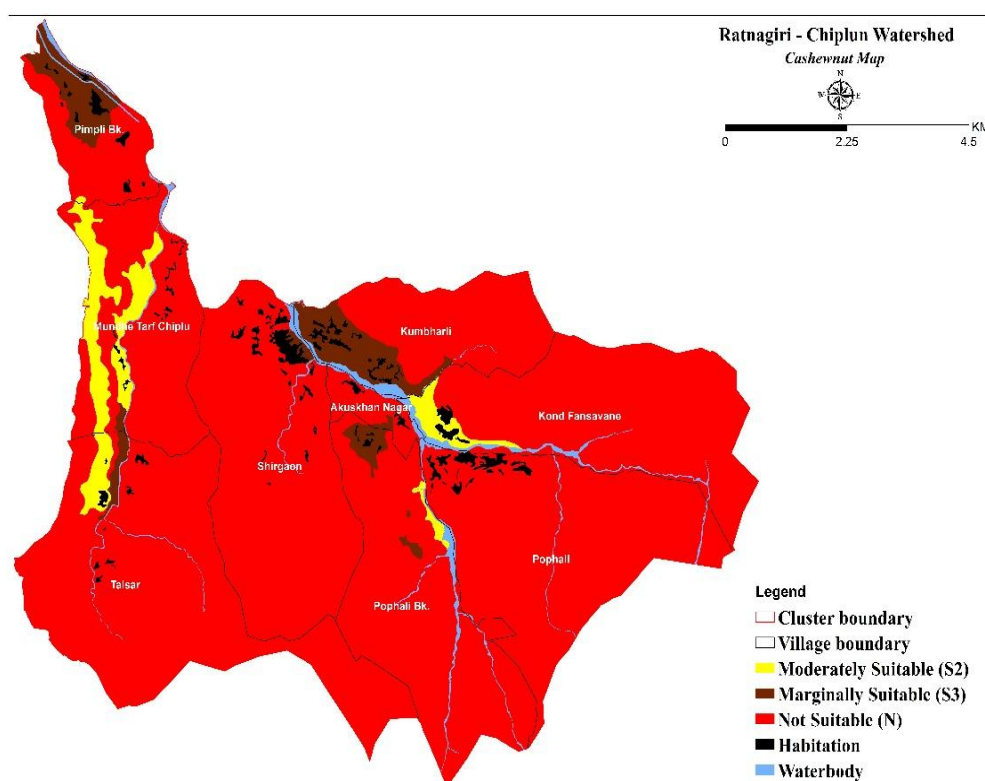


Fig. 4.24 Soil site suitability map for Cashewnut cultivation

4.8.4 Soil-Site Suitability for Jackfruit Cultivation

The results indicate that about 4% of the watershed area is only marginally suitable (S3) for jackfruit (Table 4.29, Fig. 4.25), reflecting also indicating moderate to severe limitations related to soil depth and terrain parameters that may restrict yield potential unless appropriate management practices are adopted. About 93% of the watershed area is not suitable (N) for cashew cultivation due to severe soil and site constraints.

Table 4.29 Area under suitability sub-classes for Jackfruit cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Marginally Suitable (S3)	305.3	3.7
2	Not Suitable (N)	7705.8	92.6
3	Habitation	146.6	1.8
4	Waterbody	167.2	2.0
	Total	8324.8	100.0

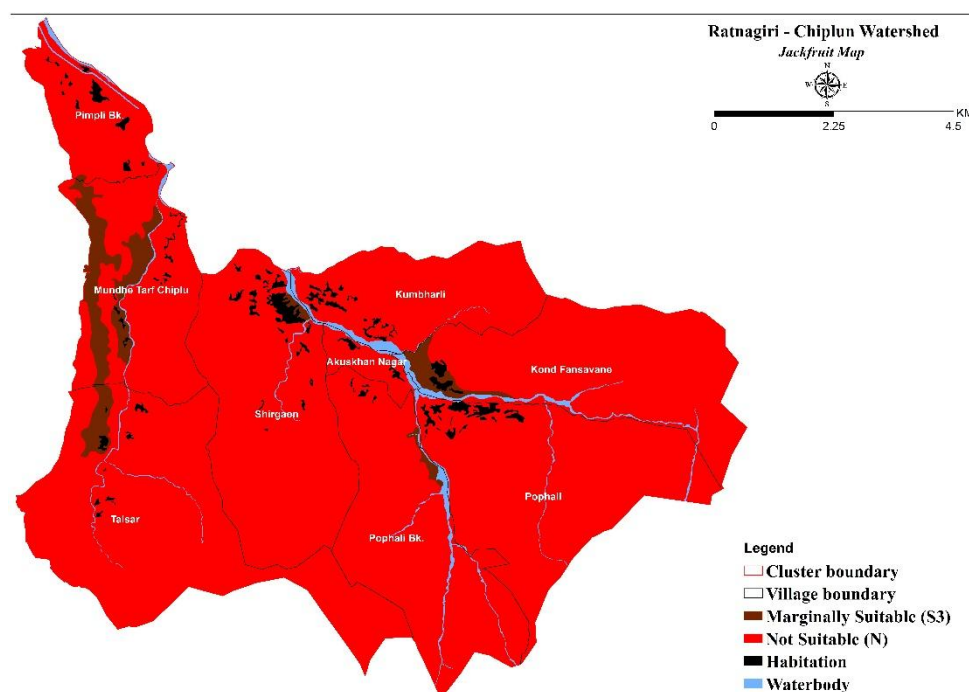


Fig. 4.25 Soil site suitability map for Jackfruit cultivation

4.8.5 Soil-Site Suitability for Arecanut Cultivation

Similar to mango, major proportion of the total geographical area (TGA) is classified as not suitable (N) for Arecanut cultivation, covering about 88.6% of the watershed. About 7.7% of the watershed area is under the moderately (S2) and marginally (S3) suitable category owing to limitations in soil depth., as shown in Table 4.30 and figure 4.26.

Table 4.30 Area under suitability sub-classes for Arecanut cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Moderately Suitable (S2)	305.3	3.7
2	Marginally Suitable (S3)	328.4	4.0
3	Not Suitable (N)	7377.4	88.6
4	Habitation	146.6	1.8
5	Waterbody	167.2	2.0
	Total	8324.8	100.0

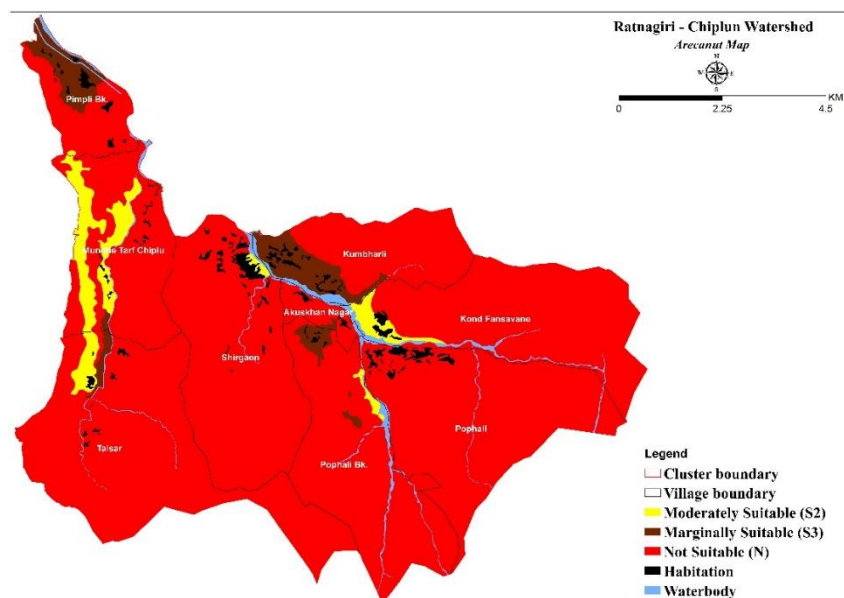


Fig. 4.26 Soil site suitability map for Arecanut cultivation

4.8.6 Soil-Site Suitability for Coconut Cultivation

Site-suitability for coconut is similar to that of Arecanut in terms of conditions favouring or antagonistic to its cultivation. About 89% of the watershed is determined to be Not Suitable for cultivation, while it is suitable in about 7% of the area (Table 4.31, Fig. 4.27).

Table 4.31 Area under suitability sub-classes for Coconut cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Moderately Suitable (S2)	305.3	3.7
2	Marginally Suitable (S3)	328.4	4.0
3	Not Suitable (N)	7377.4	88.6
4	Habitation	146.6	1.8
5	Waterbody	167.2	2.0
Total		8324.8	100.0

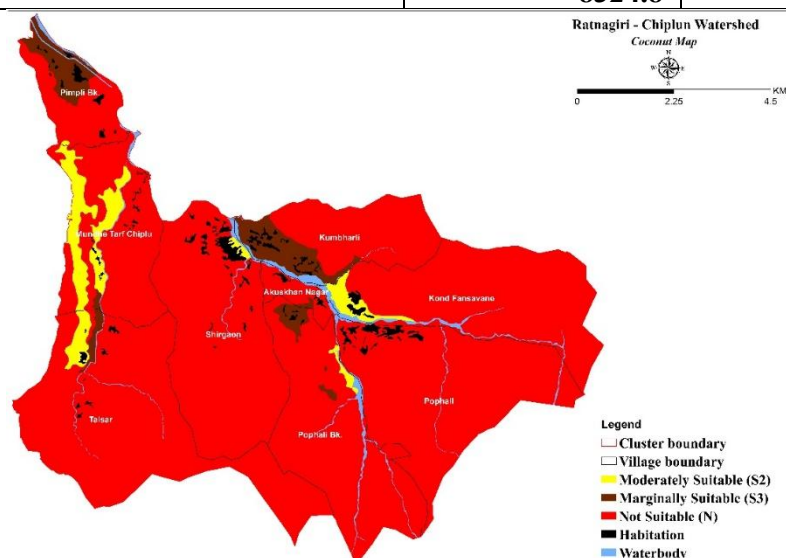


Fig. 4.27 Soil site suitability map for Coconut cultivation

4.9 Soil and Water Conservation measures

Soil and Water Conservation (SWC) refers to the management and use of soil and water resources in a way that prevents their loss, maintains fertility, enhances water availability, and supports sustainable land use. SWC practices include engineering, vegetative, and management interventions such as terracing, bunding, afforestation, silt detention structures, and in-situ moisture conservation. These measures are crucial for maintaining ecological balance, reducing soil erosion, improving groundwater recharge, and supporting agricultural productivity, particularly in regions prone to rainfall variability, steep slopes, and fragile soils.

The Ratnagiri district, located along the western coastal region of Maharashtra, has diverse landforms ranging from alluvial plains, pediments, escarpments, hills, ridges, plateaus, valleys, to waterbodies. The soils vary from deep clay in plains to shallow clay and clay loam in ridges and hills, often coupled with steep slopes and limited soil depth in upland areas. These conditions make the region susceptible to soil erosion, surface runoff, reduced infiltration, and loss of fertile topsoil, necessitating a systematic SWC approach. Implementing SWC measures in Ratnagiri is therefore essential for maintaining land productivity, conserving water resources, and protecting downstream ecosystems.

The SWC plan for cluster watershed of Chiplun Taluka has been formulated based on detailed analysis of land use, soil texture, soil depth, slope, and existing land management practices. The interventions are designed to address the conservation needs of both cultivated and forested areas, degraded lands, urban settlements, and water bodies, ensuring efficient and sustainable management of natural resources.

Among the interventions, Silt Detention Trenches in downstream areas constitute the largest coverage. These structures are primarily implemented in forested areas, degraded forests, and steep escarpments and hills, where they slow surface runoff, trap sediments, and enhance groundwater recharge, thereby reducing soil erosion and stabilizing downstream slopes.

Field bunding and strengthening of existing bunds with safe disposal of runoff water, targeting cultivable lands across pediments, and valleys. These bunds are applied on slopes ranging from gentle to steep, effectively controlling runoff, preventing topsoil loss, and maintaining soil moisture for agricultural productivity. Combined interventions of Afforestation, Contour Trenches, and Silt Detention Trenches are proposed, focusing on degraded forests and escarpments to restore vegetation, manage runoff, and reduce soil degradation.

In cultivated areas of plains, pediments, and valleys, Conservation Bench Terraces in unbunded fields or paddy fields, including bund strengthening with safe disposal of runoff water. These terraces reduce surface runoff, limit erosion, and enhance water retention, contributing to improved agricultural efficiency. Additional measures, such as Field bund/Contour bund with safe disposal of runoff water, are applied, addressing smaller cultivated patches on moderate slopes.

Urban infrastructure and water management have also been integrated into the plan. Built-up areas, covering 180.3 ha, receive runoff management measures, while Stream Bank Plantations along rivers, stabilize riverbanks and prevent erosion. Roads, covering 50.1 ha, are treated with slope and runoff management interventions. Smaller site-specific measures, including Afforestation with In-situ Moisture Conservation Measures, Bench Terraces, and Miscellaneous interventions, target degraded land patches, enhancing soil cover and moisture retention.

Water distribution and storage interventions include canals (6.3 ha) maintained for irrigation support and renovation of waterbodies (0.2 ha) based on site-specific conditions, ensuring optimum water availability for agriculture and ecological needs.

The allocation of SWC interventions across different landforms has been strictly based on field data. For instance, alluvial plains with deep clay soils receive bench terraces and field bunds in cultivated areas, while degraded forests are treated with afforestation and downstream silt detention structures. Escarpments and hills with shallow to very shallow soils have predominantly received silt detention trenches in downstream areas. Pediments and plateaus receive a combination of bench terraces, conservation bunds, and forest restoration measures, while valleys and rivers have stream bank plantations and waterbody renovation to control sedimentation and manage water flow effectively.

Overall, the proposed interventions cover a total area of 8,324.6 ha, ensuring comprehensive soil and water conservation across Chiplun Taluka. These measures are expected to enhance soil stability, improve moisture retention, control runoff, prevent land degradation, and support the long-term sustainability of agricultural and forested lands, thereby contributing to ecological balance and the socio-economic welfare of the region. At the time of execution of conservation measures, farmers' opinion may be opted and appropriate design may be done. If the site condition is not appropriate for suggested measures, alternative measures may be opted. The suggested polygon wise soil and water conservation measure is individual or combination of different conservation measures and each polygon is considered as independent unit.

Table 4.32 Proposed soil and water conservation (SWC) plan for Chiplun watershed

Sr. No.	Proposed SWC Plan
1	Silt Detention Trench in Downstream
2	Field bund/Strengthening of existing bund with safe disposal of runoff water
3	Afforestation, Contour Trench, Silt Detention Trench in Downstream
4	Conservation Bench Terrace in Unbunded Field/Field bund in Paddy Field/Strengthening of existing bund with safe disposal of runoff water
5	Built-up
6	Stream Bank Plantation
7	Field bund/Contour Bund/Strengthening of existing bund with safe disposal of runoff water
8	Afforestation, In-situ Moisture Conservation Measures

9	Bench Terrace
10	Road
11	Miscellaneous
12	Canal
13	Renovation of Waterbody as per the site condition

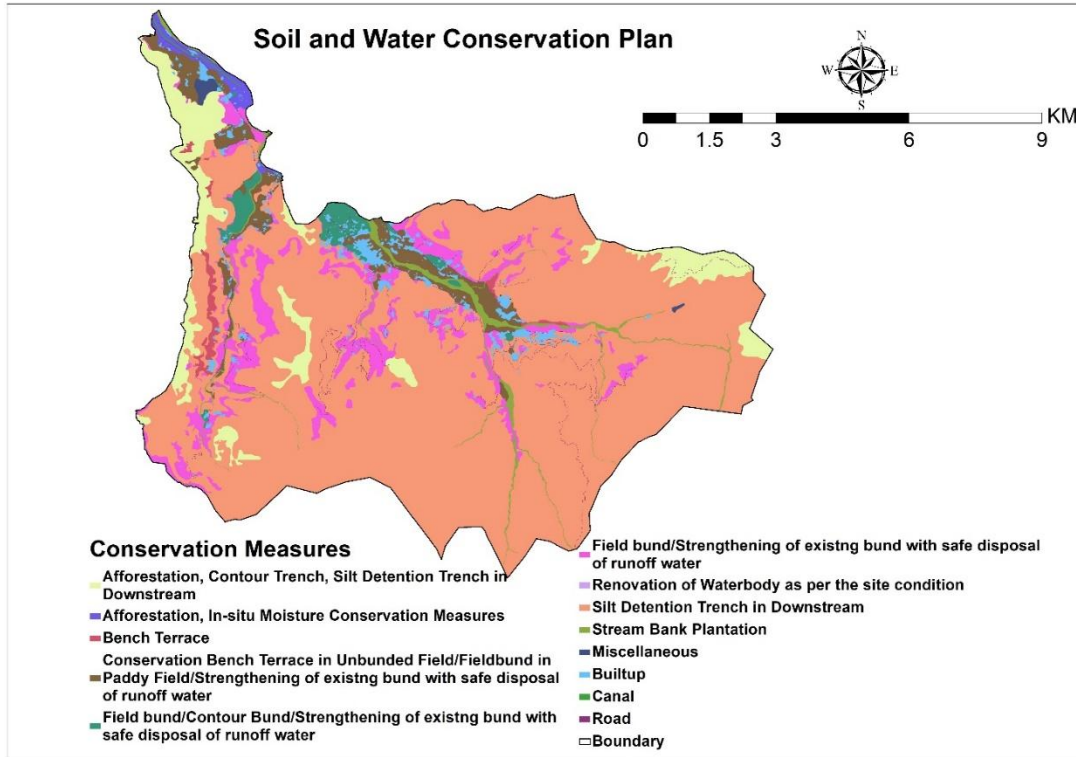


Fig. 4.28: Soil and Water Conservation measures proposed for Chiplun watershed

CHAPTER 5

SUMMARY AND CONCLUSION

5.1 SUMMARY

- The Land Resource Inventory (LRI) was conducted for the Chiplun Village Cluster-watershed in Chiplun Taluka of Ratnagiri District, Maharashtra, an area characterized by a tropical, hot, and humid climate with an average annual rainfall of 1851 mm.
- The region is hilly, with undulating terrain and widely varying slopes. The main natural resource constraints are high surface runoff, soil erosion, and subsequent water scarcity in the post-monsoon months despite heavy rainfall.
- The geological base is mainly Deccan Trap basalt, with lateritic formations on uplands and recent alluvial deposits in low-lying valleys. The geomorphology is rugged, featuring hills, ridges, and narrow valleys typical of the Konkan region.
- The assessment, carried out under the PMKSY-WDC 2.0 framework, focused on a systematic characterization of soil and land resources, assessment of land capability and soil-site suitability for crops (e.g., Rice, Mango, Cashewnut, Coconut), evaluation of groundwater potential zones, and the development of watershed-based alternate land use and soil and water conservation (SWC) plans.
- Site-specific interventions were systematically identified based on terrain analysis, land capability, and runoff potential, including proposals for structural and vegetative.

5.2 CONCLUSION

The present study demonstrates the effective application of integrated geospatial techniques and field-based observations for comprehensive watershed assessment and planning under the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) framework. The systematic analysis of terrain, drainage characteristics, slope, soil resources, and land use has enabled a detailed understanding of the hydrological and environmental conditions in the Chiplun sub-watershed, Ratnagiri district.

The assessment confirms that the agricultural system in this hilly, high-rainfall area is highly vulnerable to surface runoff and soil erosion. The identification of widespread erosion issues provides a clear mandate for location-specific interventions.

The evaluation of soil-site suitability for key crops and the mapped groundwater potential zones form a robust scientific basis for strategic planning. Successful implementation of the proposed soil and water conservation (SWC) measures.

ANNEXURE -1

Methodology for Morphometric Analysis

Morphometric analysis was carried out to understand the drainage characteristics and hydrological behaviour of the study area. A Digital Elevation Model (DEM) was used as the primary dataset to derive terrain and drainage information. The DEM was processed in a Geographic Information System (GIS) environment to remove sinks and generate flow direction and flow accumulation grids. Based on the flow accumulation threshold, the drainage network was extracted and stream orders were assigned using the Strahler stream ordering method.

Using the derived drainage network and flow direction layers, watershed and sub-watershed boundaries were delineated by identifying outlet points along the main drainage channels. The resulting hydrologically closed units were used as the basis for morphometric analysis. Linear, areal, and relief morphometric parameters were computed using standard equations widely adopted in geomorphological studies (e.g., Horton, 1945; Strahler, 1964; Schumm, 1956). Linear parameters such as number of streams, stream length, bifurcation ratio, channel length, and basin perimeter were calculated from the extracted stream network. Areal parameters including basin area, drainage density, stream frequency, form factor, elongation ratio, circularity ratio, compactness coefficient, and length of overland flow were derived to evaluate watershed shape, drainage efficiency, and runoff potential. Relief parameters such as basin relief, relief ratio, ruggedness number, and Melton ruggedness number were estimated using elevation data from the DEM to assess terrain characteristics and erosion susceptibility.

The morphometric analysis was conducted at the watershed and sub-watershed scale, as these parameters depend on natural drainage boundaries rather than administrative limits. The derived indices were subsequently interpreted to understand runoff generation, erosion susceptibility, and groundwater recharge potential within the watershed system. The results were further used to support soil and water conservation planning and watershed management strategies for the study area.

Morphometric analysis Chiplun cluster, Ratnagiri

In this study, runoff estimation, groundwater potential zone (GWPZ) mapping, and soil and water conservation (SWC) planning were performed at the village-cluster level to facilitate site-specific evaluation and practical implementation. In contrast, morphometric analysis was carried out at the watershed level because morphometric parameters are governed by natural drainage boundaries rather than administrative limits.

Morphometric analysis involves the quantitative assessment of drainage network characteristics, basin geometry, slope, and relief, all of which directly influence runoff generation, soil erosion, and groundwater recharge. These parameters must be derived from a hydrologically closed unit defined by natural divides. A watershed represents such a unit,

where streams develop in a hierarchical order and converge toward a common outlet, enabling accurate computation of indices such as drainage density, bifurcation ratio, stream frequency, form factor, and relief ratio.

Village clusters, being administrative units, do not correspond to complete drainage systems. As streams frequently traverse village boundaries, conducting morphometric analysis at the cluster level would produce truncated stream networks and distorted basin geometry, thereby leading to unreliable hydrological interpretation. Therefore, morphometric analysis was intentionally performed at the watershed level to maintain hydrological accuracy, while runoff estimation, GWPZ mapping, and SWC planning were undertaken at the village cluster level for effective local implementation. This integrated framework links natural hydrological processes with decentralized planning for sustainable water resource management.

The Chiplun cluster, Ratnagiri, Maharashtra, comprises nine villages. Together, these villages constitute the study cluster having one sub-watershed (Fig.1)

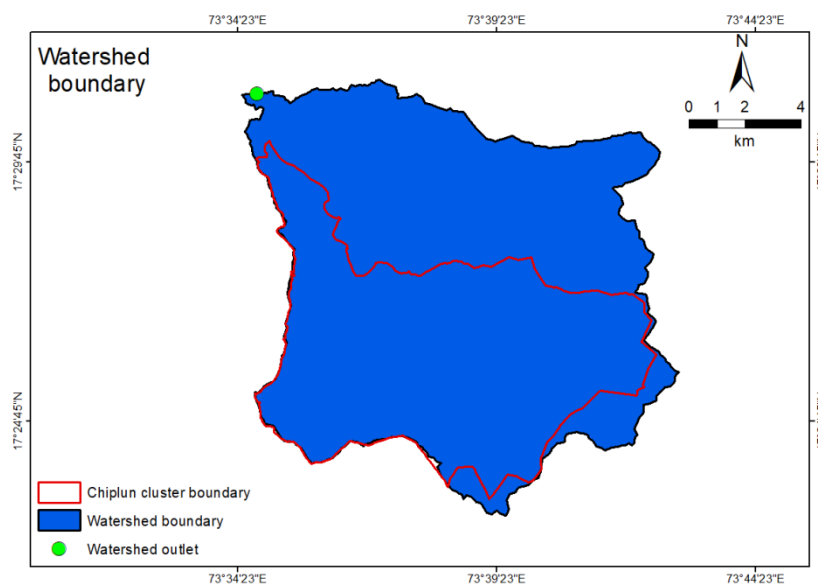


Fig. 1: Map of Chiplun Cluster depicted through sub-watershed

Table 1: Distribution of area under different sub-watershed, Chiplun cluster, Ratnagiri

Sr. No.	Sub-watershed name	Sub-watershed order	Elevation (m)	Area (km ²)	Flow origination
1	W1	4 th	6-1073	155.67	South-North west

The watershed wise area, their order, elevation range and drainage network are presented in Table 1, and Fig. 1. The morphometric characteristics of sub-watershed are analyzed under three aspects: linear, areal, and relief.

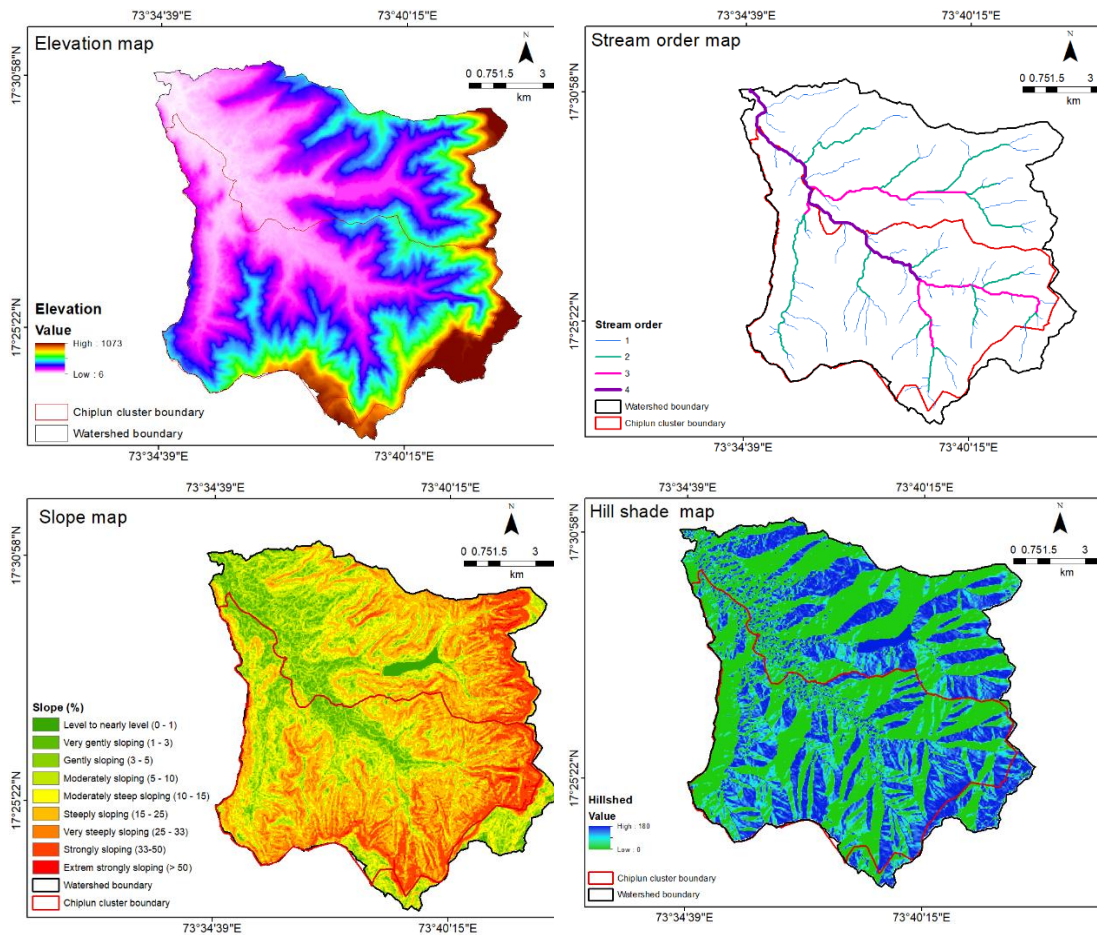


Fig. 2: Elevation, stream network, slope and hill shade map of sub-watershed

Linear aspect

Linear morphometric parameters focus on the stream network characteristics and its influence on runoff and watershed behavior. The morphometric analysis of the sub-watersheds shows clear variation in drainage characteristics.

W1 has the number of streams (106) and total stream length (149.6 km), indicating a well-developed drainage network (Table 2). The bifurcation ratio indicated as 4.4, suggesting relatively greater structural influence watershed. Mean channel length and valley length of watershed, reflecting more mature channel development. Channel index of watershed W1 (1.2), indicating greater sinuosity. Basin perimeter of W1 (63.6 km), confirming it as the most extensive sub-watershed.

Table 2: Linear morphometric parameters of sub-watersheds, Chiplun Cluster, Ratnagiri

Sl. no.	Morphometric parameter	Symbol	Unit	W1
1	No. of streams	Nu	No	106.0
2	Stream length	Lu	km	149.6
3	Bi-furcation ratio	Rb	-	4.4
4	Mean channel length	Cl	km	22.9
5	Valley Length	Vl	km	20.4
6	Channel Index	Ci	-	1.2
7	Minimum areal distance	Adm	km	18.6
8	Valley Index	Vi	-	1.1
9	Basin perimeter	P	km	63.6

Areal Aspects

Areal parameters describe the two-dimensional properties of the watershed, including shape, size, and drainage efficiency, which directly influence runoff and groundwater recharge. Basin area of watershed W1 (155.67 km²) and mean basin width is 6.6 km. Form factor (Ff) and elongation ratio (Re) in W1 (0.28 and 0.59), suggesting a comparatively more circular basin. Circularity ratio (Rc) of W1 is 0.48, while compactness coefficient (Cc) as 1.45, reflecting greater basin irregularity. Standard sinuosity index (Ssi) as 1.12, indicating relatively higher channel sinuosity in W1. Drainage parameters show that stream frequency (Fs) is 0.68 per km² and Drainage density (Dd) as 0.96 km/km². Drainage intensity (Di) follows a similar trend, with the highest value as 0.71. Length of overland flow (Lg) as (0.38 km) indicating shorter runoff travel distance in W1.

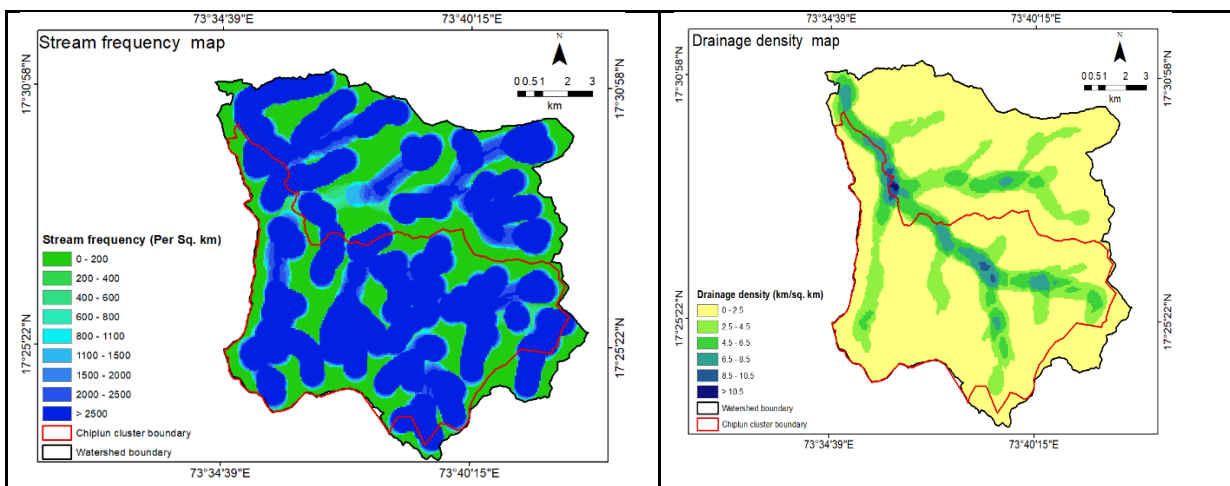


Fig. 3: Steam frequency and drainage density map of sub-watershed

Table 3: Areal morphometric parameters of sub-watersheds, Chiplun cluster, Ratnagiri

Sr. No.	Parameter	Symbol	Method/Formula	Unit	W1
1.	Mean basin width	Wb	$Wb=A/Lb$	km	6.6
2.	Basin area	A	GIS Analysis	km ²	155.7
3.	Relative perimeter	Pr	$Pr= A/P$	km	2.5
4.	Length area relation	Lar	$Lar = 1.4*A^{0.6}$	km ²	28.9
5.	Lemniscate's	k	$K = Lb^2/A$	-	3.6
6.	Form factor	Ff	$Ff = A/Lb^2$	-	0.3
7.	Elongation ratio	Re	$Re = 2/Lb*(A/\pi)$ 0.5	-	0.6
8.	Circularity ratio	Rc	$Rc = 12.57*(A/P^2)$	-	0.5
9.	Compactness coefficient	Cc	$Cc = 0.2841 * P/A^{0.5}$	-	1.5
10.	Standard sinuosity index	Ssi	$Ssi = Ci/Vi$	-	1.1
11.	Stream frequency	Fs	$Fs = Nu/A$	Per km ²	0.7
12.	Drainage Density	Dd	$Dd = Lu/A$	km/km ²	1.0
13.	Drainage Intensity	Di	$Di = Fs/Dd$	-	0.7
14.	Length of Overland Flow	Lg	$Lg = A/2*Lu$	km	0.4

Relief Aspects

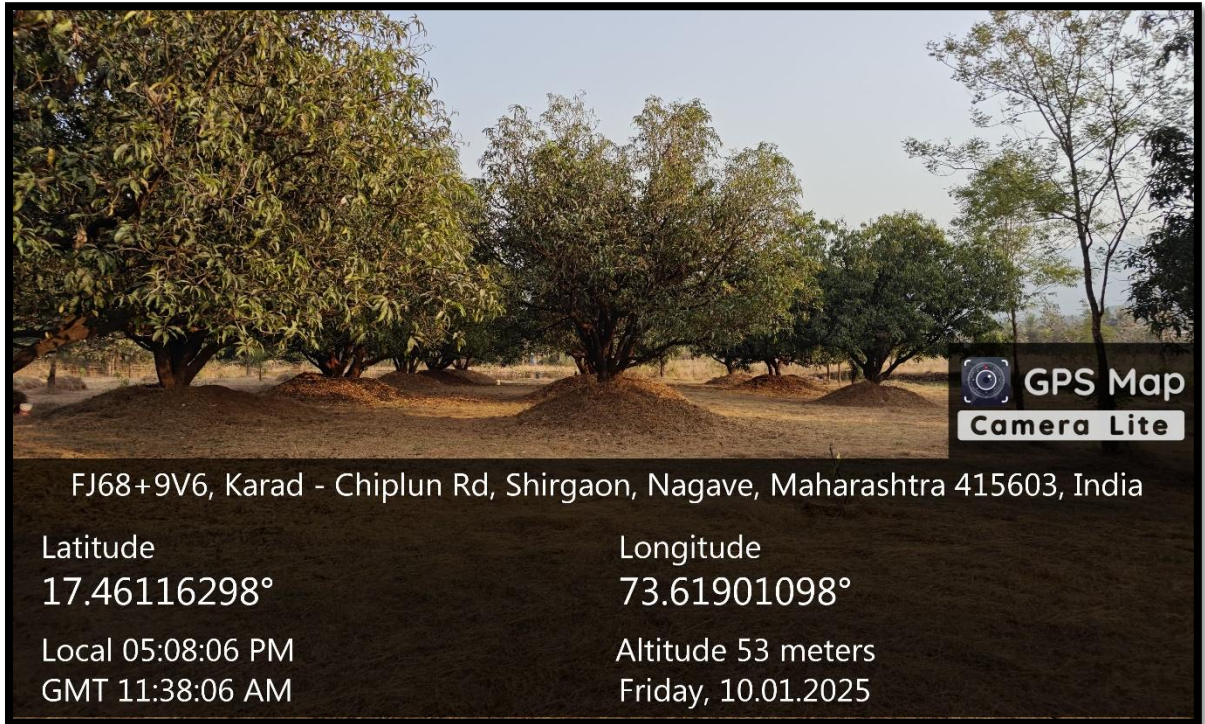
The maximum basin height (Z) of W1 (1073m) and total basin relief (H) is also maximum as (1067 m) (Table 4). Relief ratio (Rhl) as W1 (45.1), indicating steeper terrain conditions, while Relative relief ratio (Rhp) of W1 (1678.5) suggesting higher relief intensity in W1. The ruggedness number (Rn) of watershed W1 (1.03), reflecting more dissected and erosion-prone terrain. Similarly, the Melton ruggedness number (MRn) is shown in W1 (85.5), indicating comparatively higher susceptibility to runoff and erosion processes.

Table 4: Relief morphometric parameters of sub-watersheds, Chiplun Cluster

Sr. no.	Parameters	Symbol	Methods/Formula	W1
1.	Height of at basin mouth,(m)	z	DEM	6.0
2.	Maximum height of the basin, (m)	Z	DEM	1073.0
3.	Total basin relief,(m)	H	$H = Z - z$	1067.0
4.	Relief ratio	Rhl	$Rhl = H / Lb$	45.1
5.	Relative relief ratio	Rhp	$Rhp = H * 100 / P$	1678.5
6.	Ruggedness number	Rn	$Rn = Dd*(H/1000)$	1.0
7.	Melton Ruggedness number	MRn	$MRn = H / A^{0.5}$	85.5

The slope distribution of watershed indicates a predominantly steep and highly undulating terrain. Nearly level land (0–1%) occupies only 1.49% of the total watershed area, while very gently sloping areas (1–3%) cover 5.48%, showing that only a small portion of the watershed has low relief conditions suitable for intensive agricultural activities. Gently sloping terrain (3–5%) accounts for 8.16% of the area, representing limited zones with moderate runoff potential. The moderately sloping class (5–10%) occupies 18.13%, indicating the presence of undulating topography across a considerable part of the watershed. Steeper slope categories dominate the basin, where moderately steep slopes (10–15%) cover 15.66% and steep slopes (15–25%) account for the largest share with 27.24% of the total area. In addition, very steep slopes (25–33%) occupy 14.31%, while strongly sloping areas (33–50%) represent 8.89% of the watershed. A very small proportion (0.67%) falls under extremely steep slopes (>50%).

Based on the morphometric characteristics and slope distribution of watershed W1, a comprehensive soil conservation plan is required to control runoff and reduce erosion risk. The watershed exhibits a well-developed drainage network, high basin relief, high ruggedness number, and steep slope dominance, indicating strong runoff potential and high susceptibility to soil erosion. Since a large proportion of the area falls under moderately steep to very steep slopes (10–33%), structural and vegetative soil conservation measures are essential. In these steep areas, contour trenching, bench terracing, staggered trenches, and afforestation with deep-rooted vegetation should be implemented to stabilize slopes and reduce soil loss. Gully control structures, check dams, and loose boulder dams can be constructed along drainage channels to slow down runoff and trap sediments. In the moderately sloping areas (5–10%), measures such as contour bunding, graded bunds, and vegetative barriers should be adopted to minimize surface runoff and enhance soil moisture retention. The limited areas with gentle slopes (1–5%) can be managed through strip cropping, mulching, and small farm ponds to improve water infiltration and groundwater recharge. Considering the high relief and rugged terrain of watershed integrating structural measures, vegetative cover development, and water harvesting structures is essential for effective soil conservation, sustainable land use, and long-term watershed stability.



 **GPS Map**
Camera Lite

FJ68+9V6, Karad - Chiplun Rd, Shirgaon, Nagave, Maharashtra 415603, India


Latitude
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Longitude
73.61901098°

Local 05:08:06 PM
GMT 11:38:06 AM

Altitude 53 meters
Friday, 10.01.2025



 **GPS Map**
Camera Lite

 FJ4G+W5F, Shirgaon, Nagave, Maharashtra 415602, India

Latitude
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Longitude
73.62545439°

Local 08:06:51 AM
GMT 02:36:51 AM

Altitude 62 meters
Saturday, 01.02.2025



 **GPS Map**
Camera Lite

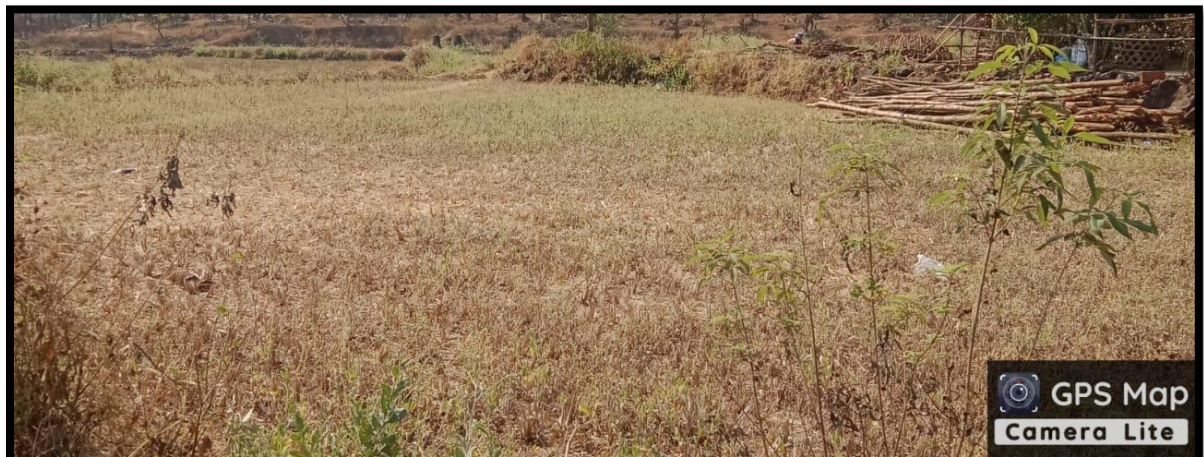
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Latitude
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Longitude
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GMT 07:59:13 AM

Altitude 440 meters
Sunday, 02.02.2025



 **GPS Map**
Camera Lite

CJQQ+9MQ, MIDC, Chiplun, Akus Khan Nagar, Maharashtra 415602, India

Latitude
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Longitude
73.64038333333333°

Local 11:17:15 AM
GMT 05:47:15 AM

Altitude 162 meters
Monday, 03.02.2025