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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: Dodamarg, Dist - Sindhudurg

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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The publication titled "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: Dodamarg, Dist – Sindhudurg" is the result of the collaborative efforts of the officials from the ICAR-National Bureau of Soil Survey and Land Use Planning (ICAR-NBSS&LUP), Nagpur and the Vasundhara Watershed Development Agency (VWDA), Government of Maharashtra.

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.

Finally, we heartfully thank to all the project staff involved in the PMKSY 2.0-Maharashtra project for their untiring and steadfast efforts in the successful implementation of the project through data collection, analysis and documentation of the report.

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EXECUTIVE SUMMARY

The Pradhan Mantri Krishi Sinchayee Yojana - Watershed Development Component (PMKSY-WDC 2.0) emphasizes a scientific and participatory approach to watershed development through systematic assessment and management of land and water resources. In this context, Land Resource Inventory (LRI) provides a critical technical input for informed planning, prioritization of interventions, and sustainable management of natural resources. The ICAR-National Bureau of Soil Survey and Land Use Planning (ICAR-NBSS&LUP) was entrusted with the responsibility of conducting the LRI and offering technical assistance in the formulation of a holistic watershed development plan in accordance with the PMKSY-WDC 2.0 guidelines. ICAR-NBSS&LUP conducted the assessment for the Sindhudurg (WDC-2.0)2/2021-22 watershed located within the Dodamarg Taluka of Sindhudurg District, Maharashtra, underlain with the characteristic basaltic terrain of the Deccan Plateau, with the Chapora river traversing the area. Agriculture constitutes the dominant land use within this watershed, primarily dependent upon monsoon precipitation, augmented by groundwater resources and various soil conservation structures.

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 conducted using the standard methodologies prescribed by ICAR-NBSS&LUP, involving pre-field analysis, detailed soil survey, laboratory characterization of soil samples, and GIS-based spatial analysis. Base maps were prepared using authenticated datasets. Soil characteristics were recorded through field observations and laboratory analysis and subsequently classified following 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 land use 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 Dodamarg sub-watershed constitutes an provide a comprehensive technical framework for scientific watershed planning and sustainable resource management, 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 Sindhudurg (WDC-2.0 3/2021-22) sub-watershed of Dodamarg 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

DODAMARG WATERSHED AT A GLANCE

2.1 Location and Extent

The watershed (Fig. 2.1) is located in Dodamarg Taluka the northernmost part of Sindhudurg District, within the coastal Konkan division of Maharashtra. This taluka, sharing its border with Goa to the south and Belagavi district of Karnataka to the east, is part of the high rainfall zone of the Western Ghats. Characterized by a rugged physiography, high-intensity monsoonal precipitation, and a largely rural and agrarian population, the region faces recurring challenges related to surface runoff, soil erosion, water scarcity post-monsoon, and declining groundwater reliability in the non-valley zones.

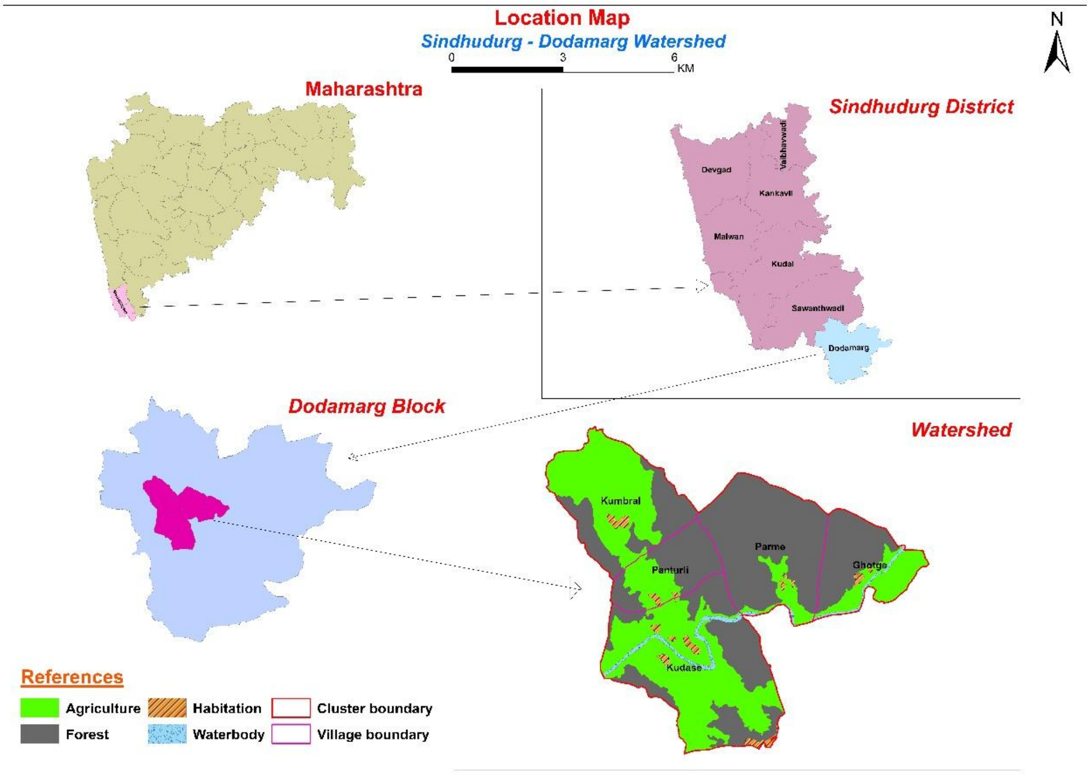


Fig. 2.1. Location map of the Dodamarg watershed

Dodamarg Taluka villages are largely rural, hilly, and mostly rainfed, with agriculture being the primary livelihood. The region is prone to high surface runoff during monsoons, leading to soil erosion, declining groundwater levels, and water scarcity during the post-monsoon months. This situation, which persists despite high annual rainfall, formed the rationale for selecting this area for watershed-based natural resource management interventions. Table 2.1 provides the general profile in respect of the watershed.

Table 2.1. Geographical and administrative profile

Sr. No.	Particulars	Details
1	District	Sindhudurg
2	Taluka	Dodamarg
3	Revenue Division	Konkan
4	Total sub-watershed Area	4262 ha (Approx)
5	Micro-watershed (cluster/treated) area	
6	Villages	05 (Kumbral, Parme, Ghotge, Kudase, Panturli)
7	Major River	Chapora River
8	Drainage Pattern	Dendritic
9	Average annual Rainfall	1885 mm

2.2 Geology

The geology of Sindhudurg District comprises rock formations ranging in age from Archean to Quaternary. The older formations are mainly represented by granite gneiss and meta-sediments belonging to the Dharwar Supergroup, which occupy a large part of the district. These rocks include schists, phyllites and amphibolites. Sedimentary rocks of the Kaladgi Group occur in scattered patches in parts of the district. In the northern areas, basaltic lava flows of the Deccan Traps are present. Lateritic formations are widely developed over the basalt and older rocks, particularly in plateau and low-lying areas. Recent geological deposits in the district mainly include alluvial sediments along river valleys and sandy deposits along the coastal belt.

2.3 Geomorphology

The Dodamarg watershed in Sindhudurg District exhibits a diverse geomorphological setting influenced by the terrain of the Western Ghats. The landscape is characterized by a combination of hills, ridges, escarpments and gently sloping pediment surfaces. The hilly and ridge areas represent the elevated and undulating parts of the terrain, while the pediment zones occur along the foothills and form relatively gentle slopes. Escarpments mark the steep slopes and abrupt changes in elevation within the terrain. These geomorphic features together influence the drainage pattern, soil development and land use across the watershed.

2.4 Physiography and Soil

The physiography of the area is mainly hilly, with steep elevation changes occurring within short distances, leading to fast runoff and localized soil erosion. The soils are mostly clay and sandy clay, with smaller patches of clay loam, sandy clay loam and loam. These soils are well-drained and range from shallow to very deep, with good moisture-retention capacity, though they are prone to erosion in the higher altitudes. Paddy is commonly grown in the low-lying fields, while Mango plantations and forest cover dominate the pediment and upland regions.

2.5 Climate

The climate of Dodamarg in Sindhudurg District is tropical humid and is strongly influenced by the southwest monsoon. The area receives very high rainfall during the southwest monsoon, with the average annual rainfall of the district being around 1885 mm, most of which occurs between June and September. Temperatures remain moderate throughout the year due to the influence of the Western Ghats and the nearby Arabian Sea. The maximum temperature generally reaches around 32-38°C during summer, while winter temperatures are comparatively mild. High humidity conditions prevail for most of the year, particularly during the monsoon season.

2.6 Drainage

The drainage system of the Dodamarg area in Sindhudurg District is mainly controlled by the hilly terrain of the Western Ghats. The region is drained by a number of small streams and seasonal nalas that originate from the surrounding hills and flow through narrow valleys. These streams generally follow the natural slope of the land and join larger river systems downstream. The drainage pattern in the area is predominantly dendritic, which is typical of regions underlain by basaltic and lateritic formations. Most of the streams carry substantial runoff during the monsoon season due to heavy rainfall, while their flow reduces considerably during the dry months. The drainage network therefore plays an important role in surface water movement and local recharge conditions in the area.

2.7 Cropping Patterns, and Demography and Socioeconomics

2.7.1 Cropping Pattern

Cropping pattern in Dodamarg Taluka remains influenced by the monsoon, with Paddy (Rice) forming the backbone of traditional cropping during the Kharif season. Cereals like Finger millet (Nagli) and Pulses are grown on a smaller scale, often for household consumption or local sale. Recent years, however, have witnessed a gradual diversification many farms now include horticultural and plantation crops, including Mango and Cashew, alongside more traditional crops. The inclusion of Mango plantations reflects the broader pattern of horticulture expansion in Sindhudurg, where fruit-crop cultivation increasingly supplements or replaces purely food-grain farming.

2.7.2 Demographic and Socioeconomic Status

Dodamarg is a close-knit, rural community. As the smallest taluka in Sindhudurg, it is home to about 49,000 people living in roughly 12,000 households, with no major urban centers in sight according to 2011 census. The community is remarkably vibrant, boasting a high literacy rate of over 82% and a demographic where women slightly outnumber men. While nearly 60% of the workforce depends on agriculture, many young men move to cities for work, leading to a significant economic role for the women who stay behind.

2.8 Water Resources

2.8.1 Surface Water

Water resources in Dodamarg Taluka are tied to the Tillari River, which flows westward through the taluka. The river is impounded by the Tillari Dam, part of the inter-state irrigation project. Downstream, when it enters Goa, the same river course is locally known as the Chapora River. Surface-water resource infrastructure is limited: apart from the reservoir, irrigation and water storage facilities remain modest - small check dams, minor canals or farm ponds are few. As a result, groundwater and seasonal rainfall continue to play a major role in fulfilling local water needs.

2.8.2 Groundwater

Groundwater occurs mostly in weathered and fractured zones of basalt rock. According to the Dynamic Ground Water Resources of Sindhudurg District (CGWB), 2024, annual extractable ground water resources place the region under the "safe" category, with the groundwater extraction level under 56%.

2.8.3 Irrigation and Water Management

In the Dodamarg cluster, even with heavy rainfall, water remains scarce during the dry months. The Tillari Irrigation Project in the cluster is a primary source of irrigation. Traditional methods like *Rahats* and *Bhands* were historically vital, modern agriculture increasingly relies on a mix of open wells and micro-irrigation systems. To combat coastal soil salinity and groundwater depletion, the district employs integrated watershed techniques such as check dam rejuvenation, farm ponds, and Broad Bed Furrow (BBF) systems for in-situ moisture conservation.

2.9 Constraints

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

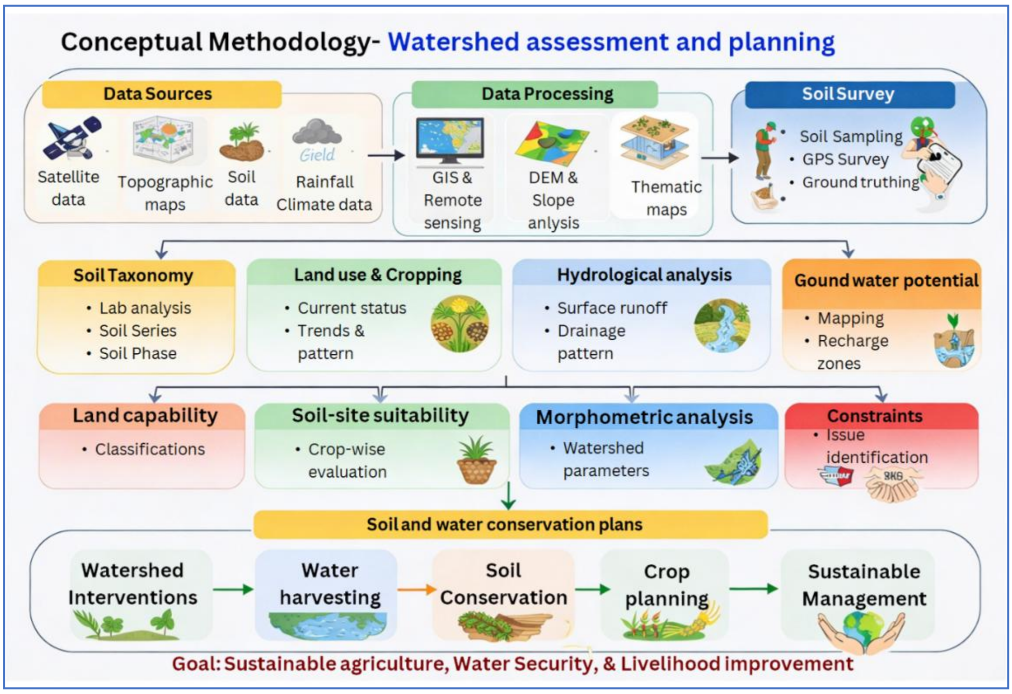
a. Excess Runoff: Despite heavy monsoon rainfall, a large portion of water drains away quickly due to steep slopes and limited water-harvesting structures.
b. Soil Erosion: Upper catchments experience erosion, reducing soil fertility and causing siltation in downstream check dams and ponds.
c. Seasonal Groundwater: Groundwater yields from dug wells and handpumps drop sharply after the monsoon; recharge is highly dependent on rainfall intensity.
d. Minimal Irrigation Coverage: Only about 1-2% of cultivated land is irrigated, mostly in valley areas; upland farming is predominantly rainfed.
e. Fallow Lands: Unreliable water supply and low returns have led to abandonment of farmland in some pockets.
f. Poor Maintenance of Assets: Many check dams and bunds built under IWMP and RKVY are in disrepair, reducing their effectiveness.

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)] was 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 Dodamarg 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 Dodamarg 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 Dodamarg 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 unbunded 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 Dodamarg watershed is presented in Table 4.1. Canal is important source of irrigation, contributing 61.7% of the total irrigation in the watershed. Dam water serves as the second important irrigation source, contributing 21.6% of the total irrigation, highlighting the significance of reservoir storage in providing irrigation water during both cropping seasons. Well irrigation contributes 8.0% of the total irrigation, indicating moderate dependence on groundwater sources for agricultural water requirements.

River water contributes 8.2% of the irrigation, mainly during the Rabi season, while Gabian structures contribute 0.6%, indicating localized water harvesting support.

The irrigation system of the watershed is primarily supported by canal irrigation supplemented by dam storage and groundwater sources, while minor contributions from rivers and Gabian structures enhance local water availability.

Table 4.1. Seasonal Distribution of Irrigation Sources in the Dodamarg Watershed

Sr. No.	Number of Farmers Interviewed (n)	Irrigation Source	Seasonal Water Availability	Contribution to Season's Total Irrigation (%)
1	92	Canal	Kharif & Rabi	61.7
2	77	Rainfed	Kharif	0.0
3	27	Dam	Kharif & Rabi	21.6
4	10	Well	Kharif & Rabi	8.0
5	8	River	Rabi	8.2
6	1	Gabian	Kharif	0.6

4.1.2 Cropping Pattern

The cropping pattern of Dodamarg is presented in Table 4.2. The gross cropped area is 286.00 ha, while the net sown area is 247.00 ha.

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

$$Cropping\ intensity(\%) = \frac{286}{247} \times 100 = 115.5\%$$

The cropping intensity of the area is calculated as 115.8%, indicating that the agricultural land is cultivated more than once in the year.

Cashew occupies the largest cropped area, covering 57.3% of the total cropped area with a productivity of 558.6 kg/ha. Arecanut and coconut covers 17.3% and 17.2% of the total cropped area, respectively. Arecanut records a productivity of 436.5 kg/ha, while coconut has a productivity of 511.2 kg/ha, indicating their importance as perennial horticultural crops.

Rice occupies 4.2% of the total cropped area under rainfed conditions with a productivity of 1962.8 kg/ha. Bananas cover 2.6% of the cropped area with a productivity of 1927.5 kg/ha.

The cropping pattern of the watershed is characterized by the perennial plantation crops and supplemented by seasonal crops. The moderate cropping intensity reflects the integration of seasonal crops with perennial plantations, contributing to improved land utilization in the region.

Table 4.2. Crop-wise Distribution in the Dodamarg watershed

Sr. No.	Season	Crop	No. of Farmers Interviewed (n)	Irrigation Type	Total Cropped Area (%)	Productivity (kg/ha)
1	Rainfed	Rice	38	Irrigated	4.2	1962.8
2	Rainfed	Coconut	144	Irrigated	17.2	511.2
3	Rainfed	Arecanut	140	Irrigated	17.3	436.5
4	Rainfed	Cashew	181	Irrigated	57.2	558.6
5	Irrigated	Banana	26	Irrigated	2.6	1927.5

4.1.3 Socioeconomic Status

4.1.3.1 Land holding pattern

The landholding pattern of farmers in Dodamarg is presented in Table 4.3. From the table it was observed that marginal farmers (<1 ha) have the highest population with 42.1% of the total farmers, having an average landholding of 0.6 ha, followed by small farmers (1-2 ha) accounting for 28.7% with an average landholding of 1.4 ha.

Semi-medium farmers (2-4 ha) constitute 19.9% of the farmers with an average landholding of 2.4 ha, while medium farmers (4-10 ha) account for 7.4% with an average landholding of 5.0 ha. A small population of farmers belong to the large farmer category (>10 ha), comprising 1.8% with an average landholding of 18.4 ha.

Average landholding size in the study area was found to be 1.8 ha, indicating that agriculture in the region is characterized by small and marginal landholdings.

Table 4.3. Land holding pattern in Dodamarg watershed

Category	Criteria Land (ha)	No. of Farmers Interviewed (n)	Farmers (%)	Average Land Holding (ha)
Marginal Farmers	<1	91	42.1	0.6
Small Farmers	1-2	62	28.7	1.4
Semi-Medium Farmers	2-4	43	19.9	2.4
Medium Farmers	4-10	16	7.4	5.0
Large Farmers	>10	4	1.8	18.4
Average land holding				**1.8**

4.1.3.2 Income distribution

The income pattern from different crops in the watershed is presented in Table 4.4. Cashew occupies the largest cropped area (57.2%) with an average income of 86,080 Rs, indicating that it is the major income-generating crop. Arecanut occupies 17.3% of the cropped area with an average income of 41,831 Rs, while coconut occupies 17.28% of the cropped area with an average income of 10,544 Rs.

Bananas cover 2.6% of the cropped area with an average income of 45,431 Rs. Rice occupies 4.2% of the cropped area with an average income of 16,277 Rs. Finger millet covers 1.2% of the cropped area with an average income of 22,818 Rs.

The results indicate that horticultural crops, particularly Cashew and Arecanut, dominate the income structure of the watershed. This pattern highlights the importance of horticultural crops in enhancing farmers' income and livelihood security in the watershed.

Table 4.4. Average annual income of farmers in Dodamarg watershed.

Name of Crops	No. of Farmers Interviewed (n)	Crop Area (%)	Average Income (Rs.)
Rice	38	4.2	16277
Coconut	144	17.2	10544
Arecanut	140	17.3	41831
Cashew	181	57.2	86080
Banana	26	2.6	45431
Finger Millet	11	1.2	22818

4.1.3.3 Education

The educational profile of the population in the villages of the watershed is presented in the table, which indicates a relatively better level of literacy compared to many other rural areas. The overall results show that secondary education constitutes the largest proportion of the population (61.11%), followed by primary education (12.96%), higher secondary education (12.04%), higher studies (6.02%), and 7.87% of the population is illiterate.

Village-wise analysis shows that Kudase recorded 14.29% illiteracy, while 47.61% of the population had secondary education, 21.43% higher secondary education, and 11.9% higher studies, indicating relatively good educational attainment. In Panturli, only 5.56% of the population is illiterate, while the highest proportion (66.66%) has completed secondary education, followed by 22.22% with primary education, and 5.56% with higher secondary education.

Similarly, Parme recorded 8.33% illiteracy, with the highest proportion of secondary education (77.78%), while 5.56% had primary education and 8.33% had higher secondary education. In Ghodage, illiteracy is relatively low (3.23%), while 61.29% of the population has secondary education, 25.81% primary education, and 6.45% higher studies.

In Kumbral, 6.74% of the population is illiterate, while 59.55% have secondary education, 13.48% primary education, 13.48% higher secondary education, and 6.74% higher studies. Overall, the results indicate that secondary education dominates across all villages, while the proportion of illiteracy is relatively low. The presence of a considerable percentage of population with higher secondary and higher education suggests comparatively better educational attainment in the watershed, which may positively influence awareness levels, adoption of improved agricultural practices, and participation in development and extension activities.

Table 4.5. Education profile of villages in Dodamarg watershed by population

Village	No Education (%)	Primary (%)	Secondary (%)	Higher Secondary (%)	Higher Studies (%)
Kudase	14.29	4.76	47.61	21.43	11.9
Panturli	5.56	22.22	66.66	5.56	0
Parme	8.33	5.56	77.78	8.33	0
Ghodage	3.23	25.81	61.29	3.23	6.45
Kumbral	6.74	13.48	59.55	13.48	6.74
Total	7.87	12.96	61.11	12.04	6.02

4.2 Land-use/Land-cover

The classification of the area reveals that agriculture is occupying 1839.2 ha, and constitutes 43.2% of the total area (Table 4.6 and Fig. 4.1). Forestland covering 2261.3 ha (53.1%) of the area, which may indicate areas unsuitable for cultivation. Waterbodies are limited to 88.1 ha, making up 2.1% of the total area, reflecting the presence of limited surface water resources in the region. This LULC distribution highlights the dominance of agricultural activities in the area with secondary coverage by Habitation and Waterbody categories.

Table 4.6. Land-use/land-cover statistics of Dodamarg watershed

Land use	Area (ha)	Percent (%)
Forest	2261.3	53.1
Agriculture	1839.2	43.2
Waterbody	88.1	2.1
Habitation	73.2	1.7
Total	**4261.7**	**100**

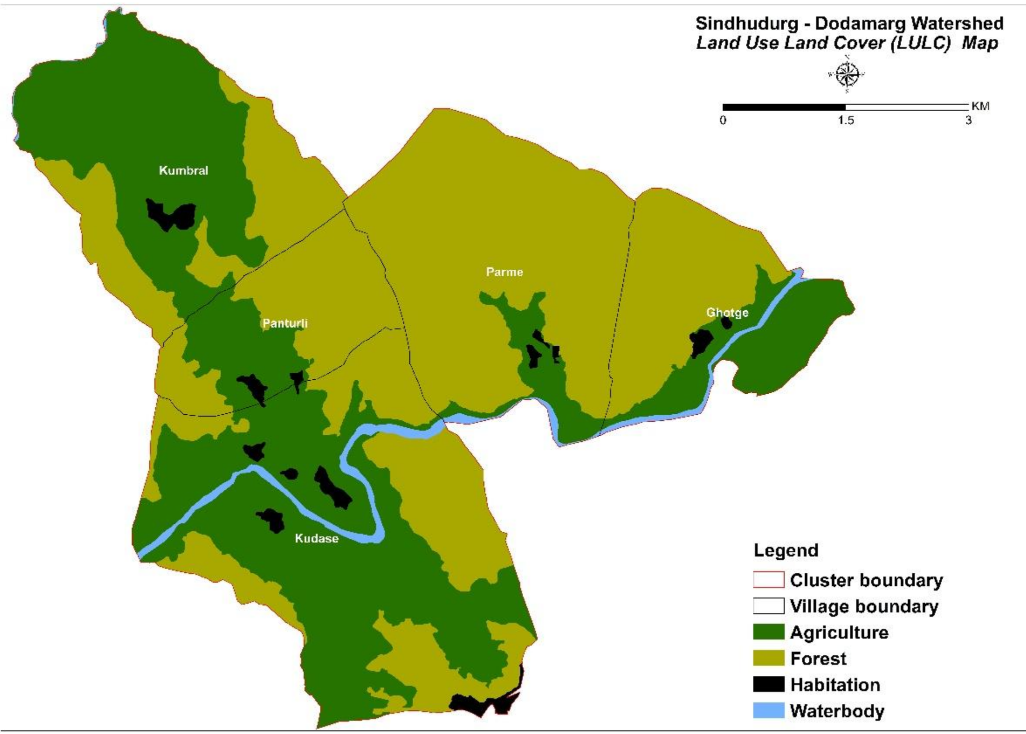


Fig. 4.1. Land-use/land-cover map

4.3 Landform Delineation

The landform analysis of the area indicates a diverse geomorphological setting. Pediment is the most extensive landform (Table 4.7), covering 1839.2 ha, or 43.2% of the total area. The Hills & Ridges covers 1328.6 ha (31.2%), while the Escarpment, often representing sloping rock surfaces, covering 932.7 ha (21.9%). Overall, the area is characterized by a prevalence of pediment features, with a mixture of erosional and depositional landforms. The landform map of the watershed is presented in Fig. 4.2.

Table 4.7. Landform features existing in Dodamarg watershed

Sr. no	Landform	Area (ha)	Percent (%)
1	Pediment	1839.2	43.2
2	Hills & Ridges	1328.6	31.2
3	Escarpment	932.7	21.9
4	Waterbody	88.1	2.1
5	Habitation	73.2	1.7
	Total	**4261.7**	**100.0**

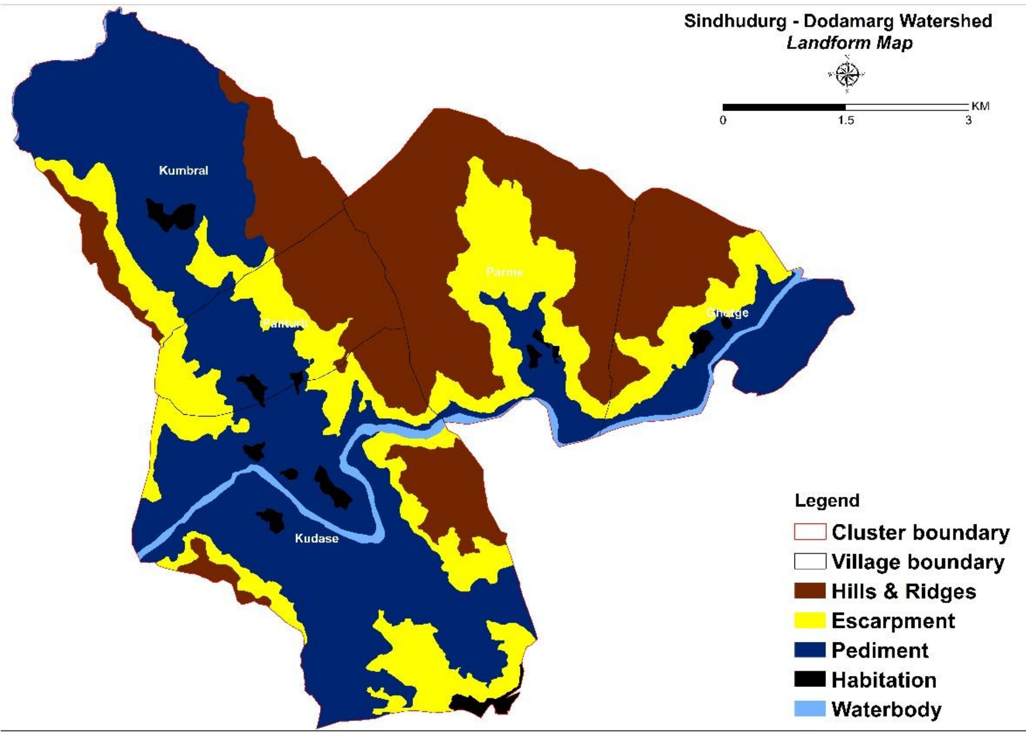


Fig. 4.2. Landform map of Dodamarg watershed

4.4 Soil series and phases

Eight soil series have been identified and mapped with soil mapping units (17 phases of series) (Fig 4.3). The taxonomic classification and mapping legend of the soil series along with its landform was shown in Table 4.8. The detailed descriptions of each phase are given in Table 4.9 and Fig. 4.4.

Table 4.8. Dominant soil series identified in the watershed.

Sr. No.	Series	Area (ha)	Percent (%)
1	Forest	1328.6	31.2
2	Panthusli	1302.0	30.6
3	Parme	690.7	16.2
4	Talkat	271.9	6.4
5	Kudase2	238.5	5.6
6	Kumbral1	207.1	4.9
7	Waterbody	88.1	2.1
8	Habitation	73.1	1.7
9	Kudase1	34.9	0.8
10	Kumbral2	26.8	0.6
	Total	**4261.7**	**100.0**

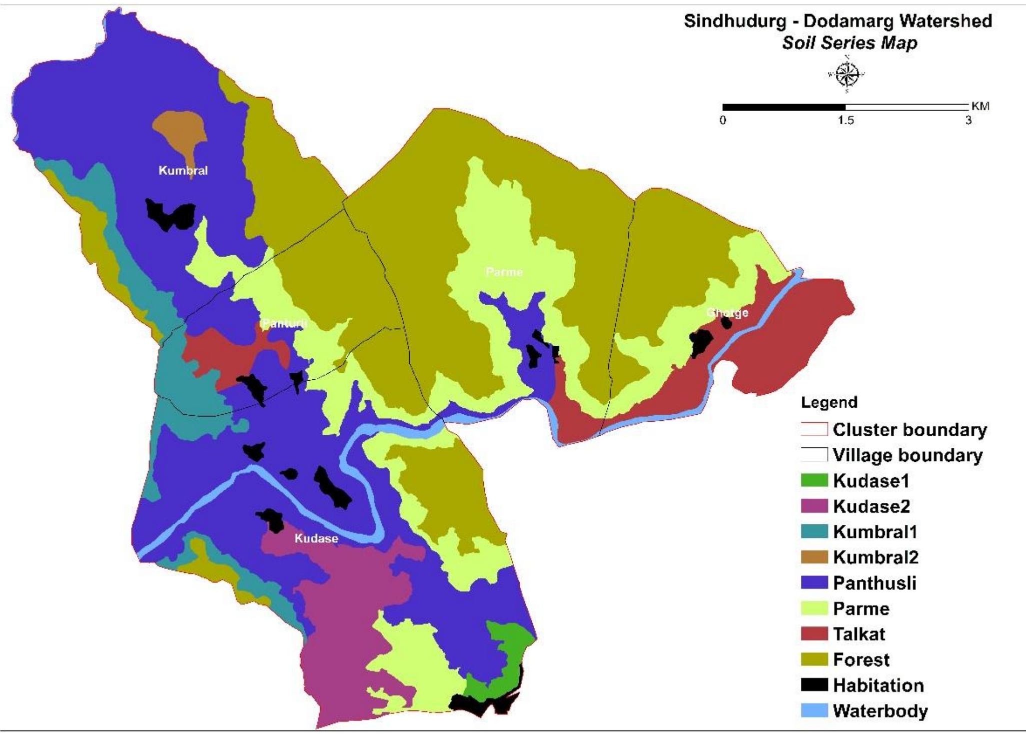


Fig. 4.3. Soil series map of Dodamarg watershed

Table 4.9. Soil phases existing in Dodamarg watershed

Sr. No.	Phase	Area(ha)	Percent (%)
1	Kub6iB3	26.8	0.6
2	Kud2mD3	34.9	0.8
3	Kum3mD3	207.1	4.9
4	Kus5iB1	238.5	5.6
5	Pan2fB3	69.2	1.6
6	Pan2hB2	85.2	2
7	Pan2hB3	38.4	0.9
8	Pan2iA3	163.9	3.9
9	Pan2iB3	214.4	5
10	Pan2mB3	615.7	14.5
11	Pan2mC3	115.2	2.7
12	Par1hA1	164.3	3.9
13	Par1iD3	265	6.2
14	Par1mB3	261.3	6.1
15	Tal3hB3	221.8	5.2
16	Tal3mC3	50.1	1.2
17	Forest	1328.6	31.2
18	Habitation	73.2	1.7
19	Waterbody	88.1	2.1
	Total	**4261.7**	**100.0**

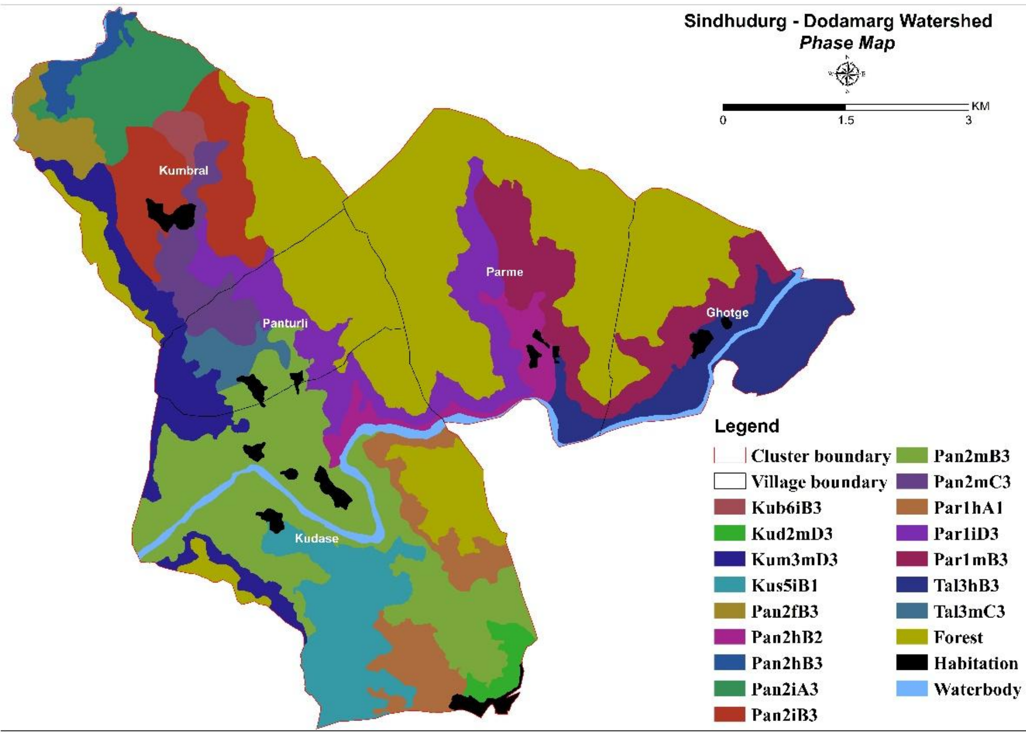


Fig. 4.4. Soil Phase map of Dodamarg watershed

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. Gentle slope tends 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, very 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. By considering the slope of land, farmers can implement soil conservation techniques, such as terracing, bunding or contour farming, to reduce erosion and optimize land use, ensuring more sustainable agricultural practices. Among the different slope classes (Table 4.10, Fig. 4.5) the maximum area of watershed is under very gently sloping (1 –3%), covering 41.6% followed by gently sloping (3-8%), covering 15.8% and level to nearly level land (0-1%) covering 3%. The analysis indicates that no steep slope categories are present in the watershed, suggesting that the area is primarily characterized by gentle terrain, which is favourable for agricultural activities and reduces the risk of severe soil erosion.

Table: 4.10. Land slope classes in Dodamarg watershed

Sr. No.	Slope Class (%)	Area (ha)	TGA (%)
1	Level to nearly level (0 - 1)	328.2	7.7
2	Very gently sloping (1 - 3)	1771.3	41.6
3	Gently sloping (3 - 8)	672.3	15.8
4	Forest	1328.6	31.2
5	Habitation	73.2	1.7
6	Waterbody	88.1	2.1
	Total	**4261.7**	**100.0**

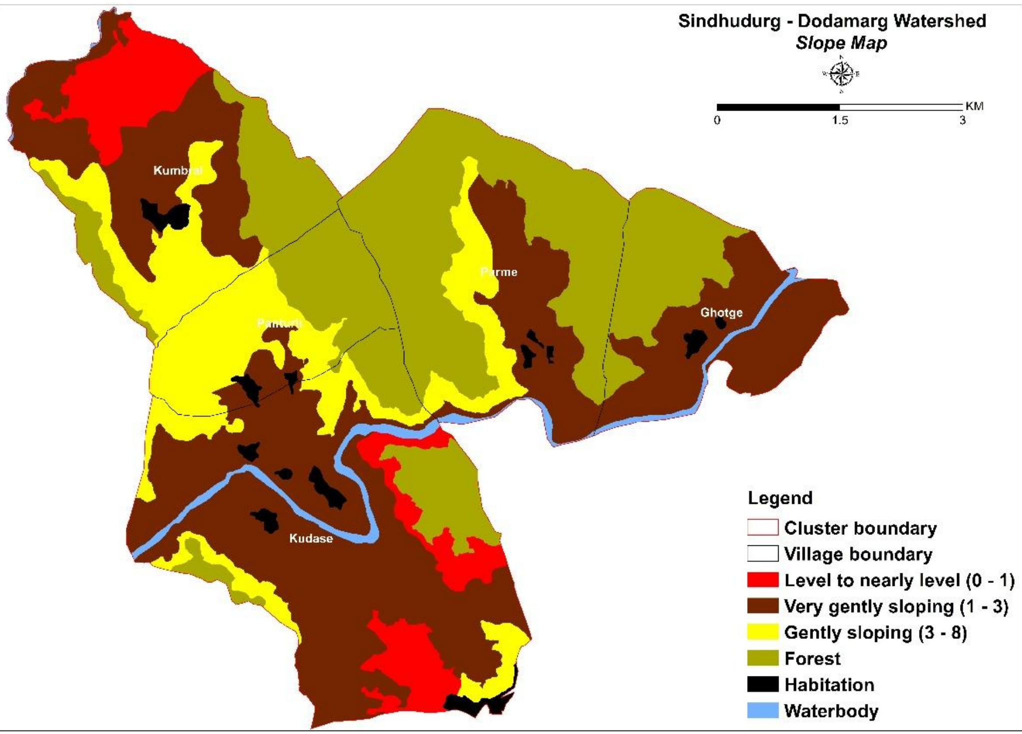


Fig. 4.5. Slope map of Dodamarg watershed

4.5.2 Soil Erosion

Soil erosion in the Sindhudurg-Dodamarg watershed varies from very slow to severe depending on local terrain and land conditions (Table 4.11). The analysis indicates that the majority of the watershed area, about 48.4%, falls under the Severe erosion category, suggesting that soil loss is present but generally not easy to manageable. A small portion of the area, 7.2%, experiences moderate-severe erosion, indicating relatively manageable soil conditions with conservation agriculture practices. However, about 9.5% of the watershed is affected by very slow erosion, representing zones were soil relatively stable soil conditions with minimal loss.

Table 4.11. Soil erosion status in Dodamarg watershed

Sr. No.	Erosion class	Area (ha)	Percent (%)
1	Very Slight	402.8	9.5
2	Moderate - Severe	307.0	7.2
3	Severe	2062.0	48.4
4	Forest	1328.6	31.2
5	Habitation	73.2	1.7
6	Waterbody	88.1	2.1
	Total	**4261.7**	**100.0**

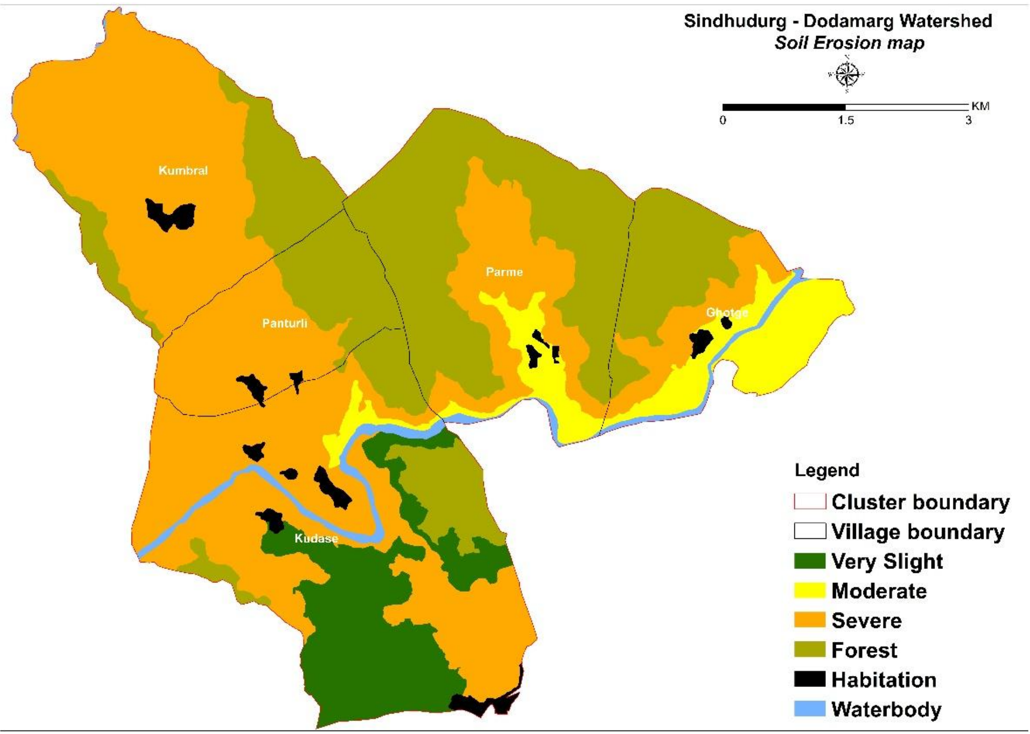


Fig. 4.6. Erosion map of Dodamarg watershed

4.5.3 Soil Depth

Soil depth is a crucial factor in agriculture as it 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 paedogenic processes such as weathering, translocation, erosion-deposition dynamics, and biological activity, all of which are strongly modulated by landscape position and hydrological condition. As a result, 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 showed that maximum area was under moderate (31.4%) followed by shallow (16.2%), moderately deep (11.2%) and very deep (6.2%).

Table 4.12. Soil depth classes in Dodamarg watershed

Sr. No.	Depth Class (cm)	Area (ha)	TGA (%)
1	Shallow (< 25)	690.7	16.2
2	Moderate (25 - 50)	1336.9	31.4
3	Moderately Deep (50 - 75)	479.0	11.2
4	Very Deep (> 100)	265.3	6.2
5	Forest	1328.6	31.2
6	Habitation	73.2	1.7
7	Waterbody	88.1	2.1
	Total	**4261.7**	**100.0**

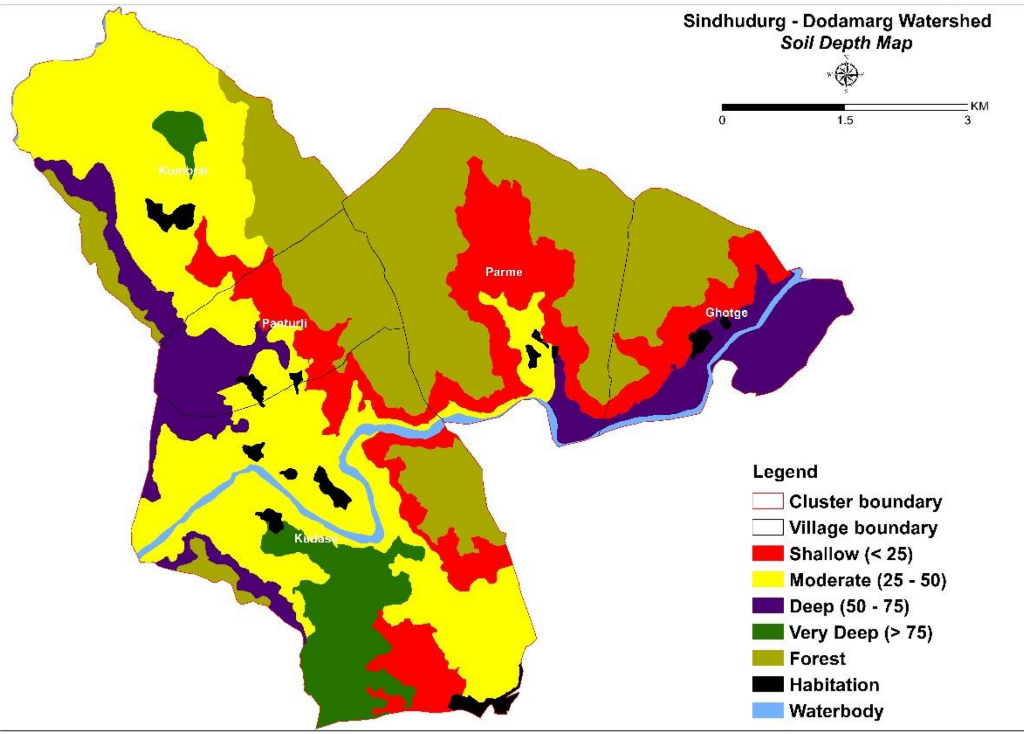


Fig. 4.7. Depth map of Dodamarg watershed

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 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 grouped into four classes (Table 4.13, Fig. 4.8). Among the different classes clay texture was found in 30.1% area followed by sandy clay covering 21.3%, sandy clay loam 12.0% and clay loam 1.6%. Based on the texture, the soils of the watershed particularly the highly sandy-clay soils are expected to be fertile and produce good crops.

Table 4.13. Soil texture distribution in Dodamarg watershed

Sr. No.	Texture	Area (ha)	TGA (%)
1	Clay	1284.2	30.1
2	Clay Loam	69.2	1.6
3	Sandy Clay	908.7	21.3
4	Sandy Clay Loam	509.7	12.0
5	Forest	1328.6	31.2
6	Habitation	73.2	1.7
7	Waterbody	88.1	2.1
	Total	**4261.7**	**100.0**

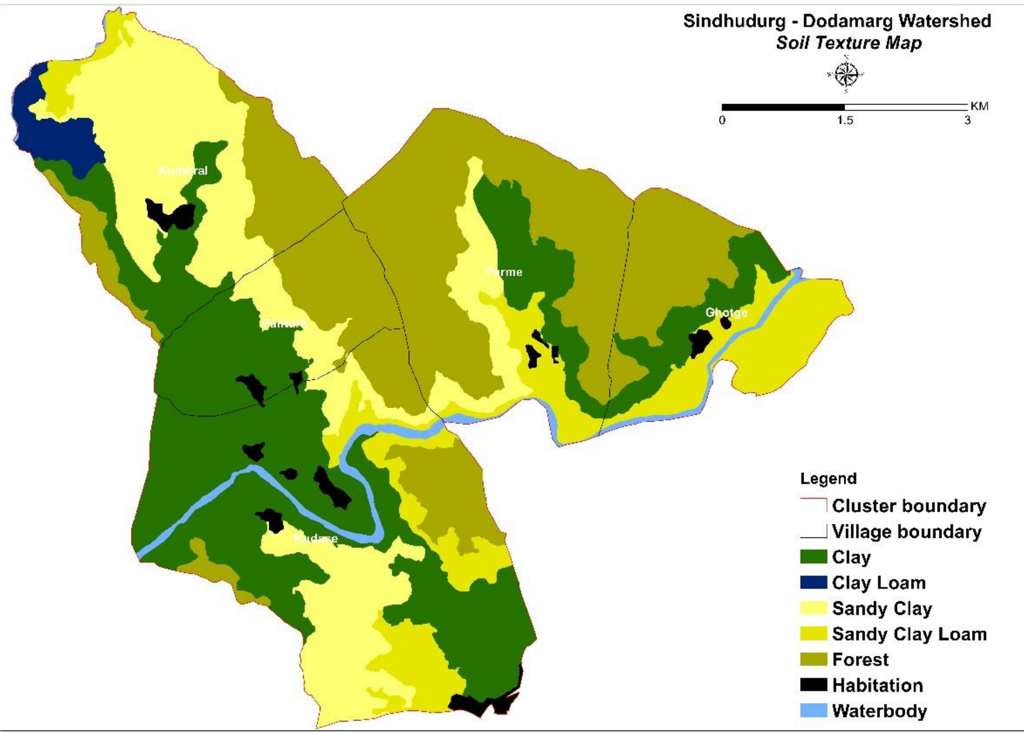


Fig. 4.8. Soil texture map of Dodamarg watershed

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. Soils of the watershed have been grouped into two soil reaction classes (Table 4.14, Fig. 4.9).

The data revealed that soils in watershed are primarily Moderately Acidic in reaction (pH 5.0 - 6.0) covering an area of about 62.4% followed by Slightly Acidic (pH 6.0 - 6.5).

Table 4.14. Soil pH distribution in Dodamarg watershed

Sr. No.	Soil pH	Area (ha)	TGA (%)
1	Moderately Acidic (5.0 - 6.0)	2659.9	62.4
2	Slightly Acidic (6.0 - 6.5)	112.0	2.6
3	Forest	1328.6	31.2
4	Habitation	73.2	1.7
5	Waterbody	88.1	2.1
	Total	**4261.7**	**100.0**

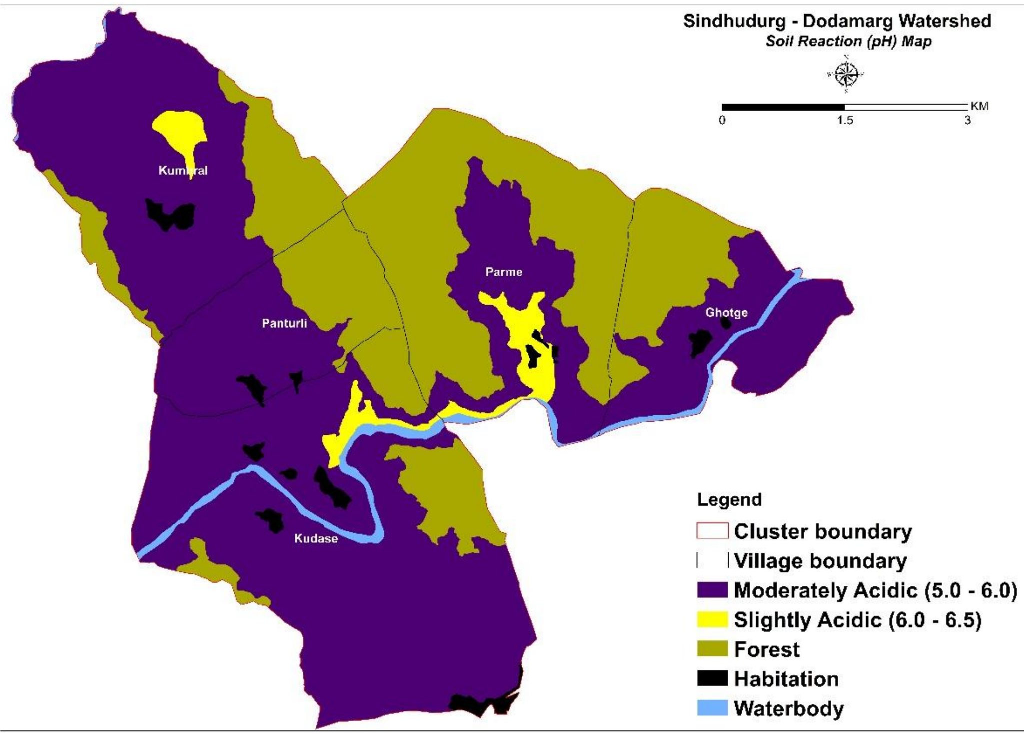


Fig. 4.9. Soil pH map of Dodamarg watershed

4.5.6 Soil salinity

Soil salinity, measured through the electrical conductivity of a solution within a unit distance, represents the content of soluble salts in the matrix. Soil conductivity is an index to measure soil water-soluble salt, which is an important indicator of mineral nutrients in the topsoil that can be quickly utilized by plants and is a factor to determine whether salt ions in soil limit crop growth. The EC of the soils of the watershed were well within the permissible limit of salinity (Table 4.15) and will Fig 4.10. The soil salinity status of the watershed (Table 4.15) shows that the majority of the area 65.0%, falls under the normal salinity class (EC < 1 dS/m), indicating minimal risk of salt-induced crop stress. The primarily of normal soils suggests that salinity is not a major constraint for agricultural activities in the Sindhudurg-Dodamarg watershed and most areas are suitable for crop cultivation without additional salinity management measures.

Table 4.15. Soil salinity classes in Dodamarg watershed

Sr. No.	Electrical conductivity (dSm^{-1})	Area (ha)	TGA (%)
1	Normal (0 - 1)	2771.9	65.0
2	Forest	1328.6	31.2
3	Habitation	73.2	1.7
4	Waterbody	88.1	2.1
	Total	**4261.7**	**100.0**

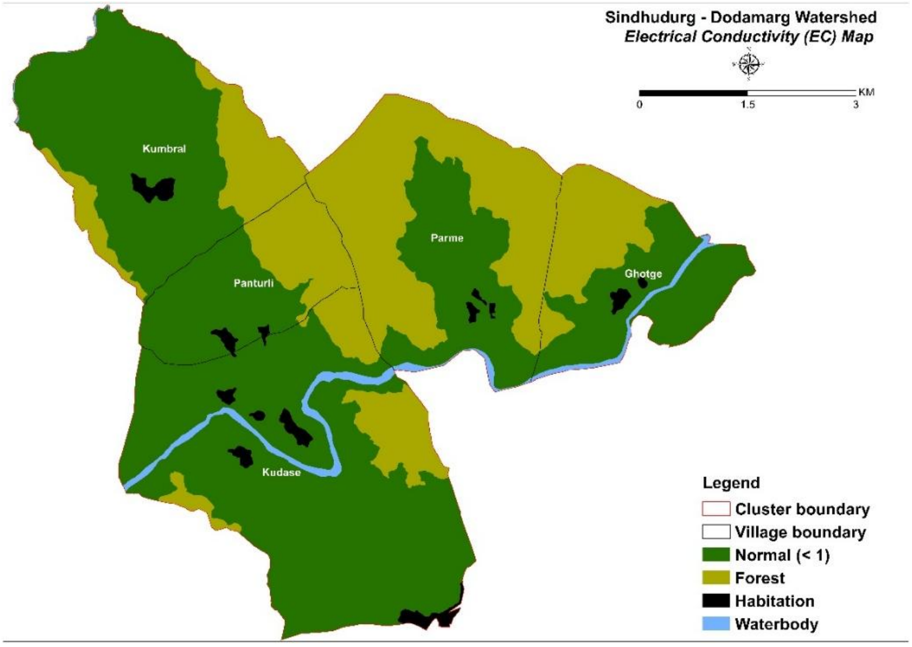


Fig. 4.10. Soil EC map of Dodamarg watershed

4.5.7 Soil organic carbon content

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.

Promotion of climate-smart practices that increase SOC can ensure healthier and productive soils. Soils of Sindhudurg-Dodamarg watershed supported very high SOC content, which can be inferred from Table 4.16 and Fig. 4.11. This is also indicated by the loamy soil texture prevalent in the watershed. Very high (>1.0%) OC soils account for 65% of the area. It is indicated that very high organic carbon for good fertility in the watershed.

Table 4.16. Extent of Soil organic carbon in soils of Dodamarg watershed

Sr. No.	Organic carbon (%)	Area (ha)	TGA (%)
1	Very High (> 1.00)	2771.9	65.0
2	Forest	1328.6	31.2
3	Habitation	73.2	1.7
4	Waterbody	88.1	2.1
	Total	**4261.7**	**100.0**

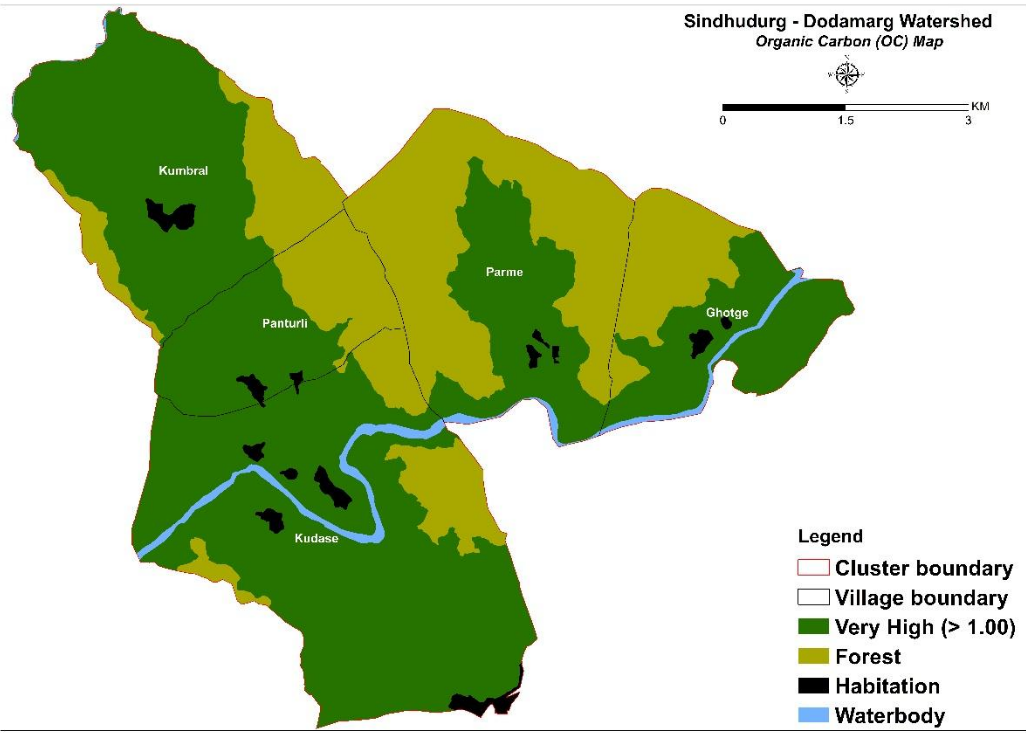


Fig. 4.11. Soil organic carbon map of Dodamarg watershed

4.5.8 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, 38.7% of the watershed area registered low N values (140-280 kg ha^{-1}) whereas in 9.6% area is very low N content (<140 kg ha^{-1}) is a matter of concern and medium N content (281-420 kg ha^{-1}) is 16.7% area. Therefore, it is advocated to apply the nitrogenous fertilizers as per crop needs to maximize crop yields in the watershed area.

Table 4.17. Available N content in soils of Dodamarg watershed

Sr. No.	Available N (kg ha^{-1})	Area (ha)	TGA (%)
1	Very Low (< 140)	410.1	9.6
2	Low (140 - 280)	1650.1	38.7
3	Medium (281 - 420)	711.7	16.7
4	Forest	1328.6	31.2
5	Habitation	73.2	1.7
6	Waterbody	88.1	2.1
	Total	**4261.7**	**100.0**

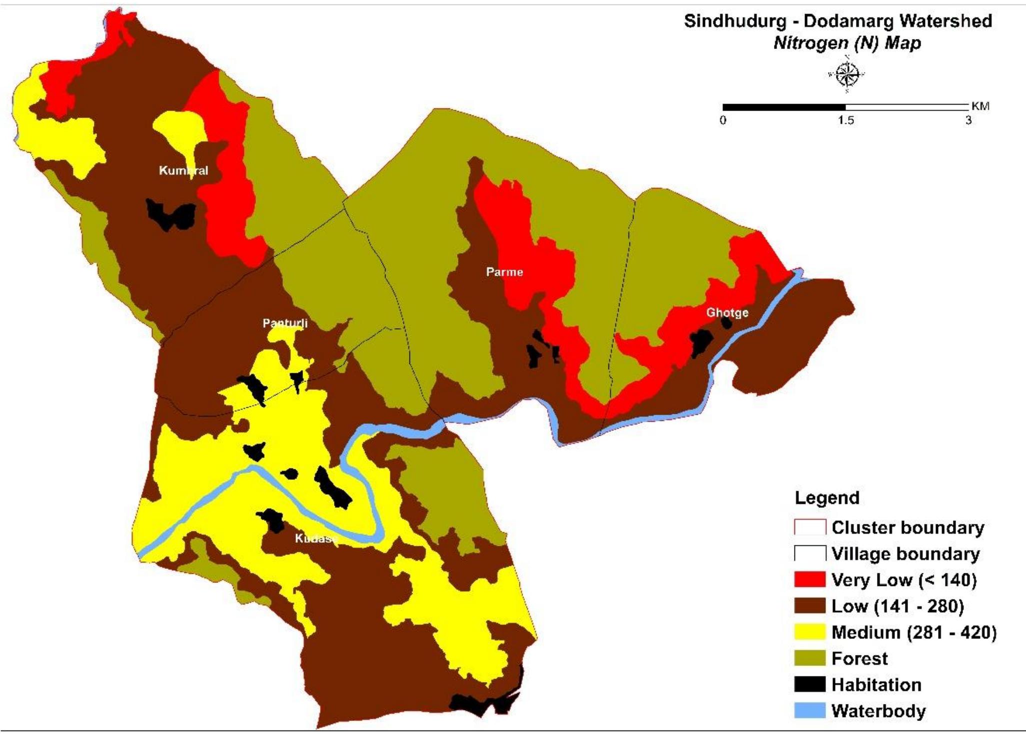


Fig. 4.12. Available soil Nitrogen map of Dodamarg watershed

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. The P content of the agricultural soils of the watershed (Table 4.18, Fig. 4.13) ranged from very low (<15 kg ha^{-1}) to Very High (> 80 kg ha^{-1}), with the highest area was under very low have P status 63% followed by very high 2%. The vast majority (two-three) of the area under very low to very high-status points to the fact that the farmers are not adequately applying phosphatic fertilizers to soils, and/or substantial amounts of applied fertilizer P is fixed in the soils owing to their calcareous nature.

Table 4.18. Available P content in soils of Dodamarg watershed

Sr. No.	Available P (kg ha^{-1})	Area (ha)	TGA (%)
1	Very Low (< 15)	2687	63
2	Very High (> 80)	85	2
3	Forest	1329	31
4	Habitation	73	2
5	Waterbody	88	2
	Total	**4262**	**100**

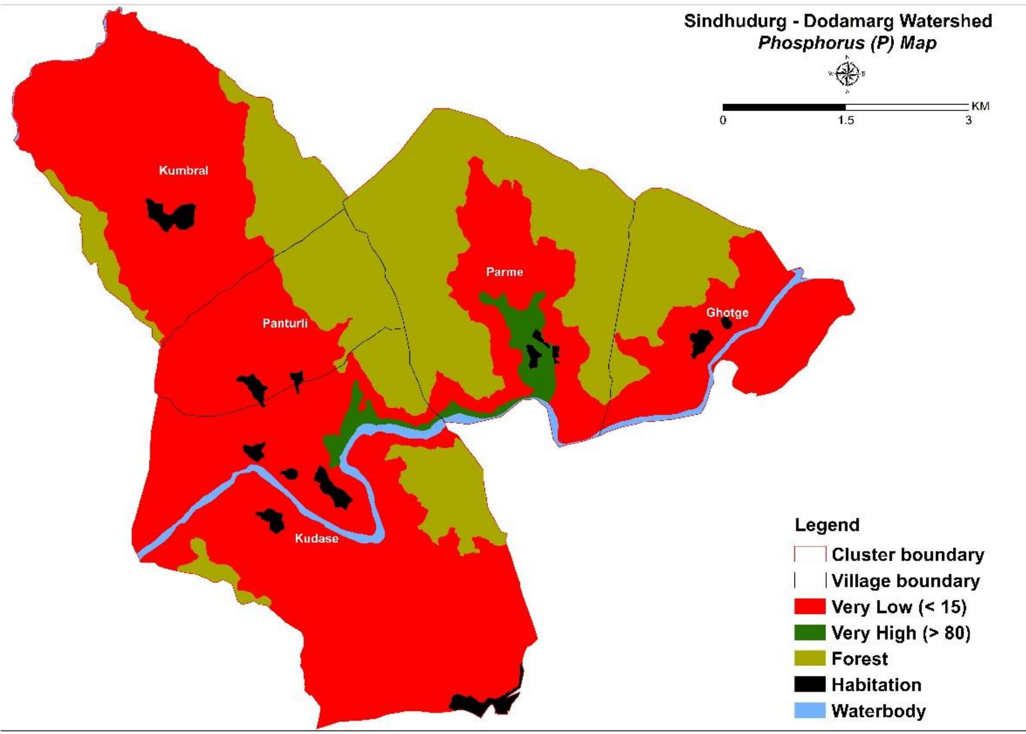


Fig.4.13. Available soil Phosphorus map of Dodamarg watershed

4.5.11 Available Potassium (K)

The importance of potassium (K) is well recognized in agriculture. Exchangeable K or available K is widely used to evaluate the soil K status and to predict the crop K requirements. Six classes of available K status (Table 4.19, Fig. 4.14) were observed in the watershed soils. Surprisingly, largest area 21.5% under the moderately high (241 - 300) K class. This is followed by low (121–180 kg/ha) soils covering 15.1%, Medium (181 - 240) soils at 12.7%, High (301 - 360kg/ha) soils at 9.5% and Very High (> 360 kg/ha) soil at 1.6%. It is indicated that large portions of the watershed have inadequate potassium for crop growth, targeted fertilization may be required in areas with low or moderate high K to optimize agricultural productivity.

Table 4.19. Available K content of soils of Dodamarg watershed

Sr. No.	Available K (kg ha^{-1})	Area (ha)	TGA (%)
1	Very Low (< 120)	200.4	4.7
2	Low (121 - 180)	642.3	15.1
3	Medium (181 - 240)	539.3	12.7
4	Moderately High (241 - 300)	915.9	21.5
5	High (301 - 360)	404.8	9.5
6	Very High (> 360)	69.2	1.6
7	Forest	1328.6	31.2
8	Habitation	73.2	1.7
	Total	88.1	2.1

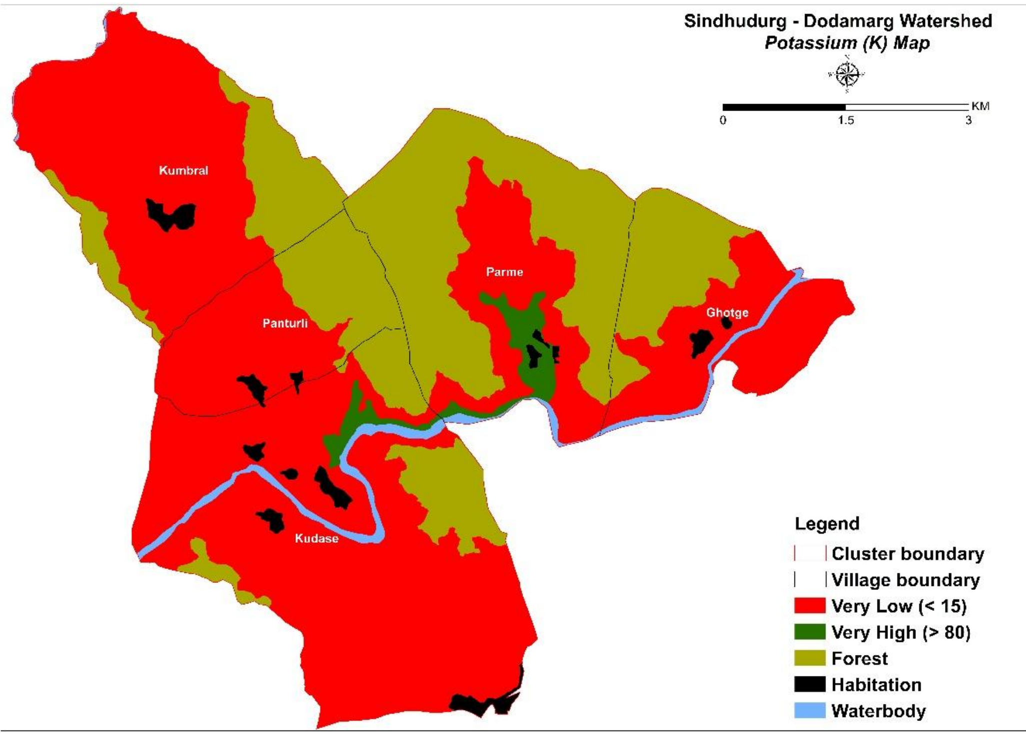


Fig. 4.14. Available soil Potassium map of Dodamarg watershed

4.5.11 Micronutrient status of soils

Although required in small quantities, soil micronutrients namely iron (Fe), zinc (Zn), copper (Cu) and manganese (Mn), measured as 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. Proper micronutrient management is particularly important in maintaining soil fertility by optimizing the efficiency of fertilizers. One class of available Fe were found in the watershed. Table 4.20 and Fig. 4.15 indicate that about 65% of the watershed area is very low Fe. About a two-third of the watershed area was categorized as very high (>10.5 mg kg-1) in DTPA-extractable Fe. Approximately 65.0% of the watershed was found in plant-available Mn content, while majority of the area is adequately supplied with Mn (Table 4.21, Fig. 4.16). Soils of the entire watershed are sufficient with respect to DTPA-extractable Cu (Table 4.22, Fig. 4.17), whereas more than 65% of the soils exhibit deficiency in available Zn (Table 4.23, Fig. 4.18), necessitating external Zn fertilization by the farmers.

Table 4.20. Available Fe content in the soils of Dodamarg watershed

Sr. No.	Available Fe (mg kg^{-1})	Area (ha)	TGA (%)
1	Very High (> 10.5)	2771.9	65.0
2	Forest	1328.6	31.2
3	Habitation	73.2	1.7
4	Waterbody	88.1	2.1
	Total	**4261.7**	**100.0**

Table 4.21. Available Mn content in the soils of Dodamarg watershed

Sr. No.	Available Mn (mg kg^{-1})	Area (ha)	TGA (%)
1	Very High (> 9.0)	2771.9	65.0
2	Forest	1328.6	31.2
3	Habitation	73.2	1.7
4	Waterbody	88.1	2.1
	Total	**4261.7**	**100.0**

Table 4.22. Available Cu content in the soils of Dodamarg watershed

Sr. No.	Available Cu (mg kg^{-1})	Area (ha)	TGA (%)
1	Very High (> 1.0)	2771.9	65.0
2	Forest	1328.6	31.2
3	Habitation	73.2	1.7
	Waterbody	88.1	2.1
	Total	**4261.7**	**100.0**

Table 4.23. Available Zn content in the soils of Dodamarg watershed

Sr. No.	Available Zn (mg kg^{-1})	Area (ha)	TGA (%)
1	Very Low (< 0.3)	866.5	20.3
2	Low (0.3 - 0.6)	1215.8	28.5
3	Medium (0.6 - 0.9)	236.5	5.6
4	Moderately High (0.9 - 1.2)	110.4	2.6
5	High (1.2 - 1.8)	342.6	8.0
6	Forest	1328.6	31.2
7	Habitation	73.2	1.7
8	Waterbody	88.1	2.1
	Total	**4261.7**	**100.0**

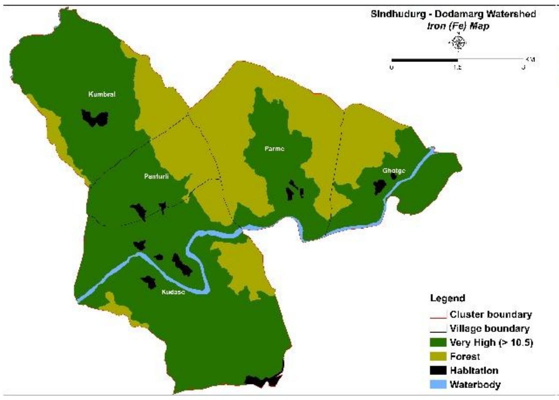


Fig. 4.15. DTPA-extractable soil Fe map of Dodamarg watershed

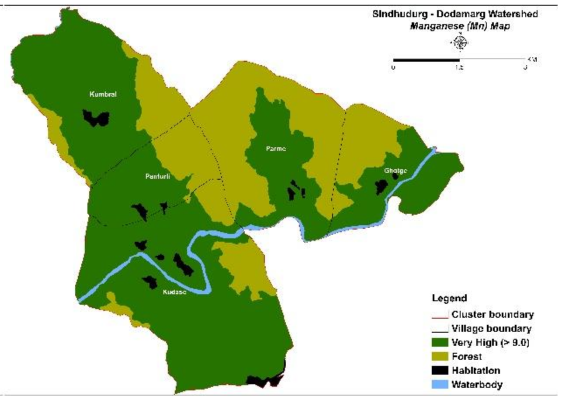
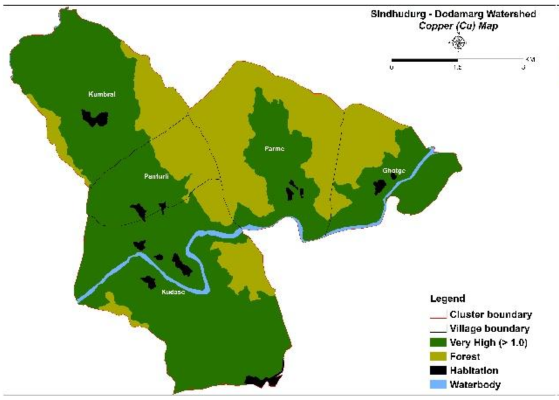


Fig. 4.16. DTPA-extractable soil Mn map of Dodamarg watershed



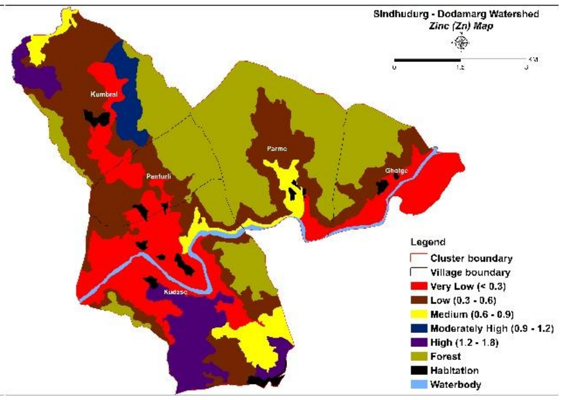


Fig. 4.17. DTPA-extractable soil Cu map of Dodamarg watershed

Fig. 418. DTPA-extractable soil Zn map of Dodamarg watershed

4.6 Surface Runoff

Surface runoff is a key component of watershed hydrology, especially in high-rainfall lateritic regions like Dodamarg Taluka. The study area, covering five villages across different landforms Escarpment, Hills & Ridges, and Pediment receives an average annual rainfall of approximately 1885 mm (2014-2024). Riverside areas generally have sufficient water due to better groundwater recharge and surface water access, but upland and hilly zones, particularly on Escarpments and Hills & Ridges, face challenges such as:

- High surface runoff and limited infiltration
- Seasonal drying of local sources post-monsoon
- Topsoil erosion during high-intensity rainfall
- Rapid drainage from unbunded or degraded slopes

These conditions required detailed runoff estimation to assess how much rainfall is lost as surface flow and to guide water-harvesting and watershed management interventions.

The annual and seasonal runoff was estimated using the SCS-Curve Number (CN) method, based on verified rainfall data, land use, and soil profiles. Daily rainfall records from IMD over 2014-2024 were compiled, and land use and soil conditions were mapped through satellite imagery, field surveys, and consultation with local farmers. Curve Numbers were assigned for each land-use and landform type, and runoff was estimated for each monsoon season, accounting for antecedent moisture. Runoff was highest in July and August, especially on paddy fields in low-slope areas of the Pediment, while Escarpments and Hills & Ridges showed rapid drainage and limited infiltration. These estimates represent potential runoff, with actual runoff moderated by bunding, infiltration, and crop water use.

Based on daily rainfall records for the 11-year period was compiled from IMD and verified land conditions. Land use and soil conditions were mapped through satellite imagery, field surveys, and consultation with local farmers. Based on this, Curve Numbers were assigned and runoff estimated for each monsoon season, adjusted for antecedent moisture based on rainfall distribution patterns.

The estimated values provide an upper limit for planning water-harvesting interventions, ensuring that structures are appropriately scaled to capture excess runoff without overdesigning storage or drainage.

Monthly Rainfall-Runoff Characteristics

The monthly rainfall and runoff values for the monsoon months (June to October) during the period 2014-2024 are presented in Table 4.24. The table indicates considerable variation in both rainfall and runoff across months and years.

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	130.4	0.0	715.1	182.1	317.7	10.4	146.7	0.1	162.8	0.0
2015	415.7	47.4	150.7	0.0	143.4	0.0	37.6	0.0	119.0	0.2
2016	219.2	1.6	669.2	189.0	574.6	104.5	128.0	0.0	28.6	0.0
2017	313.3	15.2	616.3	141.8	159.7	0.1	258.0	0.0	111.9	0.0
2018	417.1	65.5	788.7	158.3	486.0	25.0	143.3	6.3	62.7	0.0
2019	192.7	16.1	747.4	174.0	1086.1	534.8	367.1	55.7	326.8	12.0
2020	348.7	39.3	328.6	33.8	947.4	352.7	224.9	1.4	136.9	0.0
2021	450.6	119.0	620.2	232.0	157.5	0.0	241.3	7.0	121.4	0.0
2022	165.9	0.2	589.3	104.7	560.0	114.2	325.4	43.8	171.1	0.3
2023	117.3	0.0	621.4	107.7	111.6	0.0	82.3	0.0	46.2	0.0
2024	262.9	1.0	1293.5	395.7	502.5	76.2	178.5	2.1	195.8	0.6
Average	**275.8**	**27.8**	**649.1**	**156.3**	**458.8**	**110.7**	**193.9**	**10.6**	**134.8**	**1.2**

As shown in Table 1, runoff peaks in July and August, accounting for most of the seasonal runoff, while October runoff is negligible. Even in June, much of the early rainfall is absorbed by dry soils, resulting in lower runoff. Plantation areas, with canopy cover and soil protection, contribute lower runoff compared to small paddy fields on gentle slopes, which locally generate higher potential runoff.

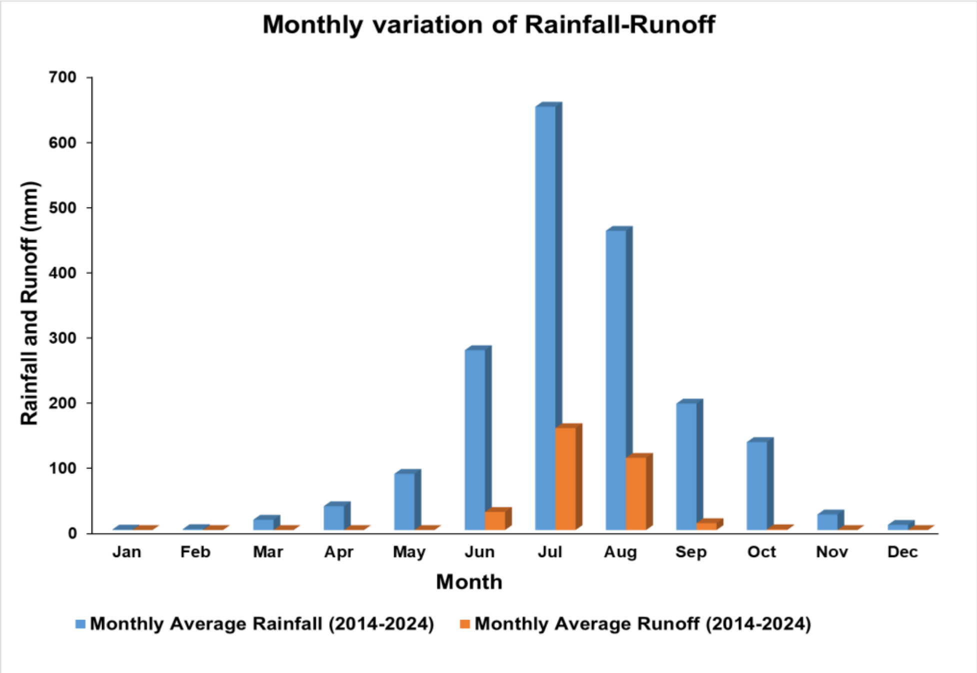


Fig 4.19. Monthly variation of rainfall-runoff in Dodamarg watershed

Annual Rainfall-Runoff Relationship

Annual rainfall, runoff depth, number of runoff events, and runoff percentage for the study period are summarised in Table 4.25.

Table 4.25. Relationship between rainfall and runoff

Year	Rainfall (mm)	Runoff (mm)	No. of Runoff Events	Runoff (%)
2014	1739.9	192.5	22	11.1
2015	1043.6	47.6	6	4.6
2016	1734.1	295.1	20	17.0
2017	1606.4	157.0	16	9.8
2018	2081.8	255.2	32	12.3
2019	2810.5	792.6	40	28.2
2020	2102.9	427.1	24	20.3
2021	1925.0	358.7	19	18.6
2022	2060.2	263.1	31	12.8
2023	1096.4	107.7	12	9.8
2024	2530.2	475.4	39	18.8
Average	**1884.6**	**306.5**	**24**	**16.3**

The study revealed that on average, about 16-17% of annual rainfall contributes to surface runoff, while the rest is absorbed by the soil, utilized by crops, or lost to evaporation. Runoff is highly seasonal, with over 87 % occurring in July and August, when rainfall intensity is highest and soils are saturated. Landforms influence runoff patterns: Escarpments and Hills & Ridges show rapid drainage and localized erosion, whereas Pediments with gentle slopes and plantations reduce runoff through infiltration and canopy interception. These patterns highlight the need for watershed-level interventions, combining water harvesting structures and vegetative measures, to manage excess runoff and improve soil moisture retention.

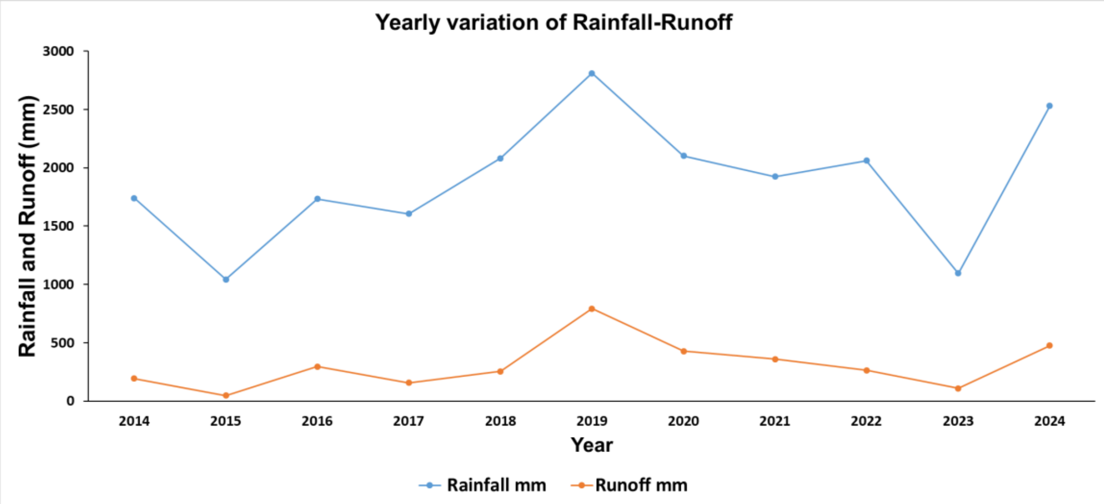


Fig 4.20. Yearly variation of rainfall-runoff in Dodamarg watershed

4.7 Mapping of Groundwater Potential Zones

Groundwater serves as a key source of drinking, domestic, and irrigation water in Dodamarg Taluka, particularly in upland and non-command areas where surface water is limited or seasonal. Despite an average annual rainfall of 1885 mm (2014-2024), recharge is uneven due to complex hydrogeology and variable infiltration, creating challenges for sustainable water management and highlighting the need for detailed groundwater potential assessment.

To address this, a Groundwater Potential Zonation (GWPZ) map was prepared for five villages cluster watershed in Dodamarg. The map was developed using multi-criteria spatial analysis of eight thematic layers: lithology, land use/land cover, drainage density, soil type, slope, elevation, landform, and rainfall distribution. Each factor was standardized and weighted through the Analytical Hierarchy Process (AHP) with expert input and literature support to reflect its influence on recharge and storage.

Weighted overlay analysis in GIS classified the watershed into five categories: Very Good, Good, Moderate, Poor, and Very Poor groundwater potential. The results indicate that 19.7% of the area falls under Very Poor potential, characterized by steep slopes, rocky terrain, and poor soil cover, while 21.3% is classified as Poor, with low infiltration and high runoff. The largest portion, 32.3%, has Moderate potential, found in undulating terrain with moderate recharge capacity. Areas with Good potential account for 22.5%, and only a small fraction, 4.2%, is classified as Very Good. Overall, this indicates that while some parts of the watershed can support effective groundwater recharge, the majority of the area requires targeted interventions to improve water availability and sustainable management.

The GWPZ map provides important spatial information for planning under PMKSY-WDC 2.0, guiding the design of recharge structures, soil moisture conservation measures, and land treatment interventions. It also identifies priority micro-watersheds requiring urgent attention and areas where alternative water supply strategies may be necessary.

Considering the complex hydrogeology of the Konkan region, this integrated assessment is crucial for sustainable groundwater management in Dodamarg Taluka. It enables judicious use and augmentation of groundwater resources in the five focus villages, ensuring long-term water security for domestic, agricultural, and ecological needs while supporting socio-economic development.

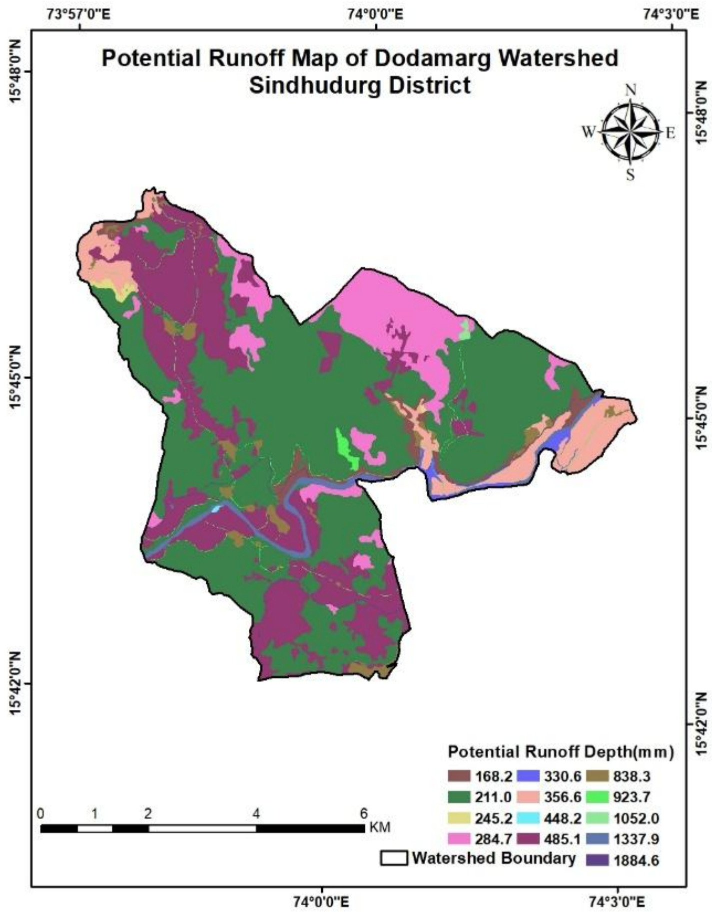


Fig. 4.21. Ground water potential zones in Dodamarg watershed

4.8 Evaluation of Soil-Site Suitability for Crops

Soil and climate are the prime factors governing optimum crop growth. Soil physicochemical properties and crop micro-environment control the availability of water and essential plant nutrients. Therefore, key soil attributes, *viz.* soil depth, texture, fertility status and drainage conditions are carefully assessed during soil-site evaluation. This enables meaningful interpretation of soil maps in terms of their suitability for field and horticultural crops and contributes to the formulation of scientific land-use plans for watershed development. The suitability of soils for crop cultivation was determined based on the criteria proposed by Naidu et al. (2006). The concept of land utilization types and the classification system for land evaluation categorizes land into different hierarchical levels, namely orders, classes, sub-classes, and units. Two major orders are recognized: ‘S’ (Suitable) and ‘N’ (Not suitable), representing the general suitability status of land. Under the suitable order (S), three classes S1, S2, and S3 indicate high, moderate, and marginal suitability, respectively, while the not suitable order (N) includes two classes N1 and N2 representing current and permanent unsuitability. The assignment of these classes is based on the degree of land limitations affecting crop production.

The major land limitations considered in this evaluation exercise include those imposed by climate (c), topography (t), wetness (w), soil fertility (f), and physical soil constraints (s). These limitations were graded on a scale from 0 to 4, where 0 indicates no limitation and optimal conditions for crop growth; 1 denotes slight limitation with nearly optimal conditions; 2 indicates moderate limitation with noticeable effects on crop performance; 3 represents severe limitation rendering the land uneconomical for the proposed use; and 4 reflects very severe limitation, where crop yields fall below economically viable levels, making the land unsuitable for the intended use.

Several soil-site parameters, including climatic variables (rainfall, temperature); topographic features (slope, landscape position, and erosion susceptibility); wetness conditions (drainage, flooding risk and soil aeration); physical soil properties (texture, depth, structure and available soil moisture); fertility attributes (soil pH, nutrient availability, organic matter content, cation exchange capacity, base saturation) and groundwater table were examined to determine land suitability for agricultural crops and other land uses. Based on the parametric integration, the watershed area was evaluated for its suitability for the following commonly cultivated and potential-for-introduction crops.

4.8.1 Soil-Site Suitability for Cashewnut Cultivation

The soil-site evaluation for Cashewnut cultivation shows areas categorized as moderately suitable (S2) which covering 265.3ha (6.2%) of the total geographical area is classified, these areas provide acceptable conditions for its cultivation, though certain soil and site constraints may affect crop performance. A portion of the watershed, covering 479.0 ha (11.2%), falls under the marginally suitable (S3) category (Table 4.26, Fig. 4.22), indicating the presence of moderate limitations that may restrict yield potential. About 2027.5 ha (47.6%) of the area is categorized as not suitable (N) for Cashewnut cultivation due to severe soil and site-related constraints. Overall, the assessment indicates that nearly half of the watershed is unsuitable for Cashewnut cultivation, while about one-tenth of the area exhibits marginally suitability.

Table 4.26. Area under suitability sub-classes for Cashewnut cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Moderately Suitable (S2)	265.3	6.2
2	Marginally Suitable (S3)	479.0	11.2
3	Not Suitable (N)	2027.5	47.6
4	Forest	1328.6	31.2
5	Habitation	73.1	1.7
6	Waterbody	88.1	2.1
	Total	**4261.7**	**100.0**

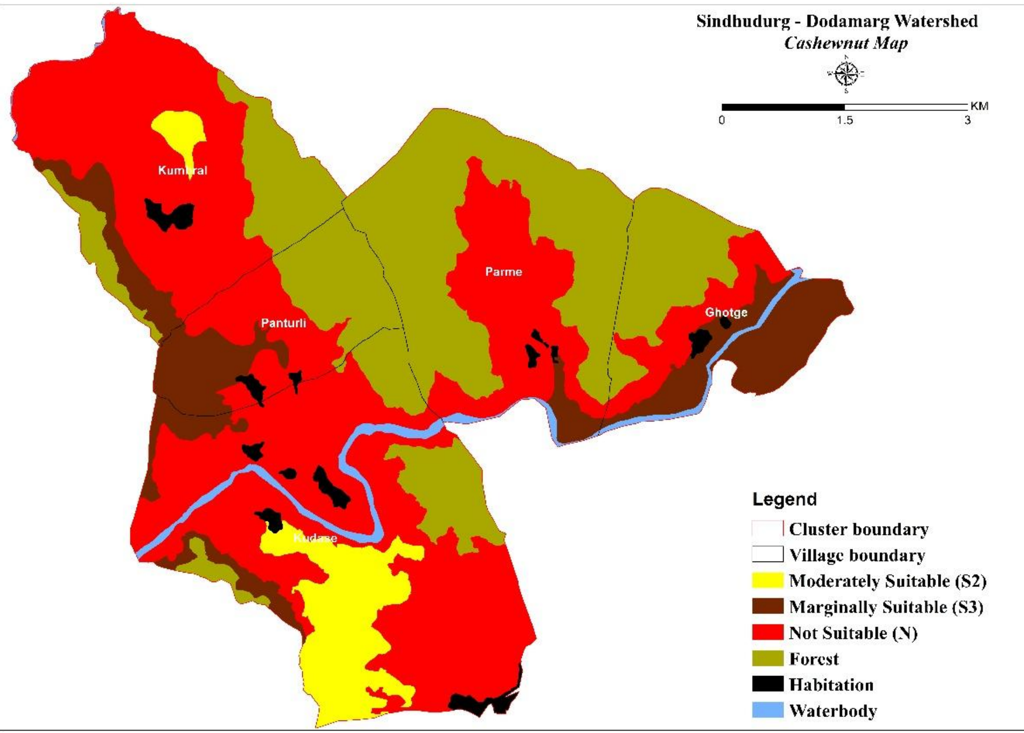


Fig. 4.22. Soil site suitability map for Cashewnut cultivation

4.8.2 Soil-Site Suitability for Rice Cultivation

Soil-site evaluation results for Rice show a varied distribution of suitability classes across the watershed (Table 4.27, Fig. 4.23). Areas categorized as moderately suitable (S2) cover 487.1 ha, accounting for about 11.4% of the total geographical area, representing zones where Rice cultivation is feasible, although certain soil or site constraints may influence yield levels. The marginally suitable (S3) category extends over 1594.0 ha (or 37.4%), suggesting the presence of noticeable limitations that may restrict optimum crop growth. About 16.2% of the watershed is not suitable (N) for Rice cultivation. These results most favorable for Rice cultivation in the Sindhudurg-Dodamarg watershed by following recommended package of practices.

Table 4.27. Area under suitability sub-classes for Rice cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Moderately Suitable (S2)	487.1	11.4
2	Marginally Suitable (S3)	1594.0	37.4
3	Not Suitable (N)	690.7	16.2
4	Forest	1328.6	31.2
5	Habitation	73.1	1.7
6	Waterbody	88.1	2.1
	Total	**4261.7**	**100.0**

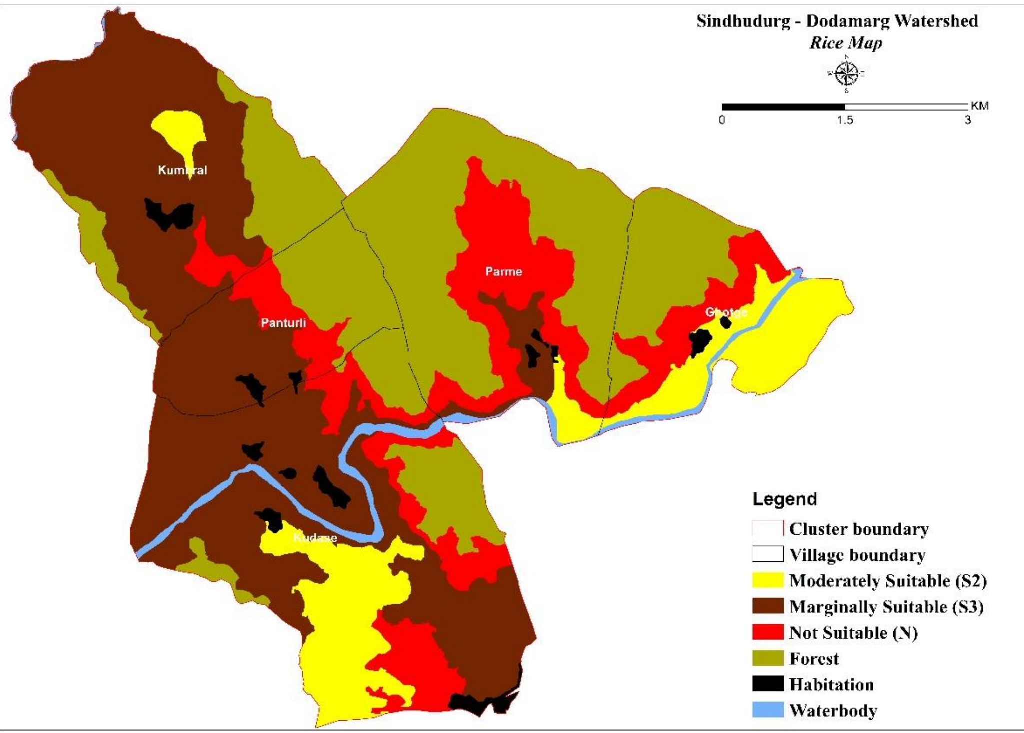


Fig. 4.23. Soil site suitability map for Rice cultivation

4.8.3 Soil-Site Suitability for Arecanut Cultivation

Only 26.8 ha (0.6%) of the watershed area was found to be highly suitable (S1) and 5.6% area was moderately (S2) suitable for Arecanut, providing optimal and/or manageable conditions for crop growth and productivity. Approximately one-tenth of the watershed can only marginally suitable for Arecanut crop, indicating moderate to severe soil, terrain and environmental constraints limiting crop productivity. An additional 2027.5 ha (47.6%) of the area is unsuitable for the crop, suggesting that Arecanut may not be the best bet for Sindhudurg-Dodamarg watershed, or needs to be cultivated by strictly following the recommended package of practices (Table 4.28, Fig. 4.24).

Table 4.28. Area under suitability sub-classes for Arecanut cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Marginally Suitable (S1)	26.8	0.6
2	Moderately Suitable (S2)	238.5	5.6
3	Marginally Suitable (S3)	479.0	11.2
4	Not Suitable (N)	2027.5	47.6
5	Forest	1328.6	31.2
6	Habitation	73.1	1.7
7	Waterbody	88.1	2.1
	Total	**4261.7**	**100.0**

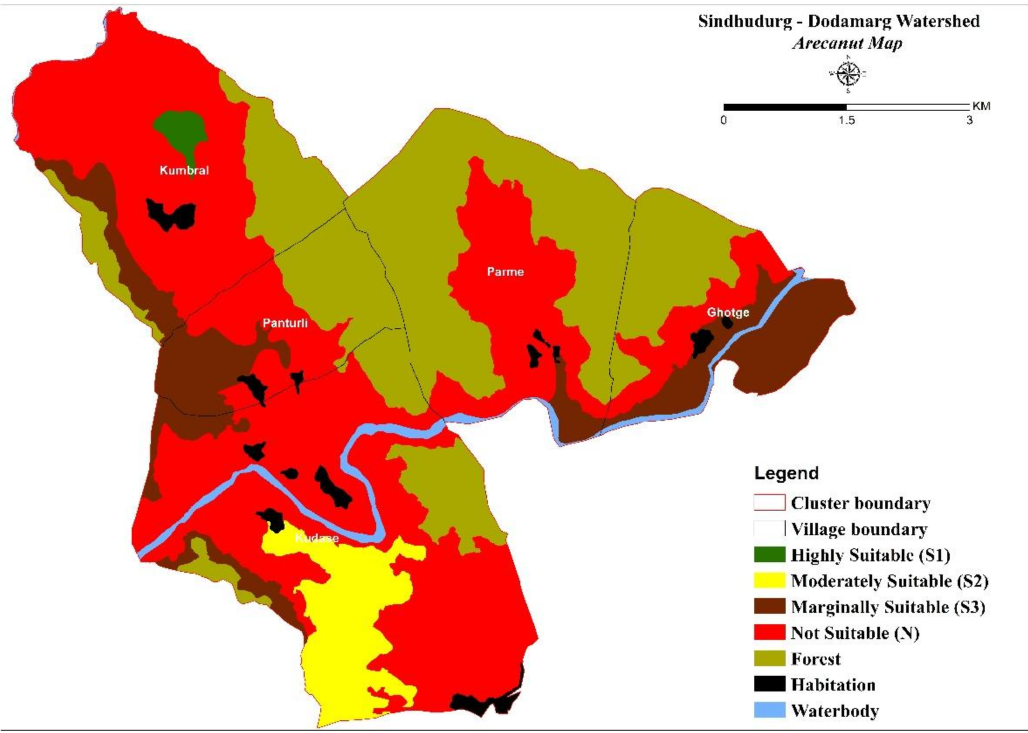


Fig. 4.24. Soil site suitability map for Arecanut cultivation

4.8.4 Soil-Site Suitability for Jackfruit Cultivation

26.8 ha (0.6%) of the watershed area is moderately suitable (S2), and another 238.5 ha (5.6%) is marginally suitable for jackfruit cultivation. While the former class represents areas with more acceptable conditions for crop growth, the latter would permit cultivation after following recommended conservation or ameliorative measures. About 58.8% of the watersheds was identified as not suitable (N) for jackfruit cultivation due to severe soil and site limitations (Table 4.29, Fig. 4.25).

Table 4.30. Area under suitability sub-classes for Jackfruit cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Moderately Suitable (S2)	26.8	0.6
2	Marginally Suitable (S3)	238.5	5.6
3	Not Suitable (N)	2506.5	58.8
4	Forest	1328.6	31.2
5	Habitation	73.1	1.7
6	Waterbody	88.1	2.1
	Total	**4261.7**	**100.0**

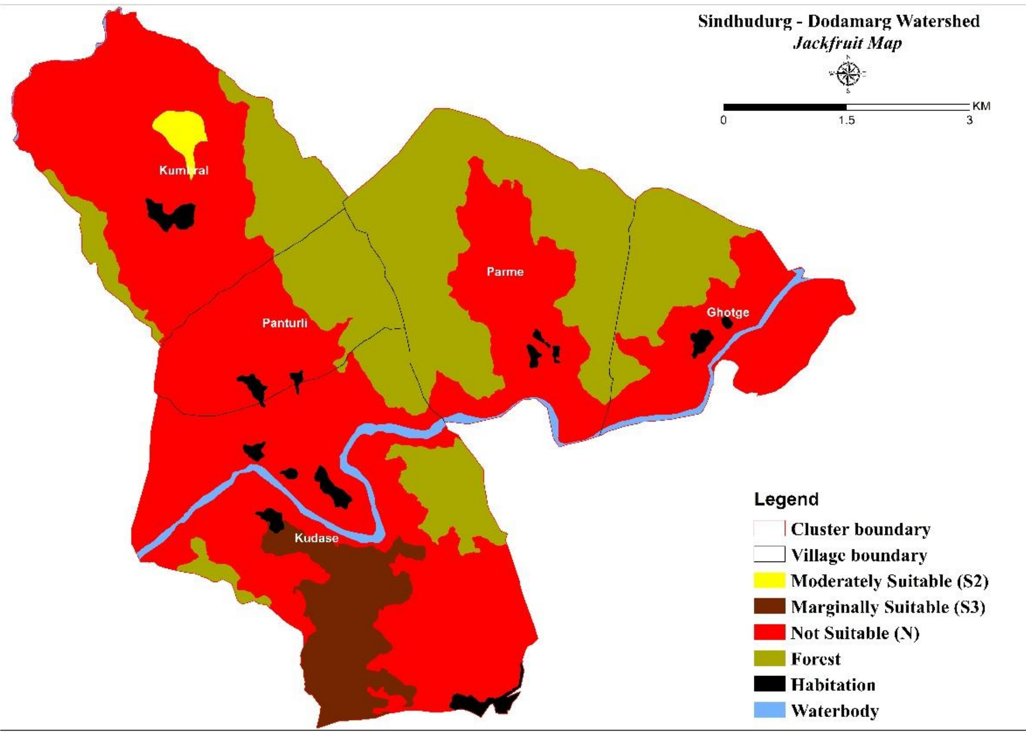


Fig. 4.25. Soil site suitability map for Jackfruit cultivation

4.8.5 Soil-Site Suitability for Mango Cultivation

The soils of the watershed were evaluated for mango cultivation based on crop-specific requirements. The distribution of suitability classes is presented in Table 4.30. The results indicate that about 26.8 ha (0.6%) of the watershed area is moderately suitable (S2), provides minor soil and environmental constraints may reduce crop productivity. Around 5.6% of the watershed was found to be marginally suitable (S3) for the crop, reflecting moderate to severe limitations related to soil and terrain parameters that may restrict yield potential unless appropriate agronomic management practices are adopted. About 58.8% of the watershed area is not suitable (N) for mango cultivation due to severe soil and site constraints. (Table 4.30, Fig. 4.26).

Table 4.30. Area under suitability sub-classes for Mango cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Marginally Suitable (S2)	26.8	0.6
2	Moderately Suitable (S3)	238.5	5.6
3	Not Suitable (N)	2506.5	58.8
4	Forest	1328.6	31.2
5	Habitation	73.1	1.7
6	Waterbody	88.1	2.1
	Total	**4261.7**	**100.0**

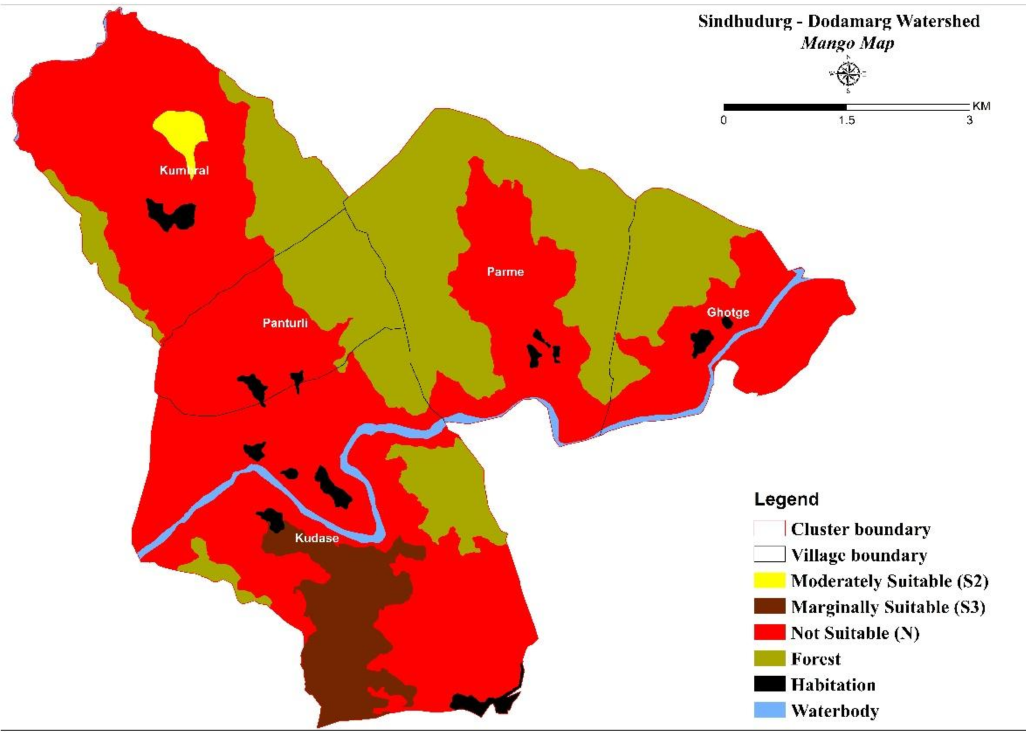


Fig. 4.26. Soil site suitability map for Mango cultivation

4.8.6 Soil-Site Suitability for Coconut Cultivation

he soils of the watershed were evaluated for coconut cultivation based on crop-specific requirements. The distribution of suitability classes is presented in Table 4.31. The results indicate that only 265.3 ha (6.2%) of the watershed area provides favorable soil and site conditions for optimal crop growth and is highly suitable (S1) for coconut. Around 11.2% of the watershed was found to be marginally suitable (S3) for the crop, reflecting moderate to severe limitations related to soil and terrain parameters that may restrict yield potential unless appropriate agronomic management practices are adopted.

Around 47.6% of the watershed area is not suitable (N) for rice cultivation due to severe soil and site constraints. Therefore, it is suggested that nearly one-tenth of the watershed may be put under coconut cultivation, and in marginally suitable areas, appropriate agronomic and soil and water management interventions may be adopted (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	Highly Suitable (S1)	265.3	6.2
2	Marginally Suitable (S3)	479.0	11.2
3	Not Suitable (N)	2027.5	47.6
4	Forest	1328.6	31.2
5	Habitation	73.1	1.7
6	Waterbody	88.1	2.1
	Total	**4261.7**	**100.0**

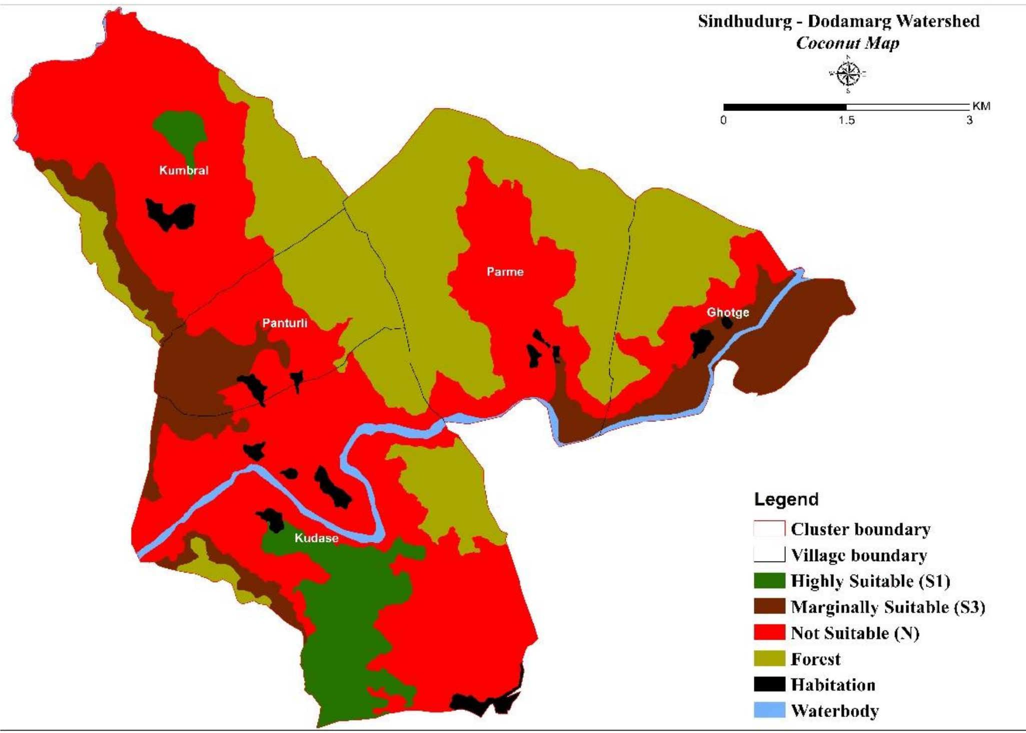


Fig. 4.27. Soil site suitability map for Coconut cultivation

4.8.7 Soil-Site Suitability for Banana Cultivation

The suitability assessment for banana cultivation across the watershed reveals a broad range of suitability classes (Table 4.32, Fig. 4.29). Areas covering 26.8 ha (0.6%), 238.5 ha (5.6%) and 479.0 (11.2%) ha have been classified under highly suitable (S1), moderately suitable (S2) and marginally suitable (S3) categories, respectively. In contrast, 2027.5ha (47.6%) of the area is classified as not suitable (N) for Banana cultivation due to severe soil and environmental limitations. The evaluation therefore points at about most of the watershed being conducive for Banana cultivation for obtaining desired yield levels, although the marginally suitable land could be productive, albeit after incurring soil restorative costs (appropriate land-use planning and targeted management interventions).

Table 4.32. Area under suitability sub-classes for Banana cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Highly Suitable (S1)	26.8	0.6
2	Moderately Suitable (S2)	238.5	5.6
3	Marginally Suitable (S3)	479.0	11.2
4	Not Suitable (N)	2027.5	47.6
5	Forest	1328.6	31.2
6	Habitation	73.1	1.7
7	Waterbody	88.1	2.1
	Total	**4261.7**	**100.0**

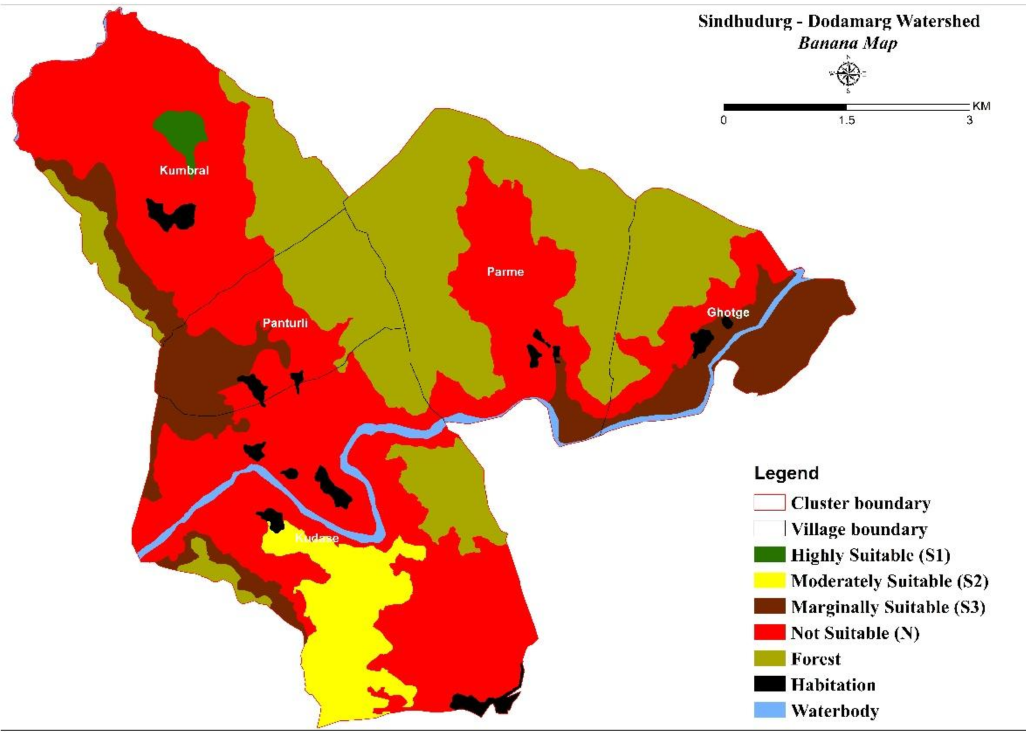


Fig. 4.28. Soil site suitability map for Banana cultivation

4.9 Soil and Water Conservation measures

Soil and water conservation is essential for maintaining the productivity and sustainability of land resources in Dodamarg Taluka. The taluka features diverse landforms, varying slopes, and soil depths, which influence water retention, runoff patterns, and soil stability. A systematic conservation plan is necessary to address these conditions, improve agricultural efficiency, and reduce land degradation.

The SWC plan for Dodamarg Taluka includes interventions across different landforms and land use categories. Silt Detention Trenches in Downstream areas, primarily applied to forested lands, degraded forest, and escarpment areas. These trenches help stabilize soil, control runoff, and enhance water retention in downstream zones.

In-situ Moisture Conservation Measures are implemented mainly in plantation and cultivated lands across escarpments, pediments, and hills. These measures improve soil moisture, prevent erosion on moderate slopes, and support sustainable agriculture. Combined interventions of Afforestation, Contour Trenches, and Silt Detention Trenches, focusing on degraded forests and escarpment zones to restore vegetation, reduce erosion, and manage runoff effectively.

Interventions involving both In-situ Moisture Conservation Measures and Farm ponds with Lining, while additional farm pond measures without lining, supporting water storage and irrigation in cultivated and plantation lands.

Urban and infrastructure areas are also included. Built-up areas, covering 91 ha, address runoff management, while Stream Bank Plantations along rivers cover 80.5 ha to stabilize banks and prevent erosion. Roads, covering 21.8 ha, are treated for slope and runoff management. Smaller interventions, including Afforestation with In-situ measures and miscellaneous treatments, address patches of degraded land. Canals, covering 13 ha, are maintained to support water distribution, and water bodies, covering 0.5 ha, are renovated according to site conditions.

Each intervention has been assigned proportionally to the area requiring treatment, ensuring that conservation efforts are both effective and practical. Through these measures, Dodamarg Taluka is expected to achieve improved soil stability, controlled runoff, enhanced water retention, and long-term sustainability of its agricultural and forested lands.

Table 4.33. Proposed soil and water conservation (SWC) plan for Dodamarg watershed

Sr. No.	Proposed SWC Plan
1	Silt Detention Trench in Downstream
2	In-situ Moisture Conservation Measures
3	Afforestation, Contour Trench, Silt Detention Trench in Downstream
4	In-situ Moisture Conservation Measures, Farm pond with Lining
5	Built-up
6	Stream Bank Plantation
7	In-situ Moisture Conservation Measures, Farm pond
8	Road
9	Afforestation, In-situ Moisture Conservation Measures
10	Afforestation, In-situ Moisture Conservation Measures
11	Miscellaneous
12	Afforestation, In-situ Moisture Conservation Measures, Farm pond with Lining
13	Renovation of Waterbody as per the site condition

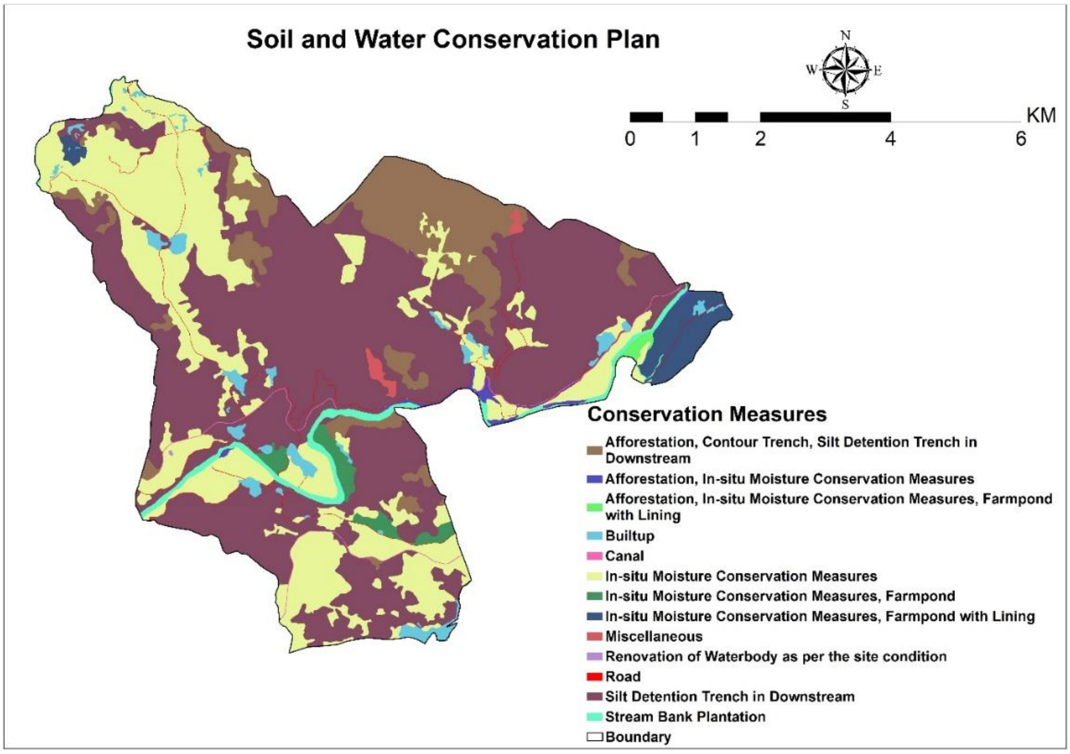


Fig. 4.29. Soil and Water Conservation measures proposed for Dodamarg watershed

CHAPTER 5

SUMMARY AND CONCLUSION

5.1 SUMMARY

- The Land Resource Inventory (LRI) was conducted for the Sindhudurg (WDC-2.0) 3/2021-22 watershed, located in the Dodamarg Taluka of Sindhudurg District, Maharashtra, under the Pradhan Mantri Krishi Sinchayee Yojana - Watershed Development Component (PMKSY-WDC 2.0).
- The area is situated in the Konkan region, characterized by the basaltic terrain of the Deccan Plateau, with the Chapora river traversing the watershed. The terrain includes diverse geomorphic units like plateau, pediment, pediplain, hills and valley landforms, with varied slopes.
- The main natural resource constraint is the agricultural system's primary dependence on and vulnerability to irregular monsoon precipitation and associated variability, necessitating efficient water management and soil conservation measures.
- The assessment focused on the systematic characterization of soil and land resources, assessment of land capability and crop site suitability, evaluation of groundwater potential zones and the development of watershed-based alternate land use and Soil and Water Conservation (SWC) plans.
- Soil-site suitability was evaluated for major local crops like Cashewnut, Rice, Arecanut, Jackfruit, Mango, Coconut, and Banana.

5.2 CONCLUSION

The effective application of integrated geospatial techniques and field-based observations for comprehensive watershed assessment and planning under the PMKSY-WDC 2.0 framework. The systematic analysis of terrain, drainage characteristics, slope, soil resources and land use in Dodamarg has enabled a detailed understanding of the hydrological and environmental conditions. The assessment confirms the vulnerability of the rainfed agricultural system to monsoon variability, making the identification of resource constraints and the prioritization of interventions essential. The evaluation of soil-site suitability for key crops and the mapping of groundwater potential zones form a robust scientific basis for strategic planning. Successful implementation of the proposed Soil and Water Conservation (SWC) measures and alternate land-use options will provide a comprehensive technical framework for scientific watershed planning and sustainable resource management, in accordance with the objectives and guidelines of PMKSY-WDC 2.0.

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 Dodamarg cluster, Sindhudurg

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

Morphometric analysis quantitatively assesses drainage network properties, basin shape, slope, and relief, which control runoff generation, soil erosion, and groundwater recharge. These parameters must be derived from a hydrologically closed system bounded by natural divides. A watershed represents such a unit, where streams develop in a hierarchical pattern and drain toward a common outlet, ensuring accurate calculation of indices such as drainage density, bifurcation ratio, stream frequency, form factor, and relief ratio.

Village clusters are administrative units that do not necessarily correspond with complete drainage systems. Since streams frequently cross village boundaries, morphometric analysis at the cluster level would lead to incomplete stream networks and distorted basin geometry, resulting in unreliable hydrological interpretation.

Therefore, morphometric analysis was deliberately conducted at the watershed level to maintain hydrological accuracy, whereas runoff estimation, GWPZ mapping, and SWC planning were carried out at the village cluster level for efficient local application. This integrated approach connects natural hydrological processes with decentralized planning for sustainable water resource management.

The Dodamarg village cluster, Sindhudurg, Maharashtra, comprises five villages. Together, these villages constitute the study cluster having one watershed (Fig. 1).

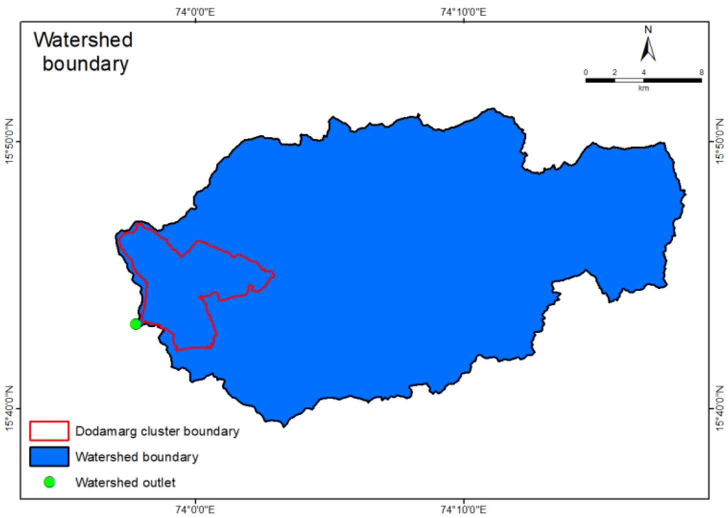


Fig. 1. Map of Dodamarg cluster, Sindhudurg depicted through sub-watershed

Table 1. Distribution of area under different sub-watershed, Dodamarg cluster, Sindhudurg

Sr. No.	**Sub-watershed name**	**Sub-watershed order**	**Elevation (m)**	**Area (km^2)**	**Flow origination**
1	W1	5^{th}	4-1034	521.9	North to South-east
			Total	**521.9**	

The sub-watershed wise area, their order, elevation rage and drainage network are presented in Table 1 and in Fig. 2. Their morphometric characteristics of these sub-watersheds are analyzed under three aspects: linear, areal, and relief.

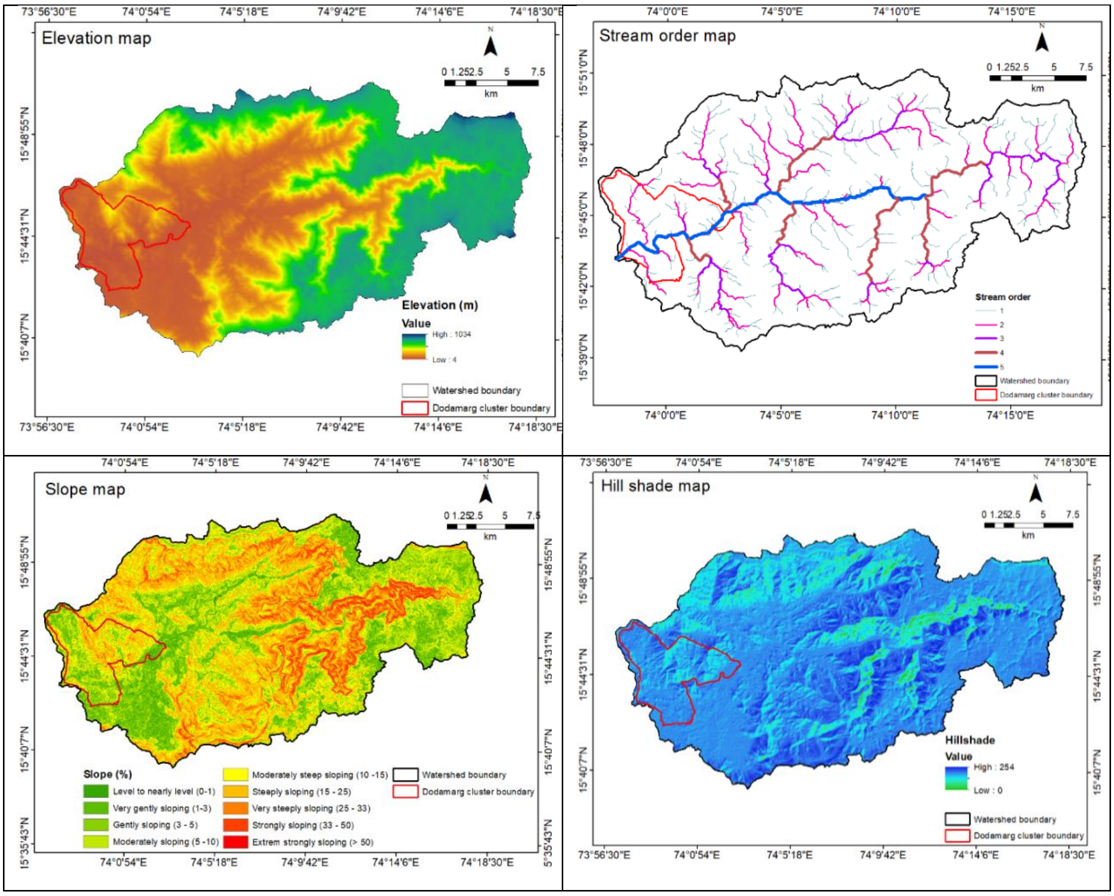


Fig. 2. Elevation, stream network, slope and hill shade map of sub-watershed

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 (412) and total stream length (504.9 km), indicating a well-developed drainage network (Table 2). The bifurcation ratio indicated as 4.5, suggesting relatively greater structural influence watershed. Mean channel length and valley length of watershed, reflecting more mature channel development. Channel index of watershed W1 (1.0), indicating greater sinuosity. Basin perimeter of W1 (128.09 km), confirming it as the most extensive sub-watershed.

Table 2. Linear morphometric parameters of sub-watersheds, Dodamarg cluster, Sindhudurg

Sr. No.	Morphometric parameter	Symbol	Unit	W1
1	No. of streams	Nu	No	412
2	Stream length	Lu	km	504.9
3	Bi-furcation ratio	Rb	-	4.5
4	Mean channel length	Cl	km	52.29
5	Valley Length	Vl	km	51.01
6	Channel Index	Ci	-	1.0
7	Minimum areal distance	Adm	km	49.9
8	Valley Index	Vi	-	1.22
9	Basin perimeter	P	km	128.09

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 (521.9 km²) and mean basin width is 9.8 km. Form factor (Ff) and elongation ratio (Re)in W1 (0.18 and 0.48), suggesting a comparatively more circular basin. Circularity ratio (Rc) of W1 is 4.08, while compactness coefficient (Cc) as 1.59, reflecting greater basin irregularity. Standard sinuosity index (Ssi) as 1.03, indicating relatively higher channel sinuosity in W1. Drainage parameters show that stream frequency (Fs) is 0.79 per km² and Drainage density (Dd) as 0.97 km/km². Drainage intensity (Di) follows a similar trend, with the highest value as 0.82. Length of overland flow (Lg) as (0.52 km) indicating shorter runoff travel distance in W1.

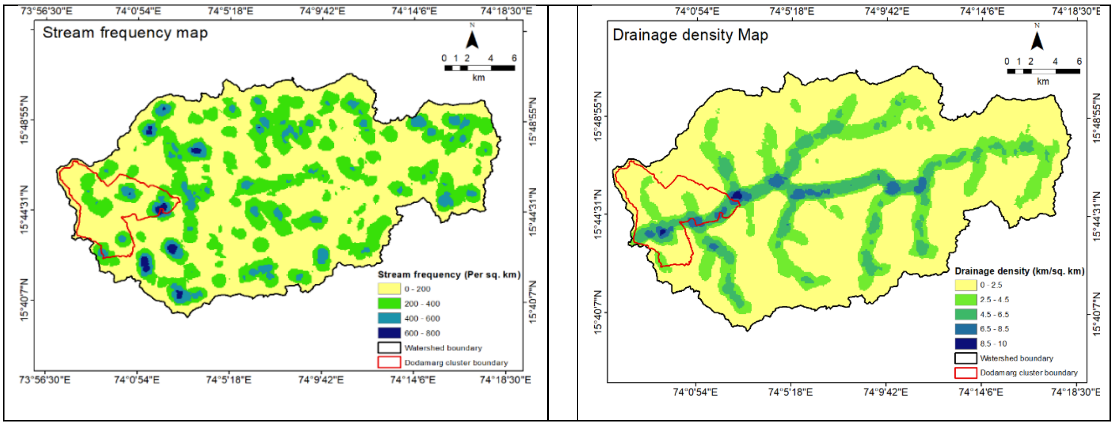


Fig. 3. Steam frequency and drainage density map of sub-watershed

Table 3. Areal morphometric parameters of sub-watersheds, Dodamarg cluster, Sindhudurg

Sr. No.	Parameter	Symbol	Method/ Formula	Unit	W1
1.	Mean basin width	Wb	Wb =A/Lb	km	9.8
2.	Basin area	A	GIS Analysis	km^2	521.97
3.	Relative perimeter	Pr	Pr= A/P	km	4.08
4.	Length area relation	Lar	Lar = 1.4*A0.6	km^2	59.80
5.	Lemniscate's	k	K = Lb2/A	-	5.5
6.	Form factor	Ff	Ff = A/Lb2	-	0.18
7.	Elongation ratio	Re	Re = 2/Lb*(A/π)0.5	-	0.48
8.	Circularity ratio	Rc	Rc = 12.57*(A/P2)	-	4.08
9.	Compactness coefficient	Cc	Cc = 0.2841*P/A0.5	-	1.59
10.	Standard sinuosity index	Ssi	Ssi = Ci/Vi	-	1.03
11.	Stream frequency	Fs	Fs = Nu/A	Per km^2	0.79
12.	Drainage Density	Dd	Dd = Lu/A	km/km^2	0.97
13.	Drainage Intensity	Di	Di = Fs/Dd	-	0.82
14.	Length of Overland Flow	Wb	Wb=A/Lb	km	9.8

Relief Aspects

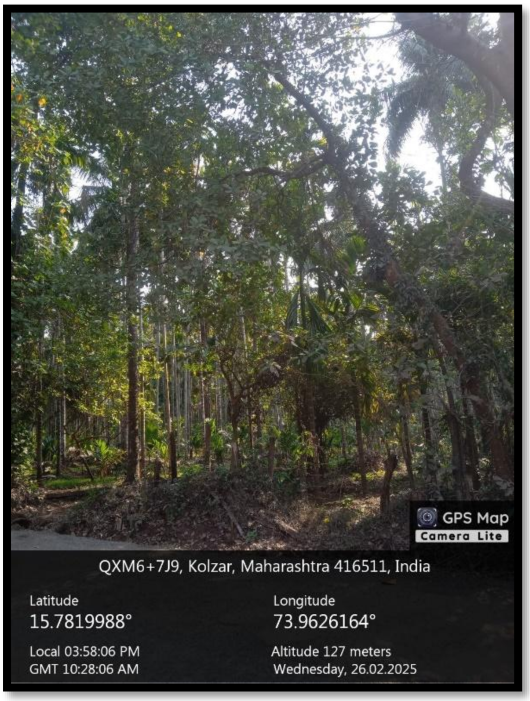
The maximum basin height (Z) of W1 (1034m) and total basin relief (H) is also maximum as (1030 m) (Table 4). Relief ratio (Rhl) as W1 (19.3), indicating steeper terrain conditions, while Relative relief ratio (Rhp) of W1 (804.1) suggesting higher relief intensity in W1. The ruggedness number (Rn) of watershed W1 (1), reflecting more dissected and erosion-prone terrain. Similarly, the Melton ruggedness number (MRn) is shown in W1 (45.1), indicating comparatively higher susceptibility to runoff and erosion processed.

Table 4. Relief morphometric parameters of sub-watersheds, Dodamarg cluster, Sindhudurg

Sr. No	Parameters	Symbol	Methods /Formula	W1
1.	Height of at basin mouth (m)	z	DEM	4
2.	Maximum height of the basin (m)	Z	DEM	1034
3.	Total basin relief (m)	H	H = Z - z	1030
4.	Relief ratio	Rhl	Rhl = H / Lb	19.3
5.	Relative relief ratio	Rhp	Rhp = H * 100 / P	804.1
6.	Ruggedness number	Rn	Rn = Dd*(H/1000)	1
7.	Melton Ruggedness number	MRn	MRn = H / A^0.5	45.1

The slope distribution of watershed W1 shows considerable variation in terrain ranging from nearly level to extremely steep slopes. Nearly level areas (0–1%) occupy a small proportion of the watershed, accounting for 2.35% of the total area. Very gently sloping terrain (1-3%) covers 11.20%, while gently sloping land (3-5%) represents 13.85% of the watershed. The moderately sloping class (5-10%) occupies the largest share with 22.06%, indicating the presence of undulating terrain across a significant portion of the basin. Moderately steep slopes (10-15%) account for 15.06% of the total area. Similarly, steeply sloping areas (15-25%) cover 22.04%, representing another major portion of the watershed. Very steep slopes (25-33%) occupy 9.04%, while strongly sloping terrain (33-50%) constitutes 4.17% of the watershed area. Only a very small part of the basin (0.23%) falls under extremely steep slopes (>50%).

Based on the morphometric characteristics and slope distribution of watershed W1, an integrated soil conservation and land use planning strategy is required to manage runoff and reduce erosion risk. The watershed shows a well-developed drainage network, high basin relief, considerable ruggedness number, and moderate to steep slopes, which indicate strong runoff generation and susceptibility to soil erosion. As a large proportion of the area falls under moderately sloping (5-10%), moderately steep (10-15%), and steep slopes (15-25%), structural soil conservation measures such as contour bunding, graded bunds, contour trenches, and gully control structures should be implemented to reduce surface runoff and stabilize soil. In steeper areas (>15%), bench terracing, staggered trenches, afforestation, and grass cover development are recommended to minimize soil loss and improve slope stability. Along drainage channels, check dams, loose boulder dams, and vegetative filter strips should be constructed to slow runoff velocity and trap sediments. From a land use planning perspective, gentle slopes (1-5%) should be prioritized for agriculture with contour farming and crop rotation, moderately sloping areas (5-10%) can support agroforestry and horticulture, while steep slopes (>15%) should preferably be kept under forest cover, pasture, or permanent vegetation to prevent land degradation. Overall, integrating morphometric analysis with slope-based land use planning and conservation practices will help reduce erosion, regulate runoff, improve groundwater recharge, and ensure sustainable watershed management in W1.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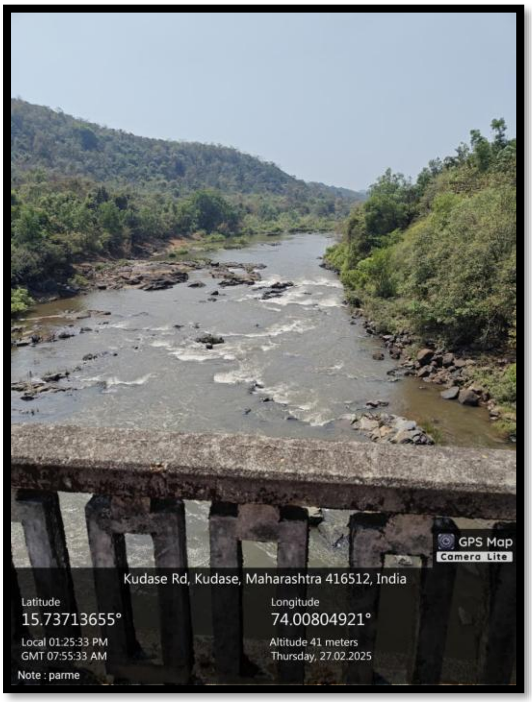
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Shot on OnePlus
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