

**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: Seloo, Dist - Wardha



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



**Vasundhara Watershed Development Agency
Pune, Maharashtra**

About the ICAR-NBSS&LUP

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

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

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PREFACE

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

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

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



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

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

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

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EXECUTIVE SUMMARY

The Pradhan Mantri Krishi Sinchayee Yojana - Watershed Development Component (PMKSY-WDC 2.0) 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 Wardha (WDC-2.0)2/2021-22 watershed located within the Seloo Taluka of Wardha District, Maharashtra, underlain with the characteristic basaltic terrain of the Deccan Plateau, with the local non-perennial streams and nalas, which ultimately join the Vena River. 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 Seloo 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 Wardha (WDC-2.0 3/2021-22) sub-watershed of Seloo 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	Dodamarg	5	5	3604.4
Solapur	Solapur (WDC-2.0)2/2021-22	Mangalvedha	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

SELOO WATERSHED AT A GLANCE

2.1 Location and Extent

The study area (Fig. 2.1) falls under Seloo Taluka, located in the central-eastern part of Wardha District in Maharashtra, and forms a distinct administrative and geographical unit within the district. The study cluster area lies between 20.76° to 20.87° N latitude and 78.83° to 78.92° E longitude. The area is predominantly rural, with agriculture forming the principal land use and the main source of livelihood for the local population. The landscape is characterized by cultivated agricultural fields interspersed with village settlements and seasonal drainage channels.

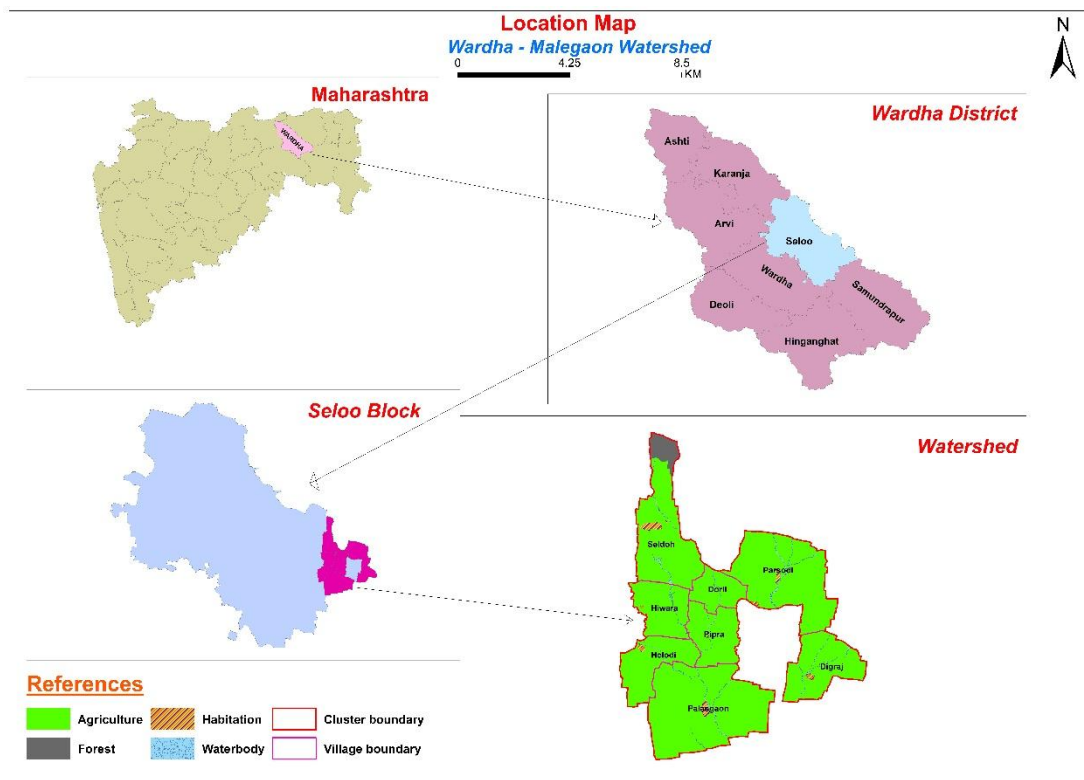


Fig. 2.1. Location map of the Seloo watershed

Within this taluka, a cluster of eight villages has been selected for detailed watershed assessment under the Pradhan Mantri Krishi Sinchayee Yojana – Watershed Development Component. These villages are predominantly rural in nature, with livelihoods largely dependent on agriculture, which is mainly rainfed and influenced by seasonal rainfall. The region is drained by local seasonal streams that contribute to the broader drainage system of the area. Table 2.1 presents the general profile of the watershed with respect to administrative and basic characteristics.

Table 2.1. Geographical and Administrative Profile

Sr. No.	Particulars	Details
1	District	Wardha
2	Taluka	Seloo
3	Revenue Division	Nagpur
4	Total sub-watershed Area	Approx. 5106 hectares
5	Villages	8 (Digraj, Dorli, Helodi, Hiwara, Palasgaon, Parsodi, Pipra, Seldoh)
6	Major River	Local non perennial River which is tributary of Vena River
7	Drainage Pattern	Sub-dendritic with seasonal streams
8	Average annual Rainfall	1097 mm

2.2 Geology

The geology of the watershed is predominantly characterized by Deccan Trap basaltic formations of Upper Cretaceous to Eocene age. The basalt occurs in successive lava flows comprising massive and vesicular varieties, which are typical of the Deccan Plateau region. These basaltic rocks are generally hard and compact, and groundwater occurrence in the area is mainly controlled by weathered, jointed and fractured zones within the basalt flows. The geological characteristics of these Deccan Trap formations play an important role in influencing the soil development, drainage behaviour and groundwater potential of the watershed.

2.3 Geomorphology

The geomorphology of watershed is predominantly controlled by the weathering and erosion of the Deccan Trap basalt that forms the regional geological base of the area. The terrain generally consists of gently undulating plains with occasional uplands and isolated hill features developed due to differential erosion of basaltic lava flows. Over time, fluvial processes associated with local streams have contributed to the formation of alluvial deposits along drainage courses and valley portions. The overall geomorphic setting reflects a denudational landscape where long-term erosion and weathering have shaped broad plains interspersed with minor elevated landforms. These geomorphic characteristics influence soil formation, drainage behaviour, and groundwater occurrence in the taluka.

2.4 Physiography and Soil

Physiographically, watershed forms part of the Deccan Plateau and is characterized by gently undulating terrain developed over basaltic formations. The elevation in the area generally ranges from about 229 to 430 m above mean sea level. The slope of the terrain is predominantly gentle, with steeper slopes occurring in limited patches, particularly around upland and hill areas. The drainage system is mainly composed of local non-perennial streams, which flow during the monsoon season and eventually join the Vena River. Overall, the physiography of the taluka reflects a moderately undulating plateau landscape that influences surface runoff, drainage behaviour, and soil development in the region.

The soil of the cluster watershed is basically derived from Deccan Trap Basalt and almost entire district consists of black soil. The soil varies in depth from very shallow to very deep. The soils of the watershed can be grouped under three textures clay, silty clay and silty clay loam, with major part of the watershed being occupied by clay texture soil.

2.5 Climate

The watershed experiences a tropical monsoonal climate with dry sub-humid characteristics, typical of the Deccan Plateau region. The climate is primarily governed by the southwest monsoon, which contributes the major share of the annual rainfall during the months of June to September. The average annual rainfall of the taluka is 1096 mm. The rainfall exhibits noticeable inter-annual variability and is crucial for agricultural activities and groundwater recharge in the watershed. Temperature variations are significant throughout the year, with very hot summers from March to May and relatively cooler winters from December to February. The mean minimum temperature is about 12.1°C, while the mean maximum temperature reaches around 42.8°C. Relative humidity remains high during the monsoon season and decreases during the summer months, and high evaporation during the pre-monsoon period often results in soil moisture stress in the absence of adequate irrigation facilities.

2.6 Drainage

The watershed is drained mainly by local non-perennial streams and nalas, which ultimately join the Vena River. These streams remain dry for most of the year and carry flow primarily during the southwest monsoon season. The drainage pattern in the watershed is generally sub-dendritic, reflecting the relatively uniform basaltic geology of the Deccan Trap formation and the gently undulating topography. Surface runoff generated during monsoon rainfall forms the main source of flow in these seasonal channels, which contributes to downstream drainage and plays an important role in soil moisture conservation and groundwater recharge within the watershed.

2.7 Cropping Patterns, and Demography and Socioeconomics

2.7.1 Cropping Pattern

The cropping pattern in the watershed is predominantly influenced by the monsoonal rainfall and the presence of black cotton soils derived from Deccan Trap basalt. Agriculture in the area is mainly rainfed, with Kharif being the dominant cropping season. Major crops grown during this season include Cotton, Soybean, Pigeon Pea (Tur), and Sorghum, which are well suited to the clayey soils and monsoon rainfall conditions. During the rabi season, crops such as Wheat, Gram, and some Oilseeds are cultivated in areas where residual soil moisture or limited irrigation is available. The overall cropping pattern reflects the dependence of agriculture on seasonal rainfall, soil moisture retention, and available irrigation sources within the watershed.

2.7.2 Demographic and Socioeconomic Status

Wardha maintains a significant rural concentration, with 67.46% of its 1.3 million residents (2011 Census) located in agrarian tracts. The population density is recorded at 206 persons

per km², with a literacy rate of 86.99%, indicating a highly literate workforce relative to regional averages. While agriculture remains the foundational employment sector, recent labor trends indicate a transition from main agricultural workers toward marginal and non-farm employment, reflecting broader economic shifts within the district's rural-urban continuum.

2.8 Water Resources

The taluka has no major perennial rivers. Seasonal nalas and ephemeral streams are the primary surface water sources. These watercourses are active only during monsoon and exhibit high runoff losses due to low storage infrastructure, and minimal in-stream retention mechanisms. There is no major canal network, and surface water use is limited to a few small percolation tanks, check dams, and farm ponds many of which are silted or non-functional.

2.8.1 Surface Water

2.8.2 Groundwater

Groundwater occurs mostly in weathered and fractured zones of basalt rock. According to the Dynamic Ground Water Resources of Wardha District (CGWB), 2024, annual extractable ground water resources place the region under the “safe” category, with the groundwater extraction level under 53.9%.

2.8.3 Irrigation and Water Management

Wardha district, characterized by its predominantly rainfed agricultural system, relies heavily on the southwest monsoon for its primary production cycles. The hydrological landscape is defined by the Wardha River and its tributaries. However, a persistent disparity exists between established irrigation potential and actual utilization. Consequently, groundwater extracted via open dug wells serves as the primary irrigation source, supporting most of the net irrigated area. To mitigate the risks associated with intra-seasonal dry spells and high surface runoff, integrated soil and water conservation strategies have been implemented to enhance groundwater recharge and provide irrigation in critical times.

2.9 Constraints

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

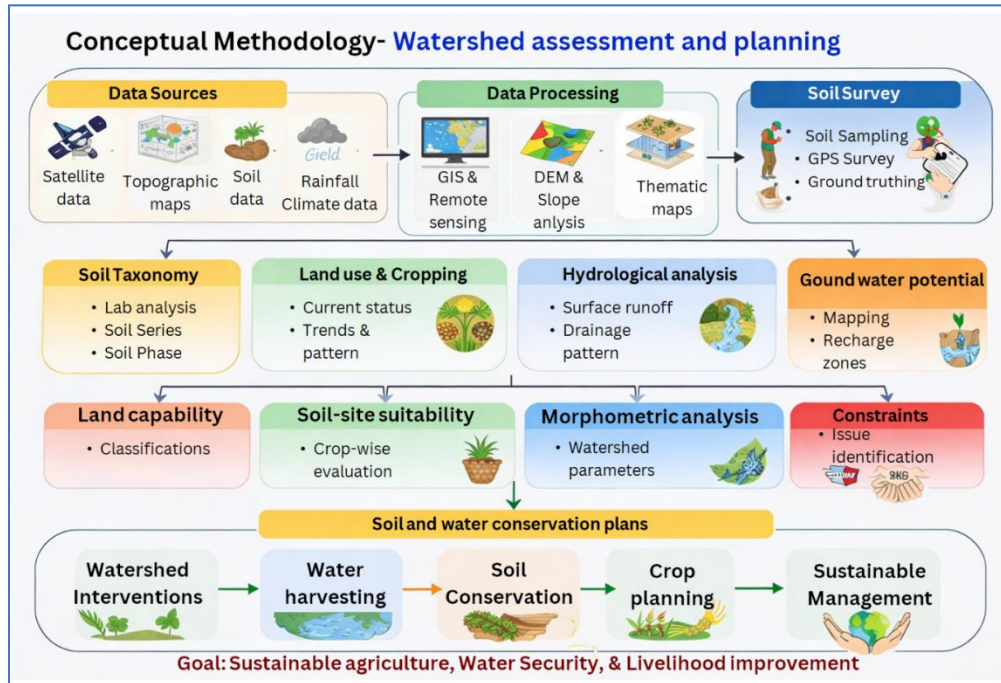
- a. Declining Water Levels of Wells & hand pumps: Many wells declining water levels by end of February, limiting Rabi cultivation and domestic supply.
- b. Unequal Groundwater Distribution: Certain lowland pockets show better recharge, while mid and upland zones remain water deficient.

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

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

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

Vegetative interventions were planned in areas characterized by scrubland, degraded lands, or drainage margins, where afforestation and stream bank plantations could help stabilize soil and reduce erosion. Horticultural plantations supported with in situ moisture conservation practices were proposed in suitable land parcels to enhance land productivity. Additional measures such as rooftop rainwater harvesting in built-up areas and road-side

drainage protection works were identified to capture and safely manage runoff from non-agricultural surfaces. Through the integration of terrain analysis, soil resource information, land use assessment, and hydrological considerations, site-specific conservation measures were systematically identified and spatially allocated within the watershed. This approach ensured that the proposed interventions are technically suitable, hydrologically effective, and aligned with the existing land resource conditions of the watershed.

CHAPTER 4

RESULTS AND INTERPRETATIONS

4.1 Irrigation, Cropping Patterns, and Demography and Socioeconomics

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

4.1.1 Irrigation and water management

The irrigation pattern of the Seloo watershed is presented in Table 4.1. wells contribute 88.86% of the total irrigation, making them the most dominant irrigation source in the region.

Canal irrigation contributes 11.14% of the total irrigation followed by lift irrigation contribute 3.17% of the total irrigation, providing supplementary irrigation support. Bore wells contribute 1.90% of the irrigation.

The irrigation system of the study area is primarily groundwater. Wells served as the major irrigation source. Canal irrigation and lift irrigation provide additional support, helping farmers meet crop water requirements during critical stages.

Table 4.1. Seasonal distribution of irrigation sources in the Seloo watershed

Sr. No.	Number of Farmers Interviewed (n)	Irrigation Source	Seasonal Water Availability	Contribution to Season's Total Irrigation (%)
1	118	Well	Kharif & Rabi	88.86
2	41	Canal	Kharif	11.14
3	22	Lift Irrigation	Kharif & Rabi	3.17
4	22	Borewell	Kharif & Rabi	1.90

4.1.2 Cropping Pattern

The cropping pattern of the Seloo watershed is presented in Table 4.2. Cotton occupies 62.4% of the total cropped area with a productivity of 726 kg/ha. Soybean covered 16.2% of the cropped area with a productivity of 1150 kg/ha. Tur (Pigeon pea) occupies 8.4% of the cropped area.

Paddy (rice) covered 4.0% of the cropped area with a productivity of 1431 kg/ha, In the Rabi season, Gram (Chickpea) covers 4.7% of the cropped area with a productivity of 980 kg/ha. Wheat occupies 2.5% of the cropped area with a productivity of 1320 kg/ha.

Orange mandarin orchards represent an important perennial horticultural crop, occupying 1.8% of the cropped area with a productivity of 9500 kg/ha. The cropping pattern is characterized by a cotton-based cropping system supplemented by Pulses, Cereals, and horticultural crops.

Table 4.2. Crop-wise distribution in the Seloo watershed

Sr. No.	Season	Crop	No. of Farmers Interviewed (n)	Irrigation Type	Total Cropped Area (%)	Productivity (kg/ha)
1	Kharif	Cotton	98	Borewells	62.4	726
2	Kharif	Soybean	36	Borewells / Wells	16.2	1150
3	Kharif	Tur (Pigeon pea)	27	Rainfed	8.4	820
4	Kharif	Paddy (Rice)	12	Borewells	4.0	1431
5	Rabi	Gram (Chickpea)	18	Wells	4.7	980
6	Rabi	Wheat	7	Borewells	2.5	1320
7	Perennial	Orange / Mandarin	98	Borewells / Wells	1.8	9500

4.1.3 Socioeconomic Status

The landholding pattern of farmers in the Seloo watershed is presented in the Table 4.3. From the table it was observed that marginal farmers (up to 1.00 ha) constitute the highest population with 35.51% of the total farmers, having an average landholding of 0.43 ha. This is followed by small farmers (1.01–2.00 ha) accounting for 31.82% with an average landholding of 1.46 ha.

Semi-medium farmers (2.01-4.00 ha) represent 22.82% of the farmers with an average landholding of 2.76 ha, while medium farmers (4.01-10.00 ha) account for 8.96% with an average landholding of 5.47 ha.

The results indicate that agriculture is largely dominated by marginal and small landholdings.

Table 4.3. Land holding pattern in Seloo watershed

Category	Criteria Land (ha)	No. of Farmers Interviewed (n)	Farmers (%)	Average Land Holding (ha)
Marginal Farmers	<1	140	35.51	0.43
Small Farmers	1-2	56	31.82	1.46
Semi-Medium Farmers	2-4	18	22.82	2.76
Medium Farmers	4-10	12	8.96	5.47
Large Farmers	>10	2	0.90	9.83
Average Land Holding				3.99

4.2 Land-use/Land-cover

The land use and land cover analysis of the Seloo watershed (Table 4.4 and Fig. 4.1) indicates a strong dominance of agricultural land, which occupies the largest share of the total area, reflecting the agrarian nature of the region and its heavy dependence on farming activities. Waterbodies cover a relatively small area, indicating limited availability of

surface water resources, while habitation occupies a minor portion of the landscape, representing the spatial extent of settlements within the watershed. Overall, the LULC pattern clearly highlights the predominance of agriculture, with limited areas under water and built-up land, underscoring the importance of sustainable land and water management practices to support agricultural productivity and resource conservation.

Table 4.4. Land-use/land-cover statistics of Seloo watershed

Land use	Area (ha)	Percent (%)
Agriculture	4884.0	95.6
Forest	104.1	2.0
Waterbody	64.8	1.3
Habitation	53.4	1.0
Total	5106.3	100.0

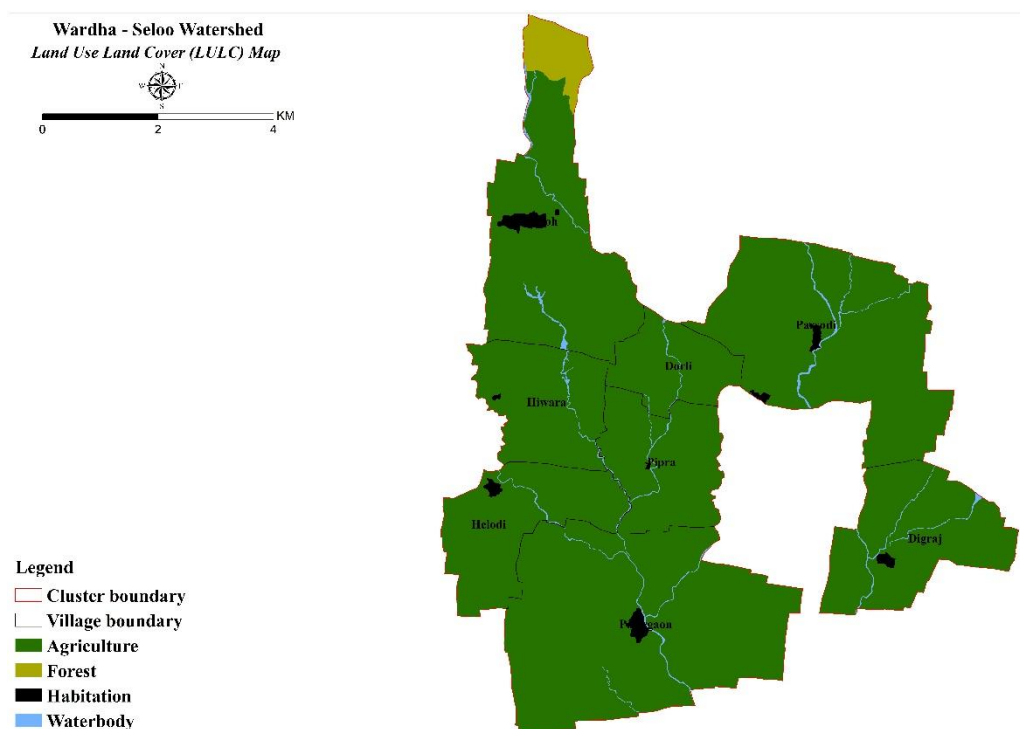


Fig. 4.1. Land-use/land-cover map

4.3 Landform Delineation

The landform analysis of the Seloo watershed (Table 4.5) indicates a terrain characterized by a combination of plains and elevated landforms. Lowland occupies the largest portion of the watershed area, followed by alluvial plain and upland, together constituting the major part of the landscape. Escarpments represent transitional zones with relatively steeper slopes between upland and lower areas, while hills occur in limited patches indicating localized elevated terrain. Waterbodies and habitation occupy relatively small portions of the watershed, and foothill areas occur in minor extent along the base of hill slopes. Overall, the dominance of lowland, alluvial plain and upland landforms reflect a landscape with gentle to moderately undulating relief across the watershed. The landform map of the watershed is presented in Fig. 4.2.

Table 4.5. Landform features existing in Seloo watershed

Sr. No	Landform	Area (ha)	Percent (%)
1	Lowland	1740.4	34.1
2	Alluvial Plain	1464.8	28.7
3	Upland	1318.1	25.8
4	Escarpment	325.8	6.4
5	Hills	104.1	2.0
6	Waterbody	64.8	1.3
7	Habitation	53.4	1.0
8	Foothill	34.9	0.7
	Total	5106.3	100.0

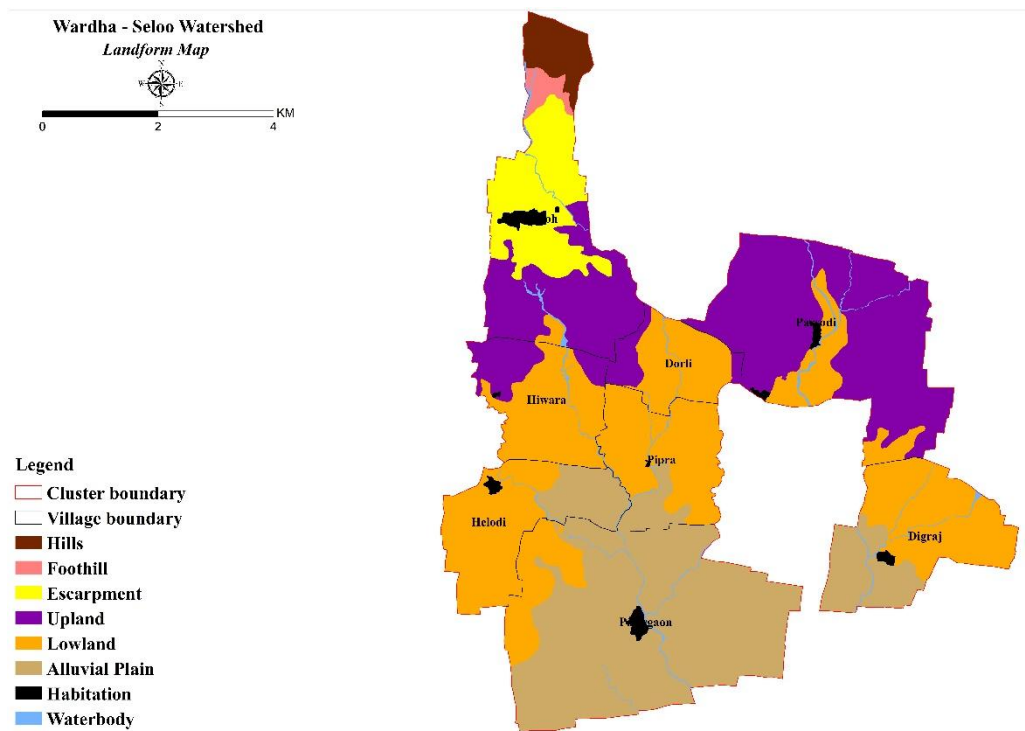


Fig. 4.2. Landform map of Seloo watershed

4.4 Soil Series and Phases

Seven soil series have been identified and mapped with soil mapping units (18 phases of series) (Fig 4.3). The taxonomic classification and mapping legend of the soil series along with its landform was shown in Table 4.6. The detailed descriptions of each phase are given in Table 4.7 and Fig. 4.4.

Table 4.6. Dominant soil series identified in the watershed

Sr. No.	Series	Area (ha)	Percent (%)
1	Dorli	1089	21
2	Hiwara	861	17
3	Helodi	842	16
4	Palasgaon	805	16
5	Digraj	626	12
6	Seldoh	361	7
7	Parsodi	300	6
8	Forest	104	2
9	Waterbody	65	1
10	Habitation	53	1
	Total	5106	100

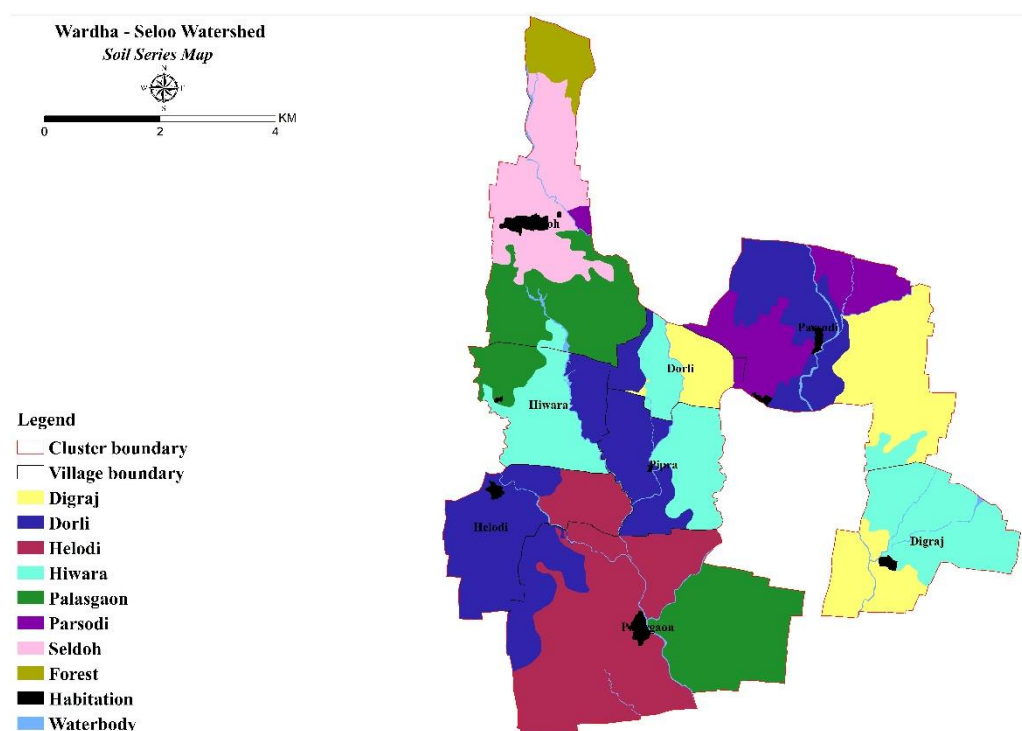


Fig. 4.3. Soil series map of Seloo watershed

Table 4.7. Soil phases existing in Seloo watershed

Sr. No.	Phase	Area(ha)	Percent (%)
1	Dig3mB2	279.0	5.5
2	Dig3mC2	347.4	6.8
3	Dor4kB2	195.6	3.8
4	Dor4mB2	639.3	12.5
5	Dor5kC1	186.8	3.7
6	Dor5mC1	67.3	1.3
7	Hel5kA1	114.7	2.2
8	Hel5mA1	727.6	14.2

9	Hiw4mA1	861.4	16.9
10	Pal2gD2	135.5	2.7
11	Pal2gD3	85.0	1.7
12	Pal2mC2	584.1	11.4
13	Par1kD3	175.3	3.4
14	Par1mD3	12.0	0.2
15	Par2mD3	112.3	2.2
16	Sel1gD3	34.9	0.7
17	Sel2gC2	116.3	2.3
18	Sel2mD2	209.5	4.1
19	Forest	104.1	2.0
20	Habitation	53.4	1.0
21	Waterbody	64.8	1.3
	Total	5106.2	100.0

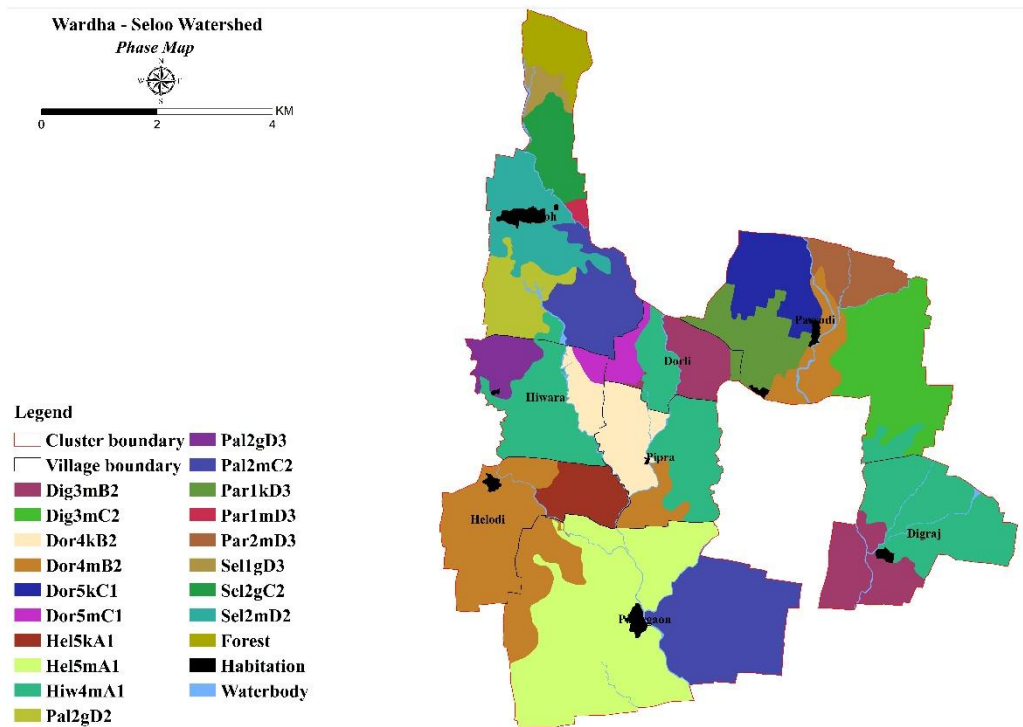


Fig. 4.4. Soil Phase map of Seloo watershed

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 4.8, Fig. 4.5) the maximum area of watershed is under gently sloping (3 - 8%), covering 35.7% followed by level to nearly level land (0-1%) covering 33.4%, very gently sloping (3-8%) covering 21.8% and moderately sloping (8 – 15%) covering 4.8%. 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 favorable for agricultural activities and reduces the risk of severe soil erosion.

Table: 4.8. Land slope classes in Seloo watershed

Sr. No.	Slope Class	Area (ha)	TGA (%)
1	Level to nearly level (0 - 1)	1703.8	33.4
2	Very gently sloping (1 - 3)	1113.9	21.8
3	Gently sloping (3 - 8)	1822.0	35.7
4	Moderately sloping (8 - 15)	244.4	4.8
5	Forest	104.1	2.0
6	Habitation	53.4	1.0
7	Waterbody	64.8	1.3
	Total	5106.2	100.0

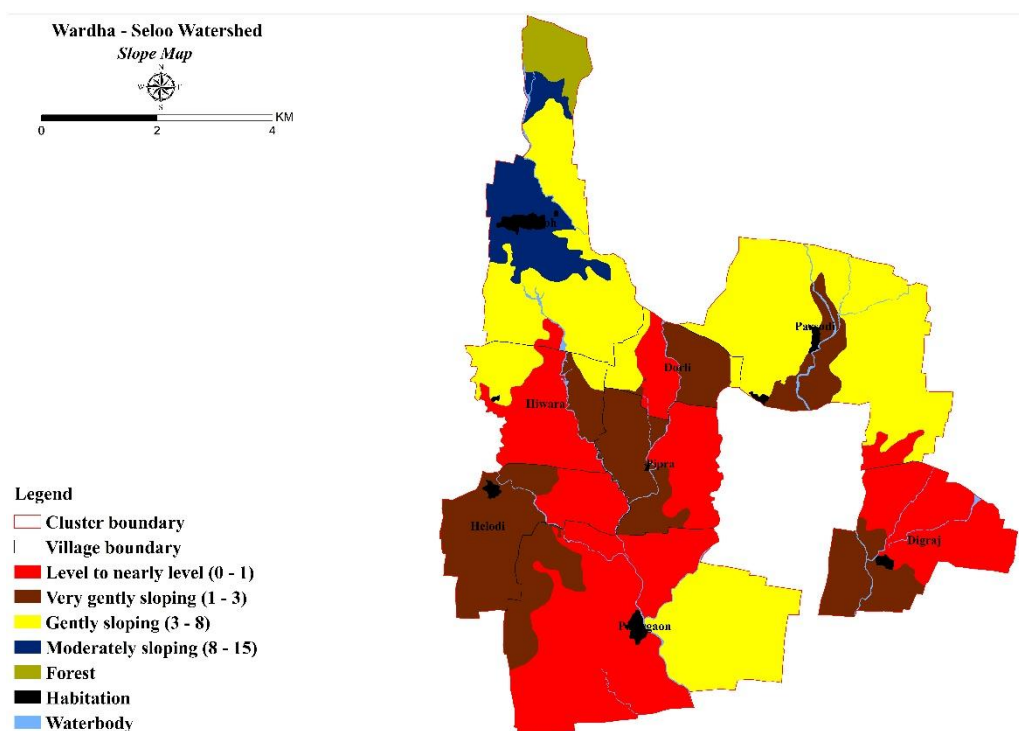


Fig. 4.5. Slope map of Seloo watershed

4.5.2 Soil Erosion

Soil erosion in the Wardha-Seloo watershed varies from very slight to severe depending on local terrain and land conditions (Table 4.9). The analysis indicates that the majority of the watershed area, about 49.1%, falls under the moderate erosion category, suggesting that soil loss is present but generally easy to manage. A small portion of the area, 8.2%, experiences severe erosion, indicating relatively constraints to manage soil conditions with conservation agriculture practices. However, about 38.3% of the watershed is affected by very slight erosion, representing zones where soil conditions are relatively stable with minimal loss.

Table 4.9. Soil erosion status in Seloo watershed

Sr. No.	Erosion class	Area (ha)	Percent (%)
1	Very Slight	1957.9	38.3
2	Moderate	2506.6	49.1
3	Severe	419.5	8.2
4	Forest	104.1	2.0
5	Habitation	53.4	1.0
6	Waterbody	64.8	1.3
	Total	5106.2	100.0

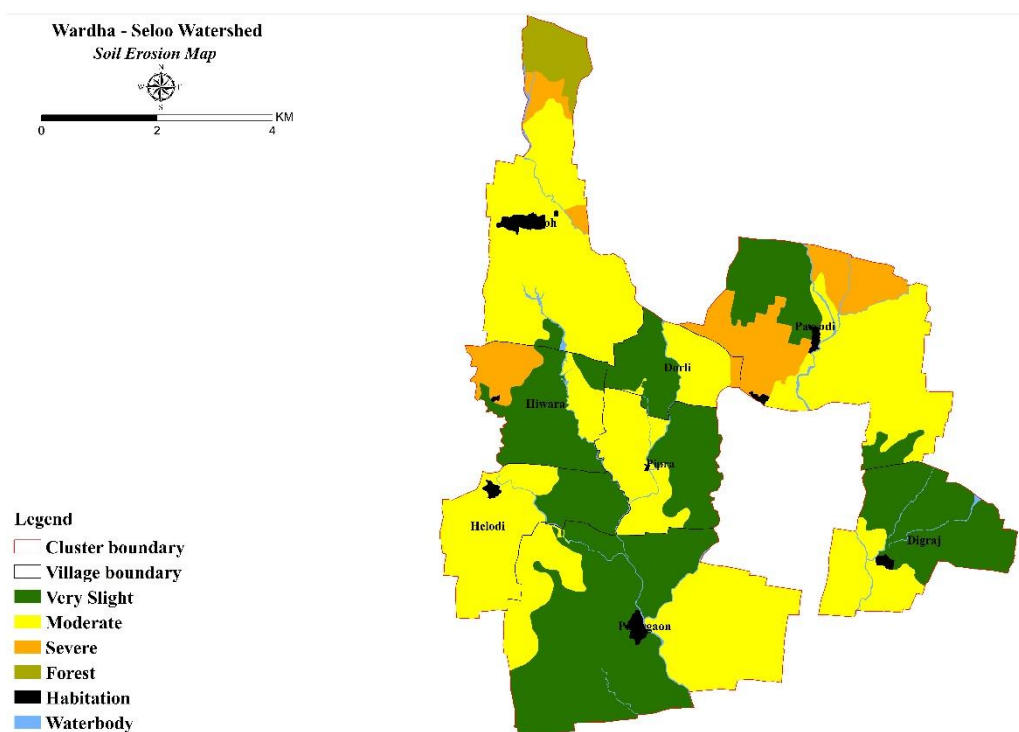


Fig. 4.6. Erosion map of Seloo watershed

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 pedogenic 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. Deep 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 very deep (37.0%) followed by moderate (22.1%), deep (17.7%), moderate deep (6.2%) and shallow (6.6%).

Table 4.10. Soil depth classes in Seloo watershed

Sr. No.	Depth Class (cm)	Area (ha)	TGA (%)
1	Shallow (< 25)	334.5	6.6
2	Moderate (25 - 50)	1130.3	22.1
3	Moderately Deep (50 - 75)	626.3	12.3
4	Deep (75 - 100)	902.2	17.7
5	Very Deep (> 100)	1890.6	37.0
6	Forest	104.1	2.0
7	Habitation	53.4	1.0
8	Waterbody	64.8	1.3

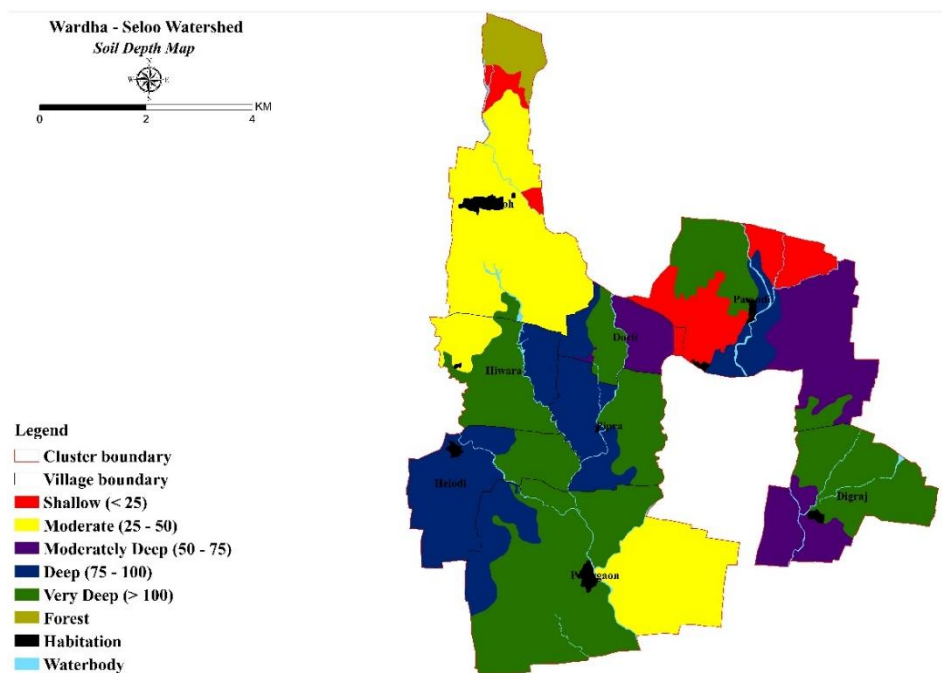


Fig. 4.7. Depth map of Seloo watershed

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 three classes (Table 4.11, Fig. 4.8). Among the different classes clay texture was found in 75.2% area followed by silty clay covering 13.2% and silty clay loam 7.3%. Based on the texture, the soils of the watershed particularly the highly silty-clay soils are expected to be fertile and produce good crops.

Table 4.11. Soil texture distribution in Seloo watershed

Sr. No.	Texture	Area (ha)	TGA (%)
1	Clay	3839.8	75.2
2	Silty clay	672.5	13.2
3	Silty clay loam	371.7	7.3
4	Forest	104.1	2.0
5	Habitation	53.4	1.0
6	Waterbody	64.8	1.3
	Total	5106.2	100.0

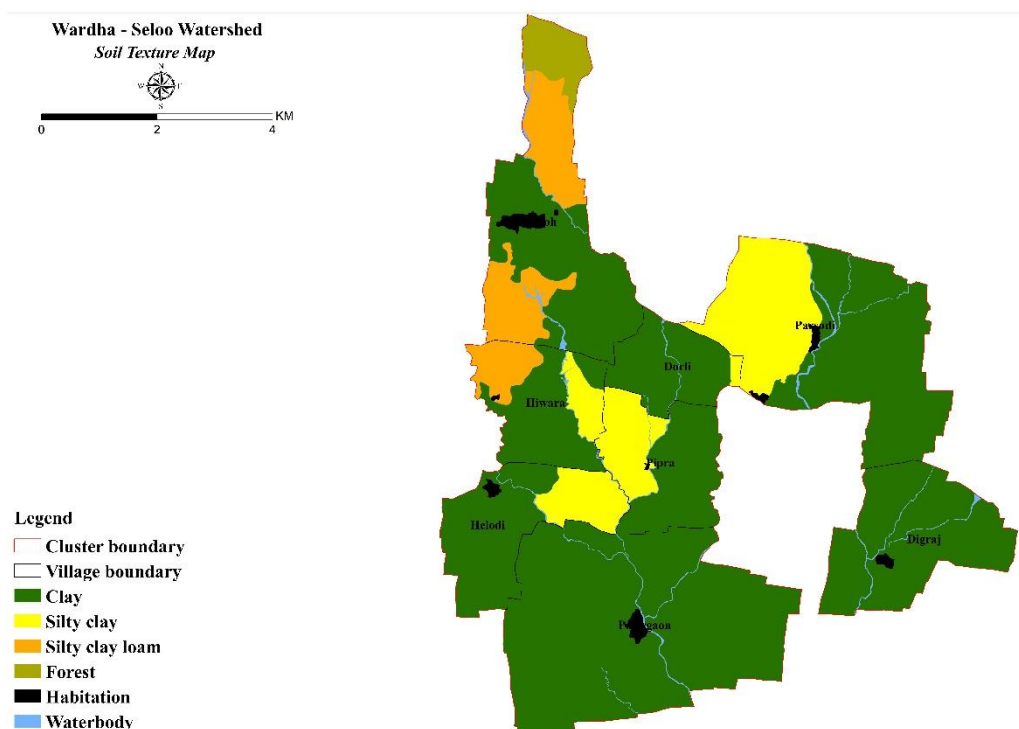


Fig. 4.8. Soil texture map of Seloo watershed

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 three soil reaction classes (Table 4.12, Fig. 4.9). The data revealed that soils in watershed are primarily Moderately Alkaline (pH 8.0 - 9.0) covering an area of about 52.5% followed by Neutral (pH 6.5 - 7.5) and Slightly Alkaline (pH 7.5 - 8.0).

Table 4.12. Soil pH distribution in Seloo watershed

Sr. No.	Soil pH	Area (ha)	TGA (%)
1	Neutral (6.5 - 7.5)	1103.2	21.6
2	Slightly Alkaline (7.5 - 8.0)	1097.9	21.5
3	Moderately Alkaline (8.0 - 9.0)	2682.9	52.5
4	Forest	104.1	2.0
5	Habitation	53.4	1.0
6	Waterbody	64.8	1.3
	Total	5106.2	100.0

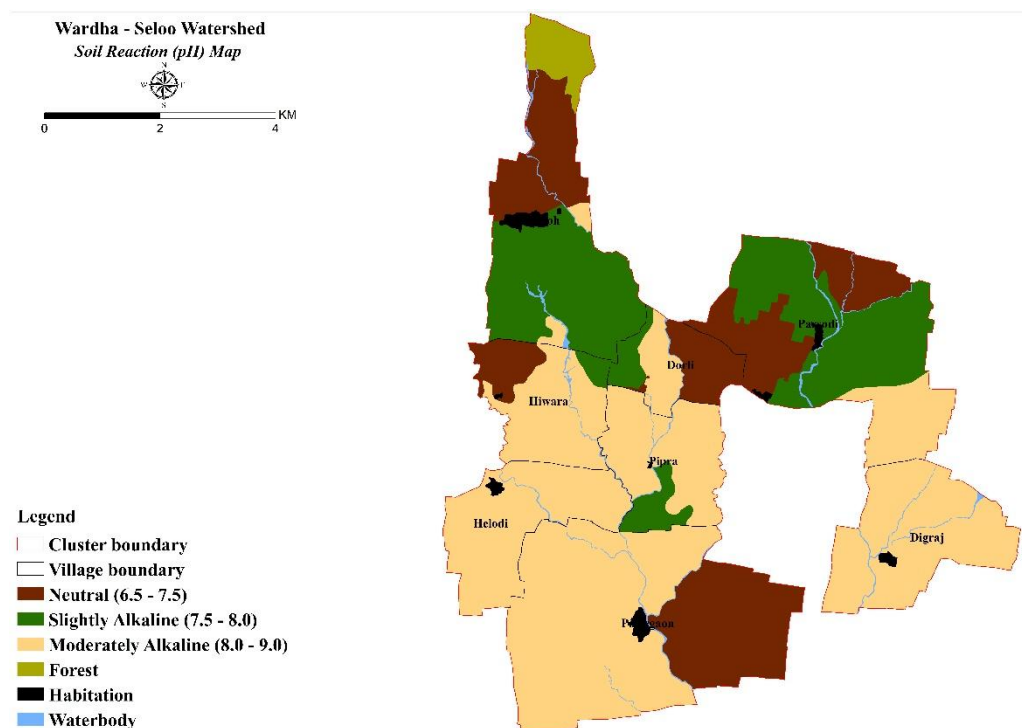


Fig. 4.9. Soil pH map of Seloo watershed

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 4.13) and will Fig 4.10. The soil salinity status of the watershed (Table 4.13) shows that the majority of the area 95.6%, 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 Wardha-Seloo watershed and most areas are suitable for crop cultivation without additional salinity management measures.

Table 4.13. Soil salinity classes in Seloo watershed

Sr. No.	Electrical conductivity (dSm^{-1})	Area (ha)	TGA (%)
1	Normal (0 - 1)	4884.0	95.6
2	Forest	104.1	2.0
3	Habitation	53.4	1.0
4	Waterbody	64.8	1.3
	Total	5106.2	100.0

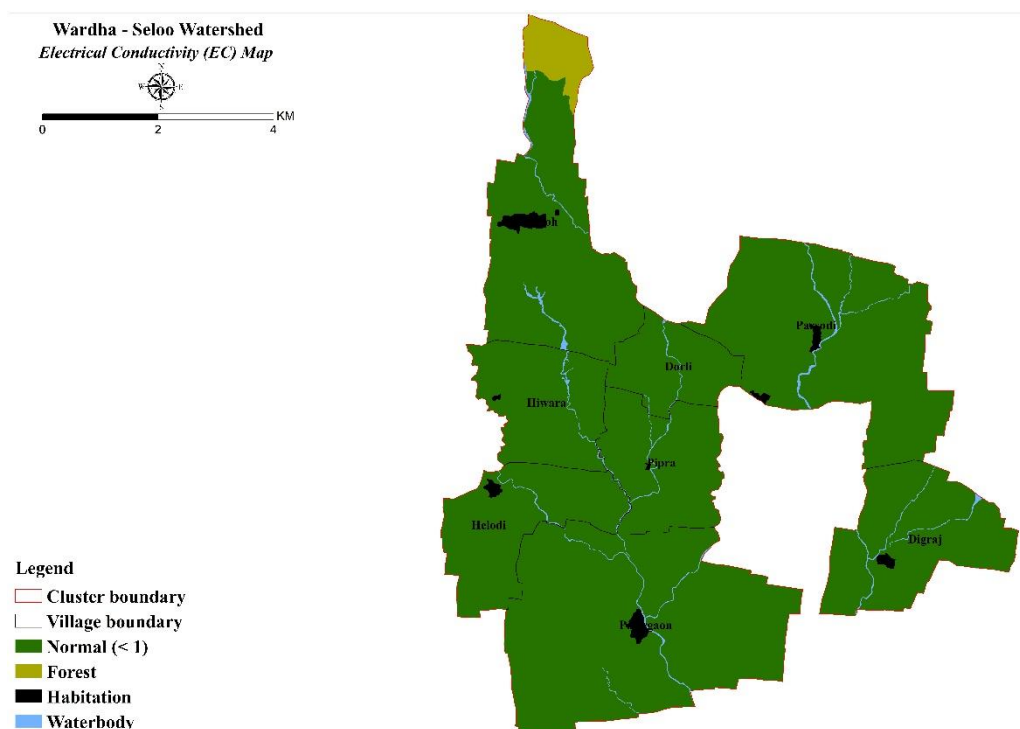


Fig. 4.10. Soil EC map of Seloo watershed

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 Wardha-Seloo watershed supported moderately high SOC

apply the nitrogenous fertilizers as per crop needs to maximize crop yields in the watershed area.

Table 4.15. Available N content in soils of Seloo watershed

Sr. No.	Available N (kg ha ⁻¹)	Area (ha)	TGA (%)
1	Very Low (< 140)	4884.0	95.6
2	Forest	104.1	2.0
3	Habitation	53.4	1.0
4	Waterbody	64.8	1.3
	Total	5106.2	100.0

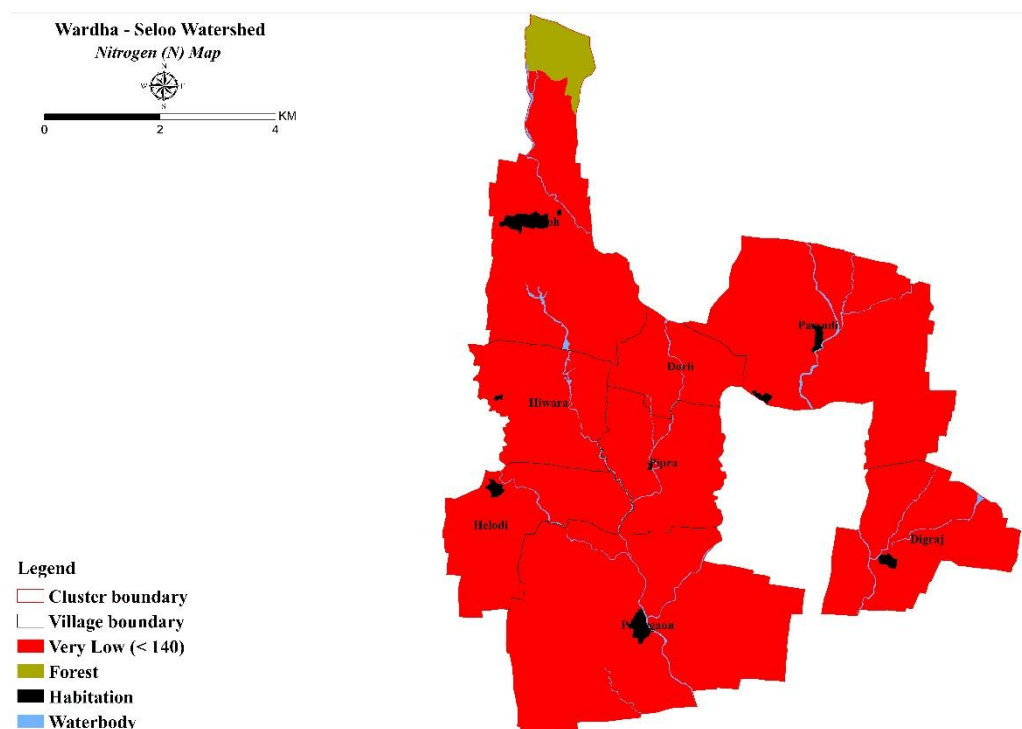


Fig. 4.12. Available soil Nitrogen map of Seloo watershed

4.5.9 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 4.16, Fig. 4.13) ranged from very low (<15 kg ha⁻¹) to Moderately High (51 -65 kg ha⁻¹), with the highest area was under low have P status 48.9% followed by very low 35.5%, Medium (31 - 50 kg ha⁻¹) covering 9.0% and Moderately High (51 - 65 kg ha⁻¹) covering 2.3%. The vast majority 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 4.16. Available P content in soils of Seloo watershed

Sr. No.	Available P (kg ha ⁻¹)	Area (ha)	TGA (%)
1	Very Low (< 15)	1810.5	35.5
2	Low (16 - 30)	2497.6	48.9
3	Medium (31 - 50)	459.6	9.0
4	Moderately High (51 - 65)	116.3	2.3
5	Forest	104.1	2.0
6	Habitation	53.4	1.0
7	Waterbody	64.8	1.3
	Total	5106.2	100.0

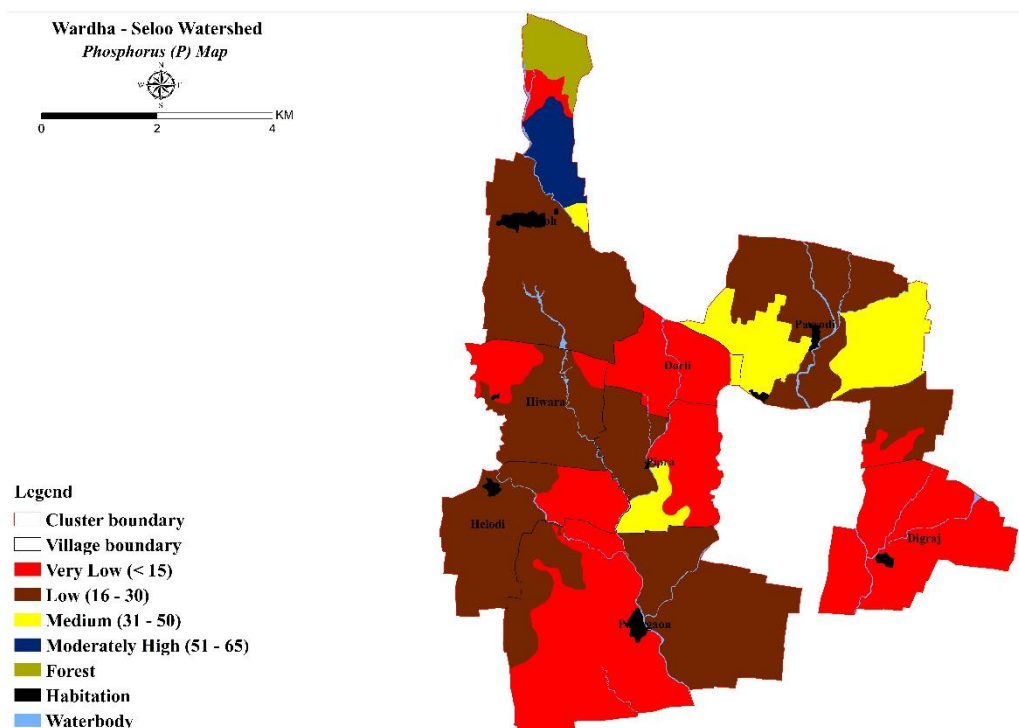


Fig.4.13. Available soil Phosphorus map of Seloo watershed

4.5.10 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 4.17, Fig. 4.14) were observed in the watershed soils. Surprisingly, largest area 46.4% under the very high (> 360 kg/ha) K class. This is followed by low (121–180 kg/ha) soils covering 16.6%, Moderately High (241 - 300 kg/ha) soils at 16.3%, High (301 - 360 kg/ha) soils at 9% and very low (< 120 kg/ha) soil at 2.3%. It is indicated that large portions of the watershed have adequate potassium for crop growth.

Table 4.17. Available K content of soils of Seloo watershed

Sr. No.	Available K (kg ha ⁻¹)	Area (ha)	TGA (%)
1	Very Low (< 120)	116.3	2.3
2	Low (121 - 180)	848.9	16.6
3	Medium (181 - 240)	260.3	5.1
4	Moderately High (241 - 300)	832.1	16.3
5	High (301 - 360)	459.0	9.0
6	Very High (> 360)	2367.4	46.4
7	Forest	104.1	2.0
8	Habitation	53.4	1.0
9	Waterbody	64.8	1.3
	Total	5106.2	100.0

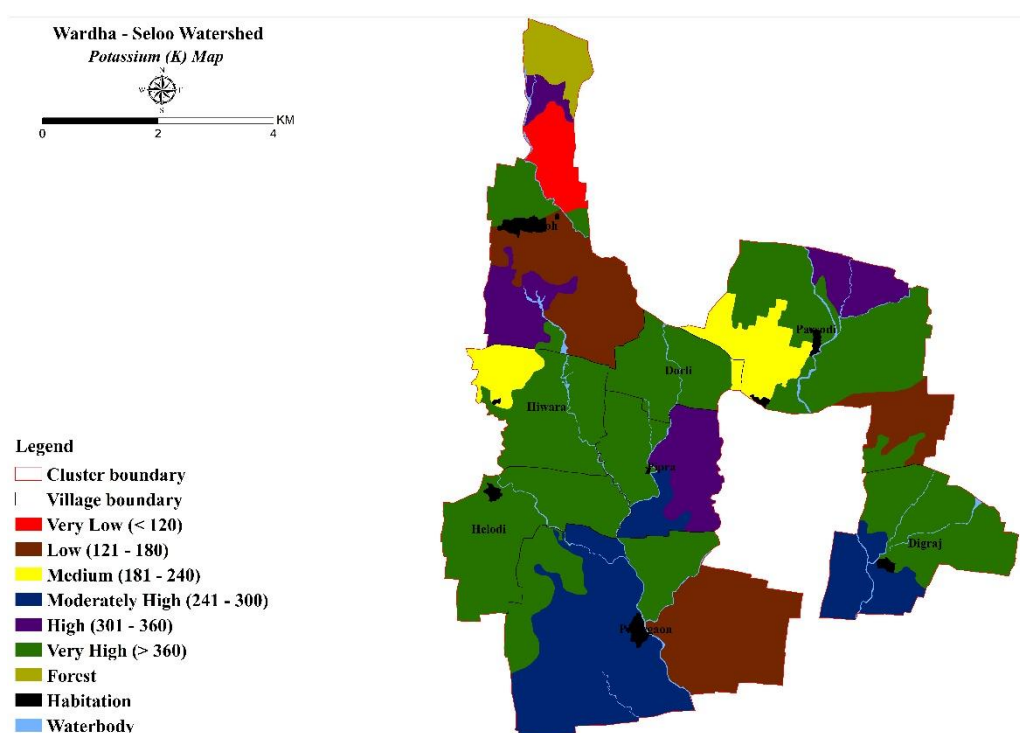


Fig. 4.14. Available soil Potassium map of Seloo watershed

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. Three class of available Fe were found in the watershed. Table 4.18 and Fig. 4.15 indicate that about 65.6% of the watershed area is very high Fe followed 18.6% moderate high Fe and 11.4% high Fe. About a two-third of the watershed area was categorized as very high (>10.5 mg kg⁻¹) in DTPA-extractable Fe. Approximately 43.8% very high of the watershed was found in plant-available Mn content, while majority of the area is adequately supplied with Mn

(Table 4.19, Fig. 4.16). Soils of the entire watershed are sufficient with respect to DTPA-extractable Cu (Table 4.20, Fig. 4.17), whereas approximately 95.6% of the soils exhibit deficiency in available Zn (Table 4.21, Fig. 4.18), necessitating external Zn fertilization by the farmers.

Table 4.18. Available Fe content in the soils of Seloo watershed

Sr. No.	Available Fe (mg kg ⁻¹)	Area (ha)	TGA (%)
1	Moderately High (6.5 - 8.5)	951.7	18.6
2	High (8.5 - 10.5)	584.0	11.4
3	Very High (> 10.5)	3348.3	65.6
4	Forest	104.1	2.0
5	Habitation	53.4	1.0
6	Waterbody	64.8	1.3
	Total	5106.2	100.0

Table 4.19. Available Mn content in the soils of Seloo watershed

Sr. No.	Available Mn (mg kg ⁻¹)	Area (ha)	TGA (%)
1	Medium (1.3 - 5.0)	229.0	4.5
2	Moderately High (5.0 - 7.0)	1661.2	32.5
3	High (7.0 - 9.0)	759.5	14.9
4	Very High (> 9.0)	2234.3	43.8
5	Forest	104.1	2.0
6	Habitation	53.4	1.0
7	Waterbody	64.8	1.3
	Total	5106.2	100.0

Table 4.20. Available Cu content in the soils of Seloo watershed

Sr. No.	Available Cu (mg kg ⁻¹)	Area (ha)	TGA (%)
1	Very High (> 1.0)	4884.0	95.6
2	Forest	104.1	2.0
3	Habitation	53.4	1.0
4	Waterbody	64.8	1.3
	Total	5106.2	100.0

Table 4.21. Available Zn content in the soils of Seloo watershed

Sr. No.	Available Zn (mg kg ⁻¹)	Area (ha)	TGA (%)
1	Low (0.3 - 0.6)	2365.8	46.3
2	Medium (0.6 - 0.9)	2158.5	42.3
3	Moderately High (0.9 - 1.2)	196.6	3.8
4	High (1.2 - 1.8)	163.2	3.2
5	Forest	104.1	2.0
6	Habitation	53.4	1.0
7	Waterbody	64.8	1.3
	Total	5106.2	100.0

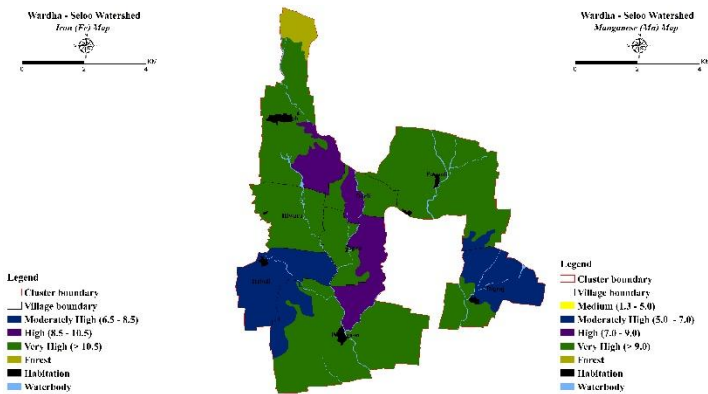


Fig. 4.15. DTPA-extractable soil Fe map of Seloo watershed

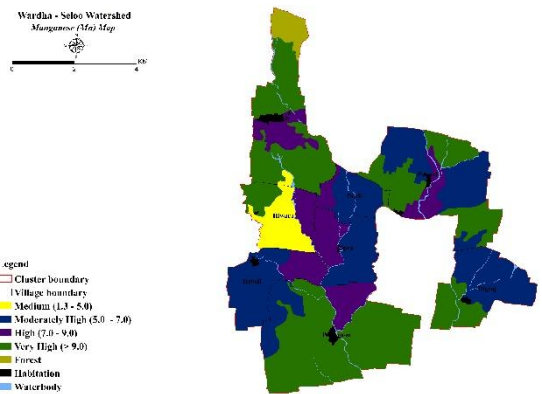


Fig. 4.16. DTPA-extractable soil Mn map of Seloo watershed

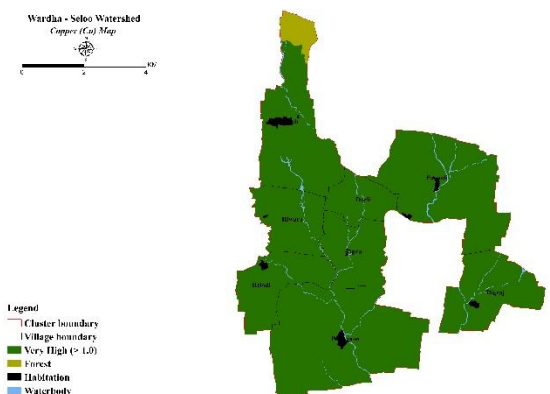


Fig. 4.17. DTPA-extractable soil Cu map of Seloo watershed

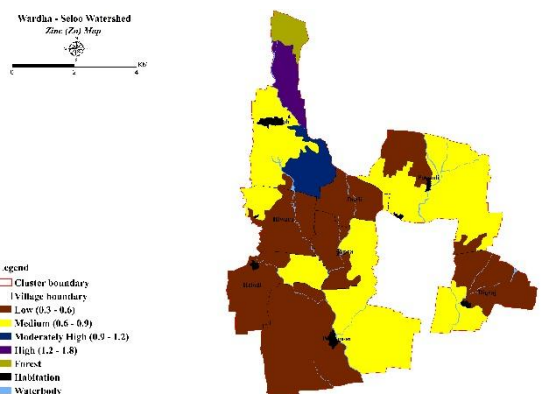


Fig. 4.18. DTPA-extractable soil Zn map of Seloo watershed

4.6 Surface Runoff

Surface runoff is a critical component in watershed hydrology, particularly in regions where rainfall occurs in intense monsoon spells and its distribution is uneven over time. In these cluster villages watershed located in Seloo Taluka of Wardha district, an assessment of surface runoff was carried out for the period 2014 to 2024, with the objective of understanding the rainfall-runoff dynamics and identifying the scope for in-situ water conservation interventions.

Based on daily rainfall records for the 11-year period compiled from IMD data and verified with 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.

This analysis was based on observed rainfall and derived runoff data across the monsoon season (June to October) for the cluster villages. The long-term average annual rainfall for the cluster stands at 1096.5 mm, with significant inter-annual variability. Considering this rainfall regime, the watershed falls under a dry sub-humid climatic condition typical of the Vidarbha region rather than a semi-arid zone. The soils in the watershed are predominantly

clayey black soils, which have high water holding capacity but may generate considerable surface runoff during high-intensity monsoon rainfall events. Runoff response has been calculated for each year, indicating the proportion of rainfall that flows as surface runoff, thereby escaping immediate infiltration or storage.

Table 4.22. 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	58.4	3.6	454.4	292.7	88.7	0.0	168.4	19.0	7.0	0.0
2015	225.3	72.2	218.2	69.9	316.8	124.7	143.8	43.0	19.4	0.0
2016	100.5	4.7	429.7	181.7	149.1	3.3	200.0	41.9	62.4	0.5
2017	165.3	33.7	220.2	48.4	316.5	91.0	163.5	27.8	27.6	0.0
2018	171.0	7.9	423.0	215.6	242.9	88.9	111.7	14.8	0.0	0.0
2019	115.2	29.8	485.8	257.7	371.7	136.3	347.6	110.6	42.3	0.8
2020	149.1	3.4	210.0	2.3	307.2	37.2	99.7	0.2	20.5	0.0
2021	226.6	37.1	306.4	73.2	132.7	19.9	263.8	22.3	22.4	0.0
2022	105.5	0.6	746.1	457.8	380.1	189.7	220.6	43.8	74.6	0.9
2023	101.3	5.8	428.7	187.1	156.1	48.6	247.6	27.3	1.8	0.0
2024	158.2	7.8	587.3	310.3	201.6	30.9	165.7	2.7	15.5	0.0
Average	143.3	18.8	410.0	190.6	242.1	70.0	193.8	32.1	26.7	0.2

Over the 11 year period, the average annual surface runoff is estimated at 316.5 mm, which corresponds to 28.9% of the total annual rainfall. This suggests that a considerable portion of the rainfall leaves the watershed as surface flow, while the remaining rainfall is either infiltrated into the soil, utilized by vegetation, or lost through evapotranspiration.

A review of the monthly distribution shows that July consistently produces the highest runoff, averaging 190.6 mm across years. This aligns with the peak monsoon phase when rainfall intensity is highest and soils are already saturated. August follows with an average runoff of 70.0 mm, while September contributes about 32.1 mm. Runoff in June and October remains low, averaging 18.8 mm and 0.2 mm respectively, due to either initial soil dryness or tapering rainfall activity toward the end of the monsoon season

Inter-annual analysis highlights years like 2019 and 2022 as high runoff years, recording runoff volumes of 535.1 mm and 692.9 mm, respectively, indicating rainfall concentration during short periods and reduced infiltration opportunities. In contrast, 2020 exhibited very low runoff generation (43.0 mm) despite receiving 892.7 mm rainfall, which may be attributed to better rainfall distribution and higher infiltration.

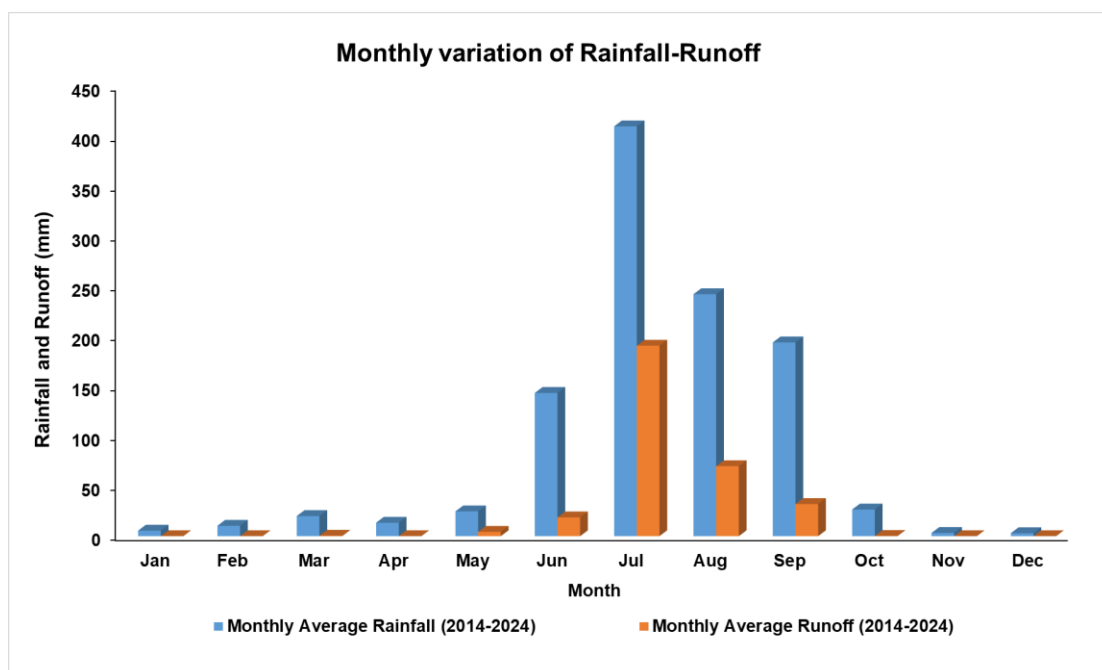


Fig 4.19. Monthly variation of rainfall-runoff in Seloo watershed

Table 4.23. Relationship between rainfall and runoff

Year	Rainfall (mm)	Runoff (mm)	No. of Runoff Events	Runoff (%)
2014	824.1	315.3	15	38.3
2015	1051.3	314.5	19	29.9
2016	1030.9	232.2	26	22.5
2017	915.9	200.8	17	21.9
2018	989.0	327.3	20	33.1
2019	1383.4	535.1	34	38.7
2020	892.7	43.0	18	4.8
2021	1028.4	152.5	25	14.8
2022	1554.8	692.9	36	44.6
2023	1138.3	316.0	31	27.8
2024	1252.5	352.1	27	28.1
Average	1096.5	316.5	24	28.9

The highest runoff percentage was recorded in 2022 (44.6%), followed by 2019 (38.7%) and 2014 (38.3%), suggesting years where intense rainfall resulted in greater surface runoff and possible loss of water from the landscape. Conversely, 2020 recorded the lowest runoff percentage (4.8%), indicating better rainfall utilization within the watershed.

Overall, the cluster watershed shows a runoff behavior typical of monsoonal regions with clayey soils, where quick runoff occurs during intense rainfall spells once the soil becomes saturated. This reinforces the importance of timely water harvesting, especially during July and August, through structures such as check dams, farm ponds, compartment bunding, and contour trenches to maximize retention and improve groundwater recharge.

The runoff trends also underline the need for location-specific treatment planning, prioritizing upland and midland areas that contribute significantly to surface flow. Ensuring that this runoff is slowed, spread, and stored within the landscape will be central to achieving the watershed development objectives in this cluster.

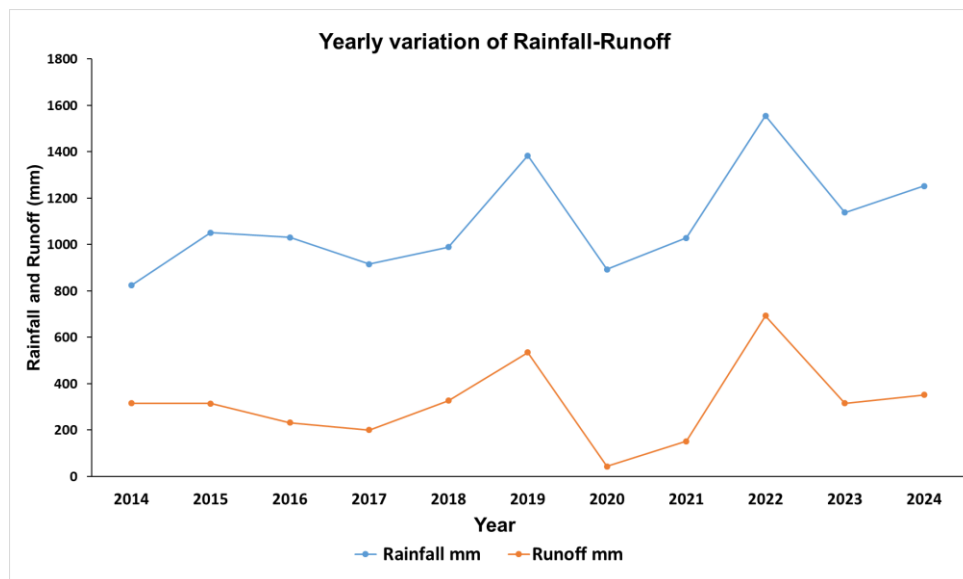


Fig 4.20. Yearly variation of rainfall-runoff in Seloo watershed

4.7 Mapping of Groundwater Potential Zones

Groundwater is the most dependable source of water in Seloo taluka of Wardha district, forming the backbone of agriculture, drinking supply, and socio-economic stability. The taluka lies in the Vidarbha region, which experiences a tropical wet and dry climate with an average annual rainfall of 1056 mm. Rainfall is concentrated in the monsoon months, leaving extended dry periods that often result in scarcity during summer. Agriculture is dominated by cotton and soybean, crops that demand dependable irrigation, and this has intensified pressure on groundwater resources. The basaltic geology of the Deccan Traps adds complexity, with aquifer properties varying sharply between fractured, weathered, and compact basalt zones.

The present condition of Seloo taluka shows declining groundwater levels in several villages due to borewell dependency and uneven rainfall distribution. Seasonal scarcity is common, particularly in years of below-average rainfall. Farmers face challenges in sustaining crop productivity, and the imbalance between demand and recharge has created stress on aquifers. Tackling these challenges requires a scientific approach to identify zones of varying groundwater potential and prioritize interventions accordingly.

To address this, groundwater potential zone mapping was undertaken in an eight-village cluster watershed of Seloo taluka. The study integrated eight thematic factors lithology, land use and land cover, rainfall, landform, soil, slope, drainage density, and elevation into a geospatial framework. Each factor was weighted using the Analytical Hierarchy Process, and a weighted overlay analysis was performed to generate a composite map. The classification delineated five categories of groundwater potential: very poor, poor,

moderate, good, and very good.

The results revealed that very good zones were concentrated in areas with fractured basalt, moderate slopes, fertile soils, and favorable geomorphic conditions. Good zones were spread across moderately weathered basalt with gentle slopes and medium drainage density. Moderate zones were associated with compact basalt and limited recharge, while poor and very poor zones were concentrated in elevated plateaus and steep slopes where runoff dominates. Quantitatively, the distribution showed that about 5.8% of the watershed falls under very good potential, 29.7% under good potential, 41.3% under moderate potential, 17.7% under poor potential, and 5.5% under very poor potential.

This mapping exercise under PMKSY is significant for Seloo taluka. By identifying recharge-prone areas and zones of limited potential, the study provides a scientific basis for targeted interventions such as check dams, percolation tanks, and farm ponds. It also informs crop planning, encouraging water-efficient practices in stressed zones and supporting sustainable cultivation in favorable areas. The results enable evidence-based decision-making, ensuring that interventions are region-specific and aligned with ecological realities.

The study establishes a reference point for future development activities in Wardha district. It demonstrates that integrating groundwater potential mapping with local climatic and geological conditions provides a more accurate picture of water availability. The approach can serve as a model for other talukas with similar tropical wet and dry conditions, ensuring that interventions are scientifically guided, replicable, and sustainable. By combining geospatial analysis with policy objectives, the exercise strengthens resilience against drought, supports agricultural productivity, and secures livelihoods, fulfilling the goals of PMKSY in ensuring water for every farm and household.

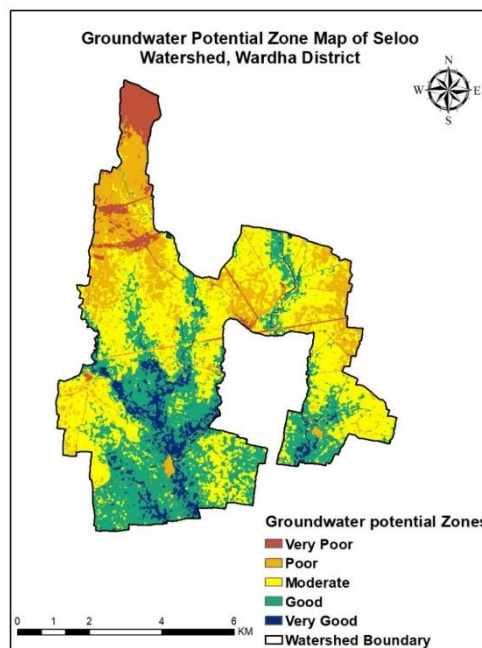


Fig. 4.21. Ground water potential zones in Seloo watershed

4.8 Evaluation of Soil-Site Suitability for Crops

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

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

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

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

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4.8.1 Soil-Site Suitability for Cotton Cultivation

The soil-site evaluation for cotton cultivation shows areas categorized as highly suitable (S1) cover 1703.8 ha, accounting for about 33.4% of the total geographical area, indicating favorable soil and site conditions for achieving good crop performance. 449.8 ha (8.8%) of the total geographical area is classified as moderately suitable (S2), these areas provide acceptable conditions for cotton cultivation, though certain soil and site constraints may affect crop performance.

A large portion of the watershed, covering 2311.0 ha (45.3%), falls under the marginally suitable (S3) category (Table 4.24, Fig. 4.22), indicating the presence of moderate limitations that may restrict yield potential. Around 419.5 ha (8.2%) of the area is categorized as not suitable (N) for cotton cultivation due to severe soil and site-related constraints. Overall, the assessment indicates that nearly one-third of the watershed is highly suitable for cotton cultivation.

Table 4.24. Area under suitability sub-classes for Cotton cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Highly Suitable (S1)	1703.8	33.4
2	Moderately Suitable (S2)	449.8	8.8
3	Marginally Suitable (S3)	2311.0	45.3
4	Not Suitable (N)	419.5	8.2
5	Forest	104.1	2.0
6	Habitation	53.4	1.0
7	Waterbody	64.8	1.3
	Total	5106.2	100.0

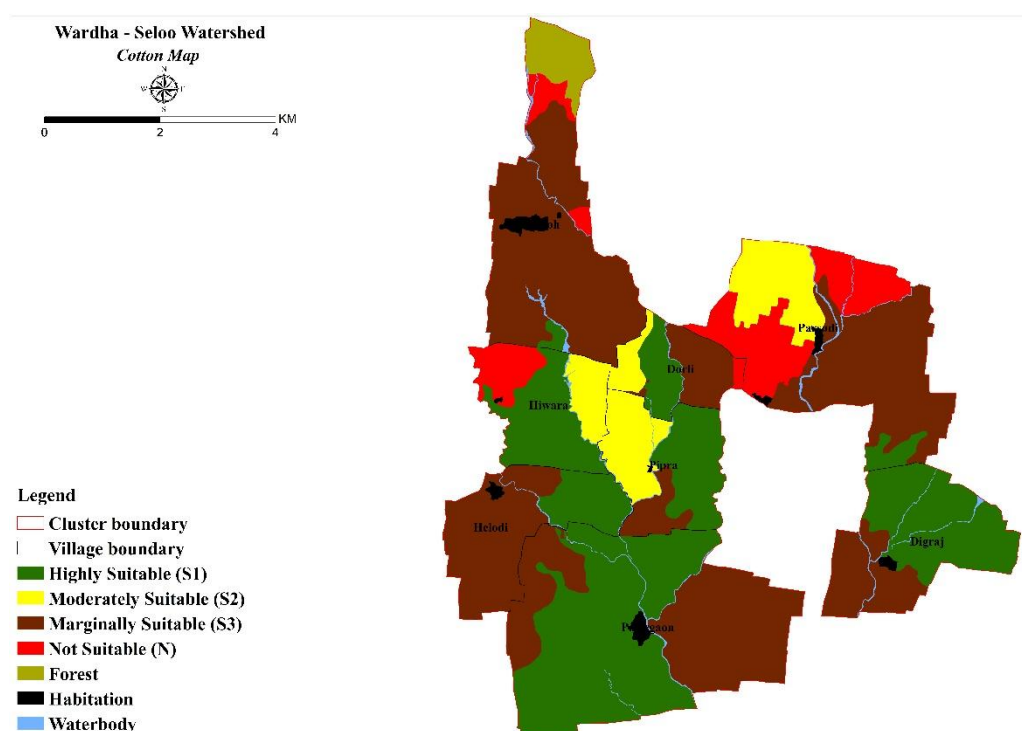


Fig. 4.22. Soil site suitability map for Cotton cultivation

4.8.2 Soil-Site Suitability for Soybean Cultivation

Soil-site evaluation results for soybeans show a varied distribution of suitability classes across the watershed (Table 4.25, Fig. 4.23). Areas categorized as moderately suitable (S2) class is covering area 3419.1 ha (67.0%), representing zones where soybean cultivation is feasible, although certain soil or site constraints may influence yield levels. 1242.6 ha (24.3%) of the watershed area is occupied under the marginally suitable (S3) category, suggesting the presence of noticeable limitations that may restrict optimum crop growth. About 4.4% of the watershed is not suitable (N) for soybean cultivation. These results most favorable for soybean cultivation in the watershed by following recommended package of practices.

Table 4.25. Area under suitability sub-classes for Soybean cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Moderately Suitable (S2)	3419.1	67.0
2	Marginally Suitable (S3)	1242.6	24.3
3	Not Suitable (N)	222.2	4.4
4	Forest	104.1	2.0
5	Habitation	53.4	1.0
6	Waterbody	64.8	1.3
	Total	5106.2	100.0

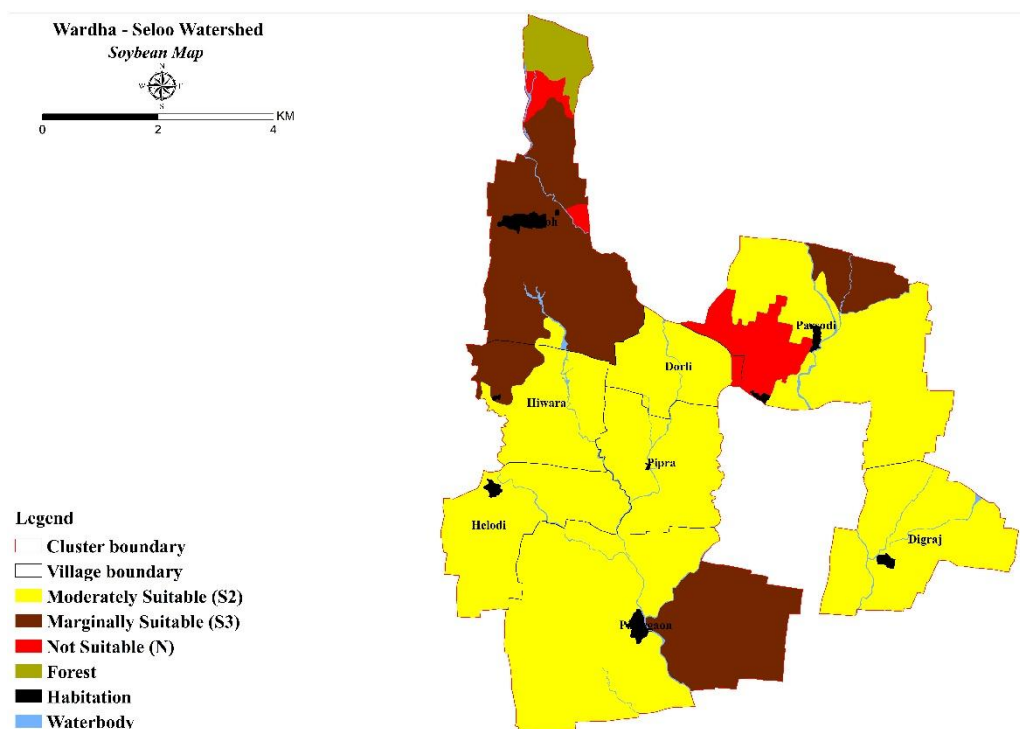


Fig. 4.23. Soil site suitability map for Soybean cultivation

4.8.3 Soil-Site Suitability for Pigeon pea (Tur/Arhar) Cultivation

2792.8 ha (54.7%) of the watershed area is moderately suitable (S2), and another 1326.7 ha (26.0%) is marginally suitable for pigeon pea 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 15.0% of the watersheds was identified as not suitable (N) for pigeon pea cultivation due to severe soil and site limitations (Table 4.26, Fig. 4.24).

Table 4.26. Area under suitability sub-classes for Pigeon pea cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Moderately Suitable (S2)	2792.8	54.7
2	Marginally Suitable (S3)	1326.7	26.0
3	Not Suitable (N)	764.5	15.0
4	Forest	104.1	2.0
5	Habitation	53.4	1.0
6	Waterbody	64.8	1.3
	Total	5106.2	100.0

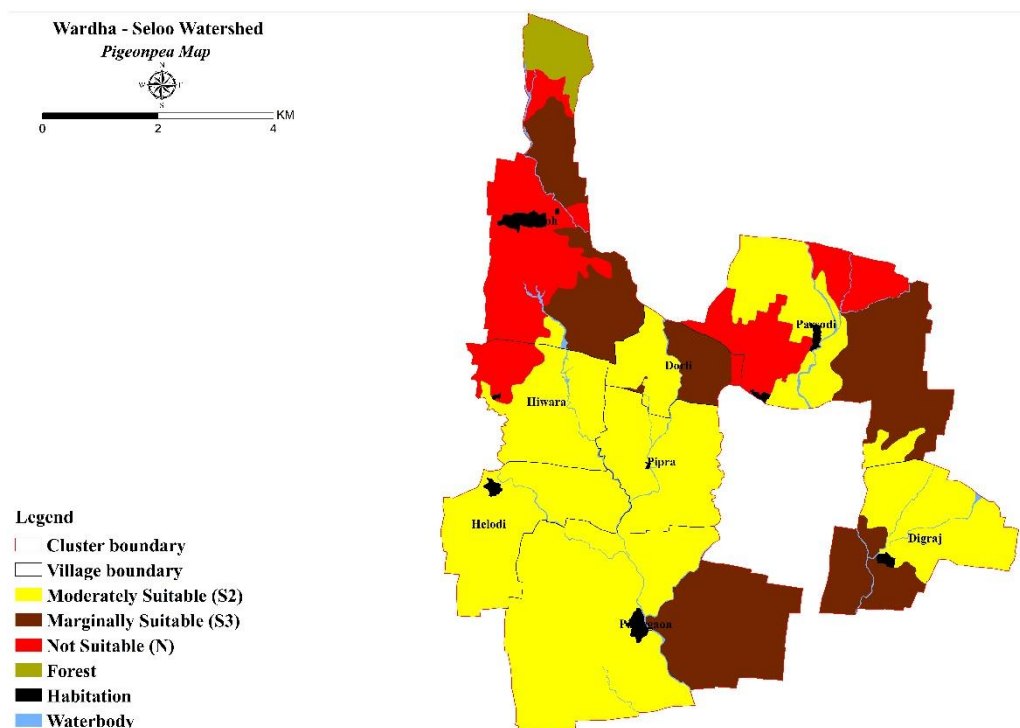


Fig. 4.24. Soil site suitability map for Pigeon pea cultivation

4.8.4 Soil-Site Suitability for Sorghum (Jowar) Cultivation

The soils of the watershed were evaluated for sorghum cultivation based on crop-specific requirements. The distribution of suitability classes is presented in Table 4.27, Fig. 4.25. The results indicate that about 2228.3 ha (43.6%) of the watershed area provides favorable soil and site conditions for optimal crop growth and is highly suitable (S1) for sorghum. The moderately suitable (S2) category covers 1190.8 ha (23.3%), wherein minor soil and environmental constraints may reduce crop productivity. Around One-fourth 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.

4.4% of the watershed area is not suitable (N) for sorghum cultivation due to severe soil and site constraints. Therefore, it is suggested that nearly one-fourth of the watershed may be put under sorghum cultivation in marginally suitable areas, appropriate agronomic and soil and water management interventions may be adopted.

Table 4.27. Area under suitability sub-classes for Sorghum (Jowar) cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Highly Suitable (S1)	2228.3	43.6
2	Moderately Suitable (S2)	1190.8	23.3
3	Marginally Suitable (S3)	1242.6	24.3
4	Not Suitable (N)	222.2	4.4
5	Forest	104.1	2.0
6	Habitation	53.4	1.0
7	Waterbody	64.8	1.3
	Total	5106.2	100.0

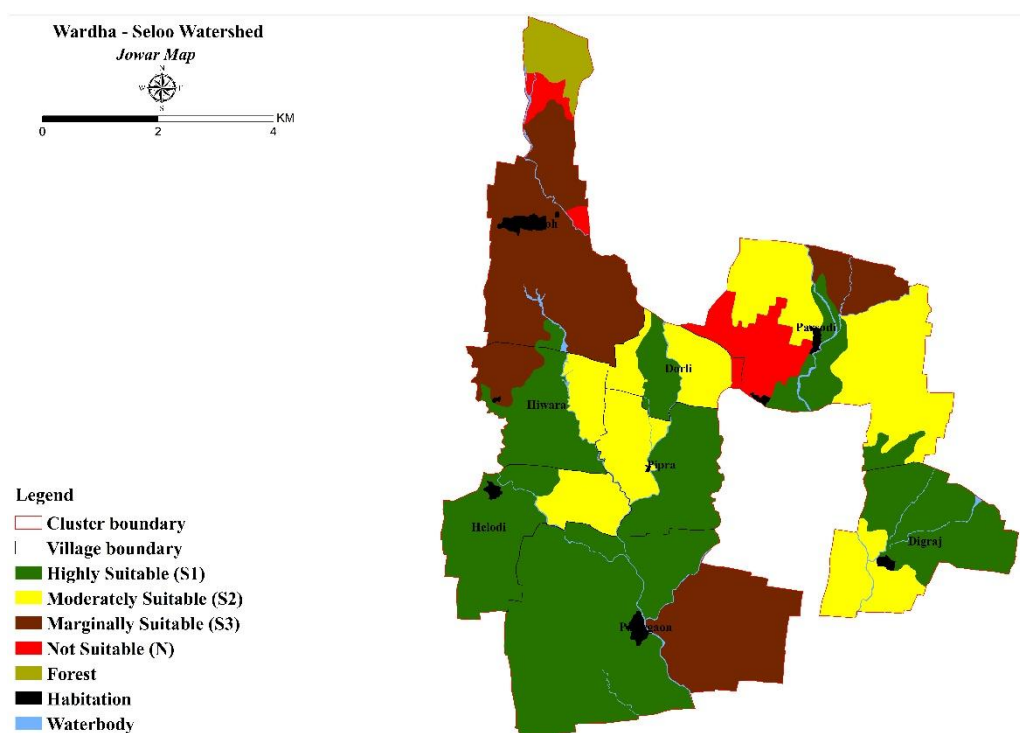


Fig. 4.25. Soil site suitability map for Sorghum (Jowar) cultivation

4.8.5 Soil-Site Suitability for Wheat Cultivation

The suitability assessment for wheat cultivation across the watershed reveals a broad range of suitability classes (Table 4.28, Fig. 4.26). Areas covering 2538.7 ha (49.7%), 880.4 ha (17.2%) and 1242.6 ha (24.3%) ha have been classified under highly suitable (S1), moderately suitable (S2) and marginally suitable (S3) categories, respectively. Only 4.4% of the area is classified as not suitable (N) for wheat cultivation due to severe soil and environmental limitations. Overall report indicated that watershed area is moderate to highly suitable for wheat cultivation.

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

1	Highly Suitable (S1)	2538.7	49.7
2	Moderately Suitable (S2)	880.4	17.2
3	Marginally Suitable (S3)	1242.6	24.3
4	Not Suitable (N)	222.2	4.4
5	Forest	104.1	2.0
6	Habitation	53.4	1.0
7	Waterbody	64.8	1.3
	Total	5106.2	100.0

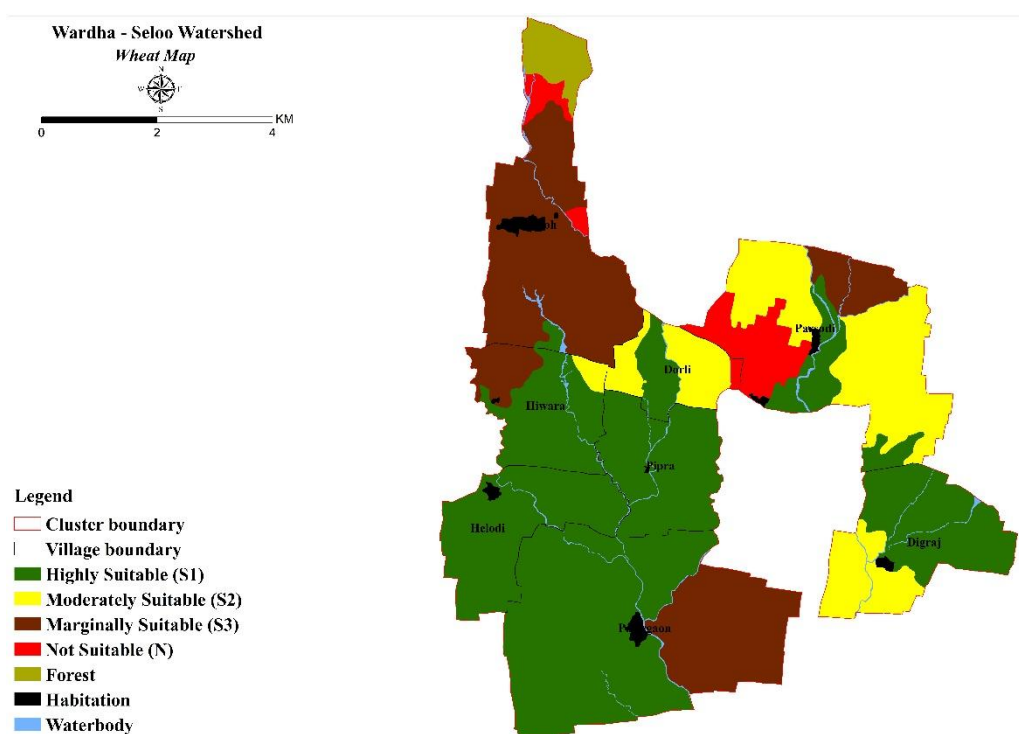


Fig. 4.26. Soil site suitability map for Wheat cultivation

4.8.6 Soil-Site Suitability for Chickpea Cultivation

3419.1 ha (67.0%) of the watershed area were categorized under moderately (S2) suitable, respectively, for Chickpea cultivation, whereas 1242.6 ha (24.3%) of area was found to be marginally suitable (S3), reflecting moderate to severe constraints primarily associated with soil and environmental factors, which may restrict yield potential without appropriate management practices. Only 4.4% area of watershed is not suitable(N) for Chickpea. Chickpea is recommended for cultivation in major portion of the watershed (Table 4.29, Fig. 4.27).

Table 4.29. Area under suitability sub-classes for Chickpea cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Moderately Suitable (S2)	3419.1	67.0
2	Marginally Suitable (S3)	1242.6	24.3
3	Not Suitable (N)	222.2	4.4
4	Forest	104.1	2.0
5	Habitation	53.4	1.0
6	Waterbody	64.8	1.3
	Total	5106.2	100.0

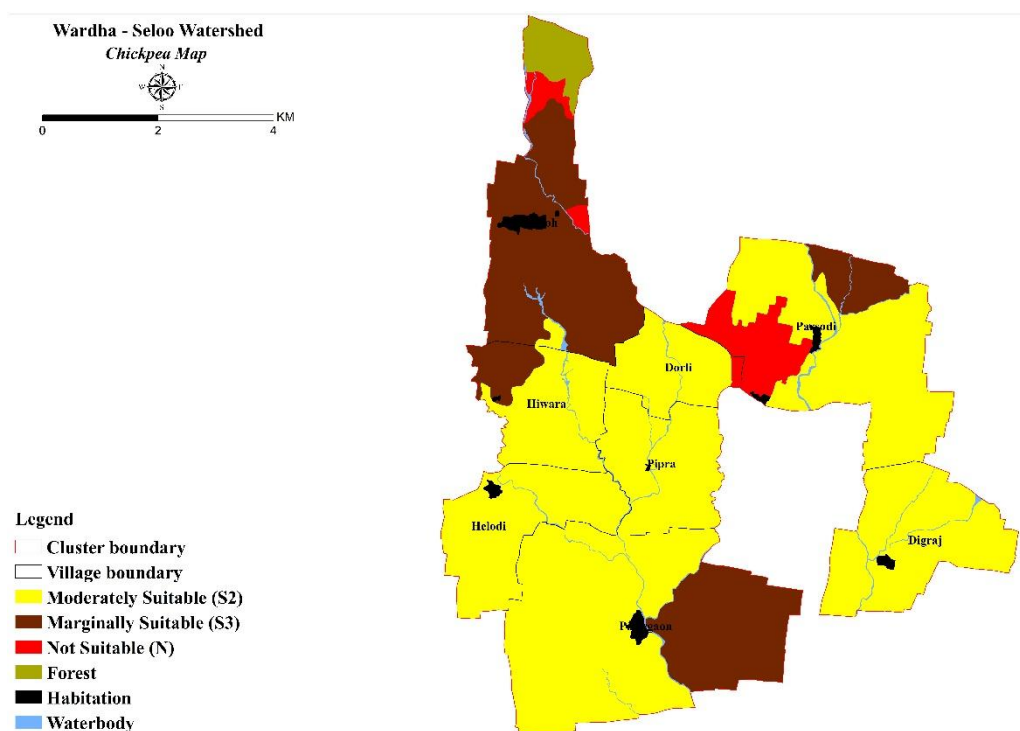


Fig. 4.27. Soil site suitability map for Chickpea cultivation

4.8.7 Soil-Site Suitability for Sugarcane Cultivation

The soil-site suitability analysis for sugarcane cultivation reveals a wide variation in land capability across the watershed. Area 2792.8 ha (54.7%) of the watershed area is moderately suitable for sugarcane (Table 4.30, Fig. 4.28). These areas represent zones where sugarcane cultivation can be practiced with moderate limitations. Another 626.3 ha (12.3%) of the area is marginally suitable (S3), indicating the presence of noticeable constraints that may affect crop establishment and productivity. In contrast, a dominant share of the watershed, accounting for 28.7% cannot be put under sugarcane due to severe soil and site limitations.

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

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Moderately Suitable (S2)	2792.8	54.7
2	Marginally Suitable (S3)	626.3	12.3
3	Not Suitable (N)	1464.9	28.7
4	Forest	104.1	2.0
5	Habitation	53.4	1.0
6	Waterbody	64.8	1.3
	Total	5106.2	100.0

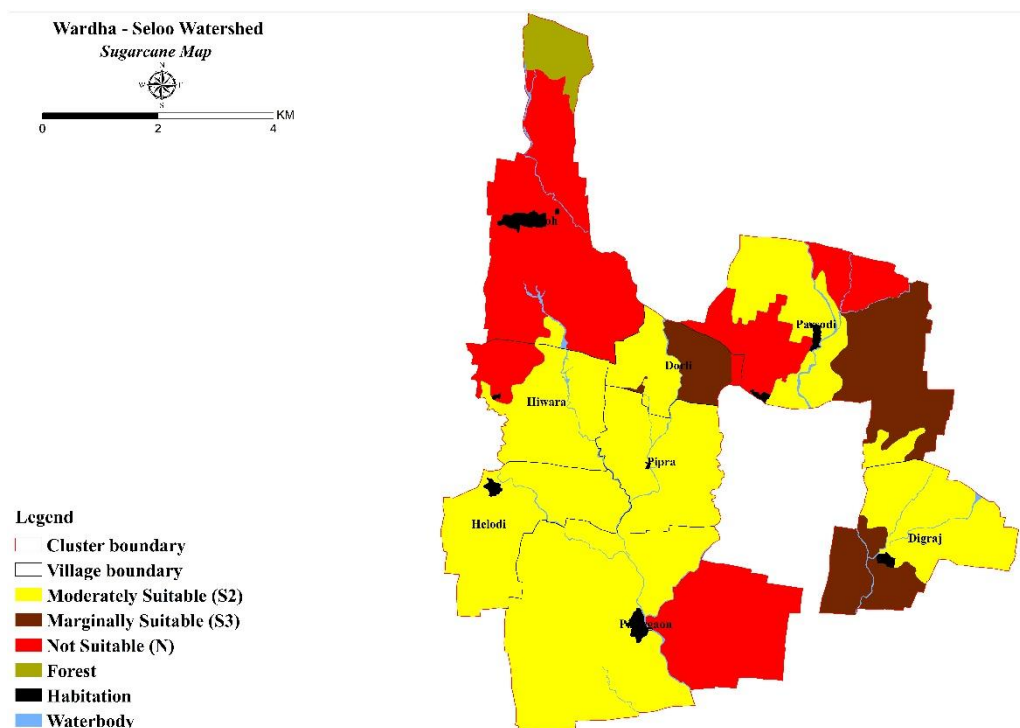


Fig. 4.28. Soil site suitability map for Sugarcane cultivation

4.8.8 Soil-Site Suitability for Black Gram (Urad) Cultivation

The soil-site suitability analysis for black gram cultivation reveals a wide variation in land capability across the watershed. Areas identified as moderately suitable (S2) extend over 3419.1 ha, constituting 67.0% of the total geographical area, indicating with manageable limitations for crop establishment and growth. Around 24.3% area of the watershed is categorized as marginally suitable (S3), indicating the presence of noticeable constraints that may affect crop establishment and productivity. Only 4.4% area of watershed is not suitable (N) for black gram. Black Gram is recommended for cultivation in major portion of the watershed (Table 4.31, Fig. 4.29).

Table 4.31. Area under suitability sub-classes for Black Gram (Urad) cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Moderately Suitable (S2)	3419.1	67.0
2	Marginally Suitable (S3)	1242.6	24.3
3	Not Suitable (N)	222.2	4.4
4	Forest	104.1	2.0
5	Habitation	53.4	1.0
6	Waterbody	64.8	1.3
	Total	5106.2	100.0

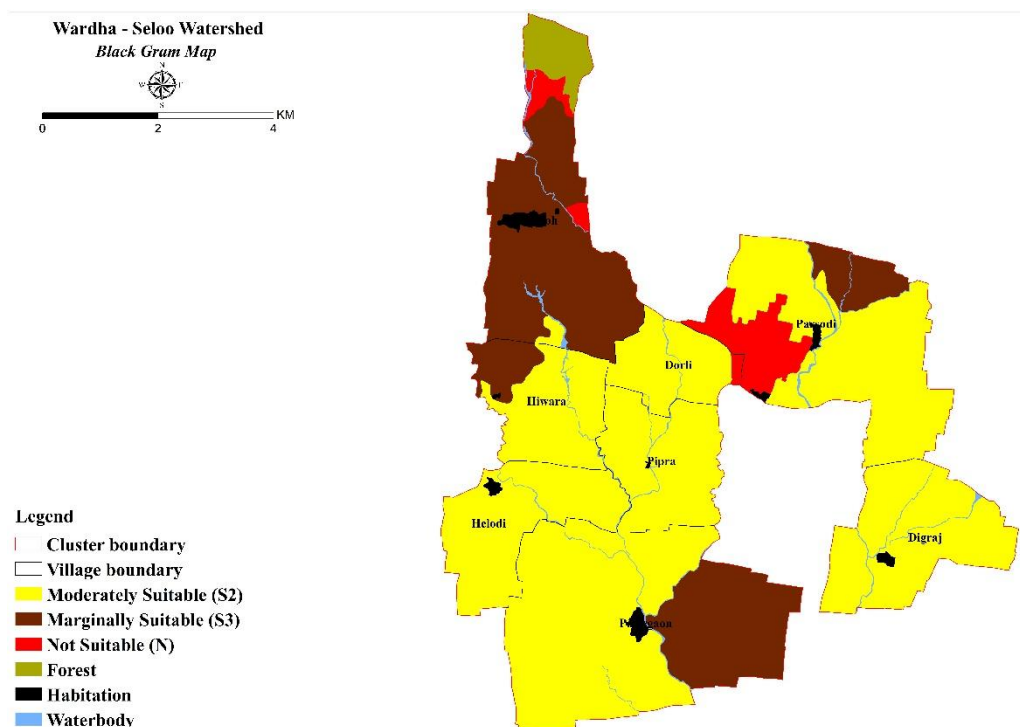


Fig. 4.29. Soil site suitability map for Black Gram (Urad) cultivation

4.8.9 Soil-Site Suitability for Green Gram Cultivation

A larger proportion of the watershed, 3419.1ha (67.0%), is categorized as moderate suitable (S2), wherein crop yields would be manageable limitations, as these areas provide relatively stable conditions for crop establishment and growth. Green Gram can be cultivated in about 24.3% of the watershed area (1242.6 ha) with constrained by soil and site factors, resulting in reduced productivity under normal management practices. Only 4.4% area of watershed are not suitable(N) for crop cultivation (Table 4.32 and Fig. 4.30.). The major land emphasizes the need for careful site selection when planning green gram cultivation within the watershed.

Table 4.32. Area under suitability sub-classes for Green Gram cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Moderately Suitable (S2)	3419.1	67.0
2	Marginally Suitable (S3)	1242.6	24.3
3	Not Suitable (N)	222.2	4.4
4	Forest	104.1	2.0
5	Habitation	53.4	1.0
6	Waterbody	64.8	1.3
	Total	5106.2	100.0

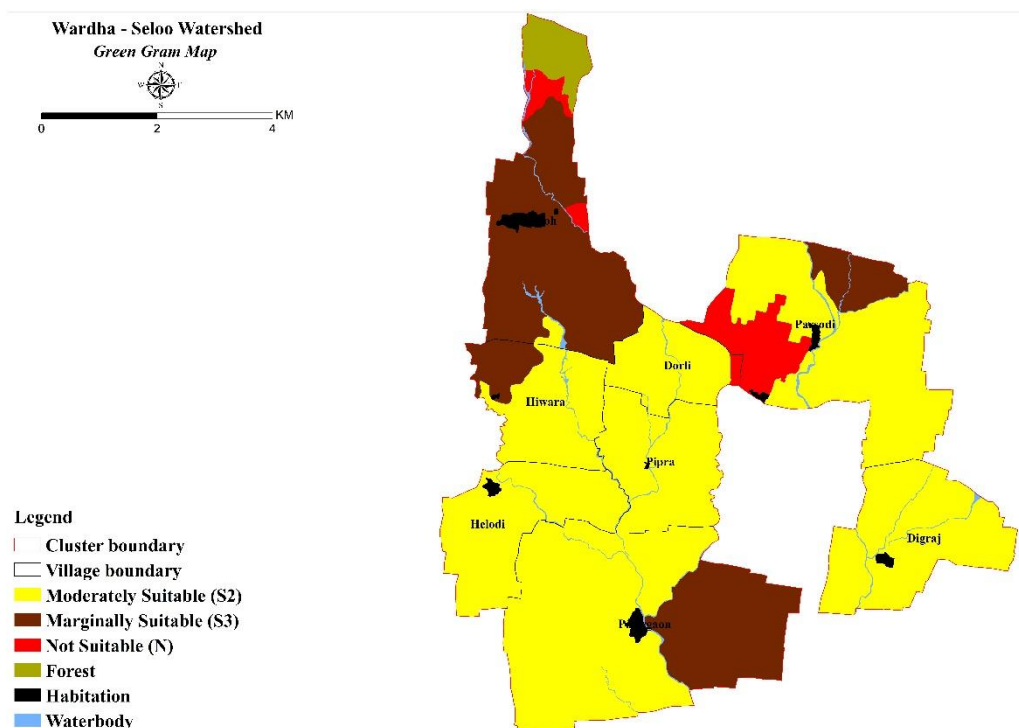


Fig. 4.30. Soil site suitability map for Green Gram cultivation

4.8.10 Soil-Site Suitability for Turmeric Cultivation

22.0% of the watershed area were categorized under moderately suitable(S2) occupy 1123.5 ha, respectively, for Turmeric cultivation, whereas 69.3% of area was found to be marginally suitable (S3), reflecting moderate to severe constraints primarily associated with soil and environmental factors, which may restrict yield potential without appropriate management practices. Only 4.4% area of watershed are not suitable(N) for crop cultivation (Table 4.33 and Fig. 4.31).

Table 4.33. Area under suitability sub-classes for Turmeric cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Moderately Suitable (S2)	1123.5	22.0
2	Marginally Suitable (S3)	3538.3	69.3
3	Not Suitable (N)	222.2	4.4
4	Forest	104.1	2.0
5	Habitation	53.4	1.0
6	Waterbody	64.8	1.3
	Total	5106.2	100.0

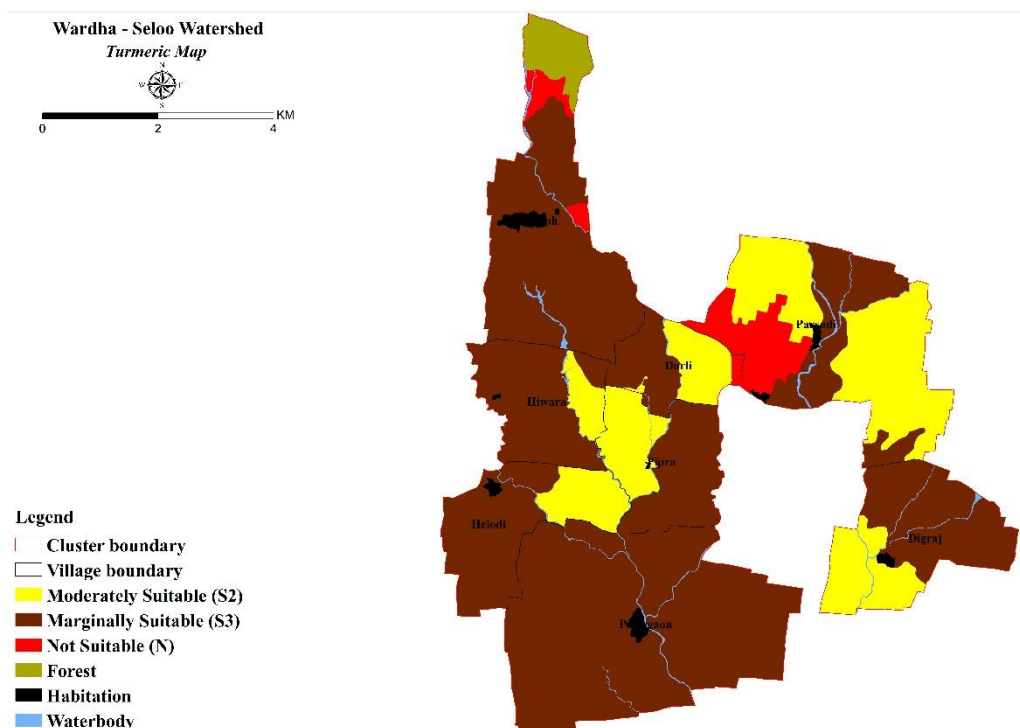


Fig. 4.31. Soil site suitability map for Turmeric cultivation

4.8.11 Soil-Site Suitability for Orange Cultivation

38.3% of the watershed area were categorized under moderately (S2) suitable occupy 1957.9 ha, respectively, for orange cultivation, whereas 28.6% of area was found to be marginally suitable (S3), reflecting moderate to severe constraints primarily associated with soil and environmental factors, which may restrict yield potential without appropriate management practices. 28.7% of the watershed area is not suitable (N) for orange cultivation due to severe limitations (Table 4.34, Fig. 4.32).

Table 4.34. Area under suitability sub-classes for Orange cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Moderately Suitable (S2)	1957.9	38.3
2	Marginally Suitable (S3)	1461.2	28.6
3	Not Suitable (N)	1464.9	28.7
4	Forest	104.1	2.0
5	Habitation	53.4	1.0
6	Waterbody	64.8	1.3
	Total	5106.2	100.0

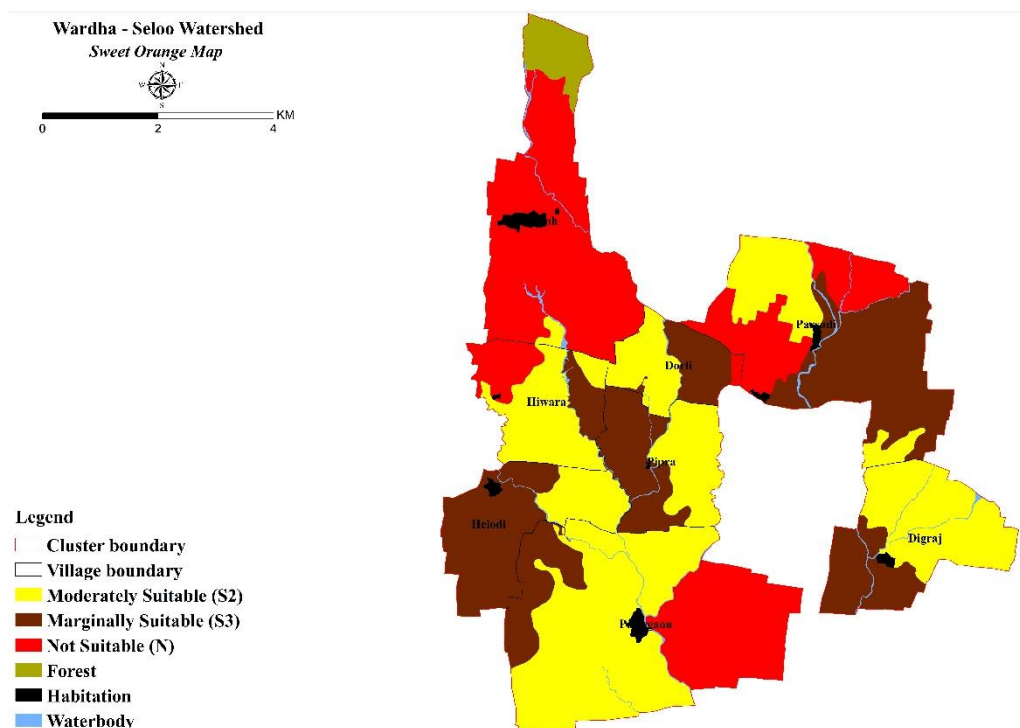


Fig. 4.32. Soil site suitability map for Orange cultivation

4.8.12 Soil-Site Suitability for Lemon Cultivation

The soils of the watershed were evaluated for Lemon cultivation based on crop-specific requirements. The distribution of suitability classes is presented in Table 4.35, Fig.4.33. The results indicate that about 114.7 ha (2.2%) of the watershed area provides favorable soil and site conditions for optimal crop growth and is highly suitable (S1) for lemon. 2678.1 ha (52.4% of the total geographical area of the watershed) is classified as moderately suitable (S2), certain limitation for lemon growth and productivity. A considerable portion of the watershed around 12.3% of the area is categorized as marginally suitable (S3), reflecting moderate to severe constraints related to soil properties and terrain slope, which may restrict yield potential unless appropriate management practices are adopted.

28.7% of the watershed area is not suitable (N) for Lemon cultivation due to severe limitations associated with rocky soil, topography, waterlogging, steep slope and alkalinity of soil. Overall, the evaluation suggests that more than half of soil is moderately suitable for lemon cultivation.

Table 4.35. Area under suitability sub-classes for Lemon cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Highly Suitable (S1)	114.7	2.2
2	Moderately Suitable (S2)	2678.1	52.4
3	Marginally Suitable (S3)	626.3	12.3
4	Not Suitable (N)	1464.9	28.7
5	Forest	104.1	2.0
6	Habitation	53.4	1.0
7	Waterbody	64.8	1.3
	Total	5106.2	100.0

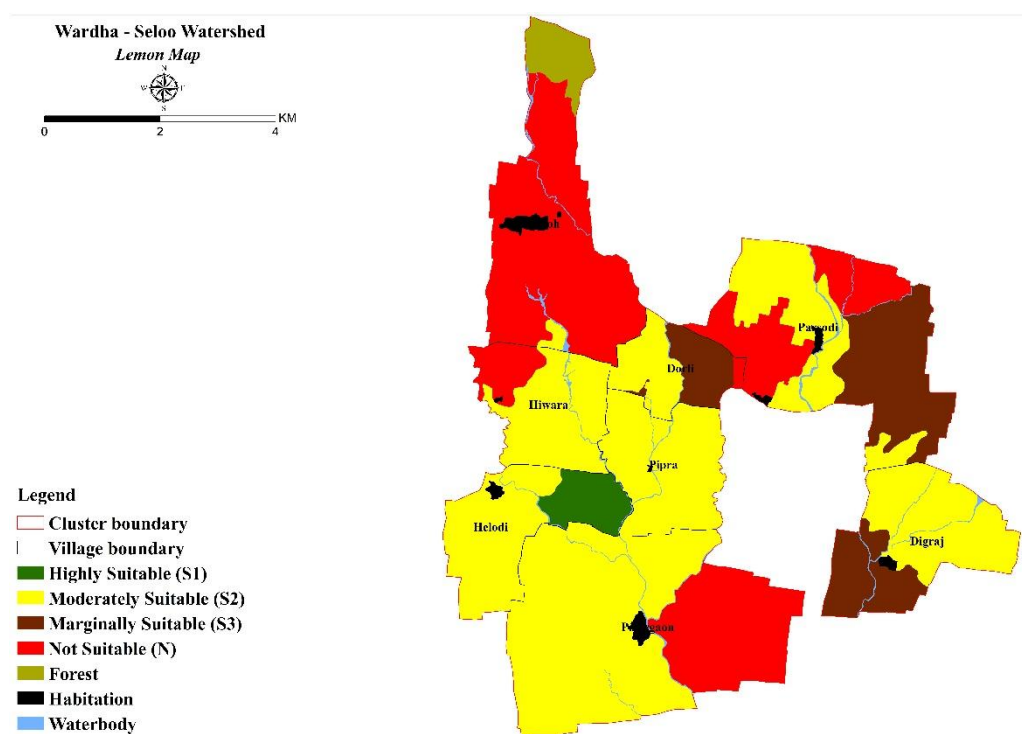


Fig. 4.33. Soil site suitability map for Lemon cultivation

4.8.13 Soil-Site Suitability for Sweet Orange Cultivation

The soils of the watershed were evaluated for Sweet Orange cultivation based on crop-specific requirements. The distribution of suitability classes is presented in Table 4.36 and Fig. 4.34. The results indicate that only 1957.9 ha (38.3% of the total geographical area of the watershed) is classified as moderately suitable (S2), providing certain limitations for Sweet Orange growth and productivity. A considerable portion of the watershed around 28.6% of the area is categorized as marginally suitable (S3), reflecting moderate to severe constraints related to soil properties and terrain slope, which may restrict yield potential unless appropriate management practices are adopted.

28.7% of the watershed area is not suitable (N) for Sweet Orange cultivation. Overall, the evaluation suggests that while soil is marginally suitable to moderately suitable for Sweet Orange cultivation.

Table 4.36. Area under suitability sub-classes for Sweet Orange cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Moderately Suitable (S2)	1957.9	38.3
2	Marginally Suitable (S3)	1461.2	28.6
3	Not Suitable (N)	1464.9	28.7
4	Forest	104.1	2.0
5	Habitation	53.4	1.0
6	Waterbody	64.8	1.3
	Total	5106.2	100.0

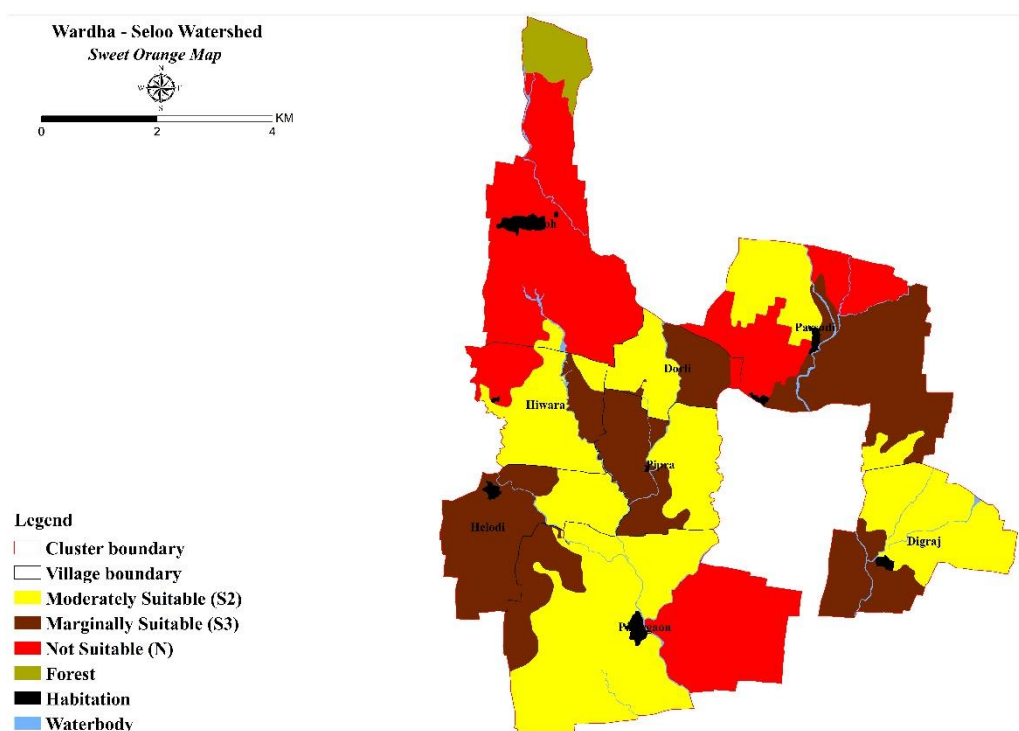


Fig. 4.34. Soil site suitability map for Sweet Orange cultivation

4.9 Soil and Water Conservation measures

Soil and Water Conservation (SWC) refer to scientific measures adopted to control soil erosion, manage runoff, enhance water storage, and sustain long-term agricultural productivity. SWC practices play an essential role in protecting soil structure, improving moisture retention, and reducing land degradation, thereby ensuring stable crop performance and productivity. These measures are crucial in landscapes where variable soil depth, slope gradients, and rainfall intensity influence surface runoff and moisture availability.

The SWC interventions proposed for the watershed are planned based on the existing land use, landform characteristics, terrain conditions, and drainage features. The terrain of the watershed is predominantly characterized by gentle to steep slopes, which allows the

implementation of several in-situ moisture conservation measures and runoff management practices. Different conservation treatments have therefore been assigned to specific land units such as agricultural fields, plantation areas, drainage lines, forest patches, and built-up sections to minimize soil erosion and improve water availability.

For drainage line management and water harvesting, structures such as cement nala bunds, earthen nala bunds, and repair and desilting of nallas have been recommended to regulate runoff flow and enhance groundwater recharge. Renovation of existing water bodies has also been proposed wherever suitable site conditions exist in order to increase storage capacity and improve water availability during non-monsoon periods. In moderately sloping agricultural lands, conservation bench terracing along with bund strengthening has been suggested to control soil erosion and manage runoff effectively.

Vegetative conservation measures have also been incorporated to improve ecological stability and soil protection. These include afforestation with contour trenching and silt detention trenches, horticultural plantation with in-situ moisture conservation measures, and stream bank plantation along drainage channels to stabilize stream banks and reduce erosion. In built-up areas, rooftop rainwater harvesting systems have been proposed to capture rainwater for domestic use and support groundwater recharge.

Certain land units such as roads, railway tracks, and canal areas represent existing infrastructure where structural SWC interventions are limited, but runoff management considerations remain important. The combined implementation of these structural and vegetative measures is expected to reduce soil erosion, improve soil moisture availability, enhance water storage, and strengthen agricultural sustainability within the watershed.

The planned interventions collectively aim to reduce soil erosion, conserve rainwater at its source, support the controlled disposal of excess runoff, improve crop productivity, and enhance groundwater recharge across the Wardha landscape. The comprehensive allocation of area under each treatment is provided in the SWC summary table, ensuring structured implementation and resource prioritization. The total area and specific SWC measures applied across all landforms and LULC types are summarized in Table 4.37 and illustrated in Fig. 4.35.

Table 4.37. Proposed soil and water conservation (SWC) plan for Seloo watershed

Sr. No.	Proposed SWC Plan
1	Afforestation, Contour Trench, Silt Detention Trench in Downstream
2	Afforestation, In-situ Moisture Conservation Measures
3	Broad Bed and Furrow (BBF) system/Field bund/Strengthening of existing bund with safe disposal of runoff water
4	Broad Bed and Furrow (BBF) system/Field bund/Strengthening of existing bund with safe disposal of runoff water, Farm pond
5	Canal
6	Cement Nala Bund, Earthen Nala Bund / Repairing of Cement Nala Bund and Desilting of Nallas

7	Conservation Bench Terrace in Unbundled Field/Field bund/Strengthening of existing bund with safe disposal of runoff water
8	Field bund/Strengthening of existing bund with safe disposal of runoff water
9	Field bund/Strengthening of existing bund with safe disposal of runoff water, Farm pond
10	Horticultural Plantation, In-situ Moisture Conservation Measures
11	Horticultural Plantation, In-situ Moisture Conservation Measures, Farm pond
12	Railway Track
13	Renovation of Waterbody as per the site condition
14	Renovation/Desilting of Farm pond as per the site condition
15	Road
16	Rooftop Rainwater Harvesting
17	Stream Bank Plantation

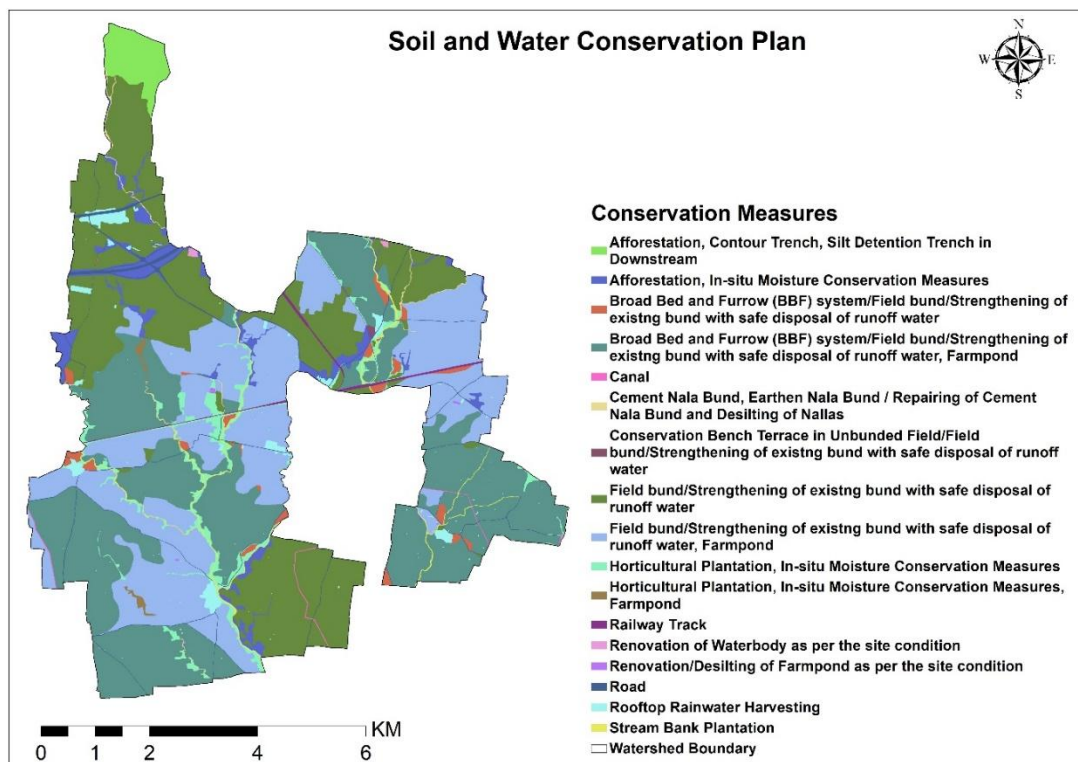


Fig. 4.35. Soil and water conservation measures proposed for Seloo watershed

CHAPTER 5

SUMMARY AND CONCLUSION

5.1 SUMMARY

- The Seloo watershed, assessed under the PMKSY-WDC 2.0 initiative, is situated in the Seloo Taluka of Wardha District, Maharashtra. It is characterized by the Deccan Plateau's basaltic terrain, with the local non-perennial streams and nalas, which ultimately join the Vena River.
- Agriculture constitutes the dominant land use and the local farming is primarily reliant on monsoon precipitation, complemented by groundwater resources and existing soil conservation structures. The project's overall objective is to measure improvements and ensure the long-term health of farming and related activities in rainfed areas.
- The primary objectives of the study included the systematic characterization and mapping of the soil and water resources, assessment of land capability and crop-site suitability, development of watershed-based alternate land use options, and evaluation of groundwater potential.
- The assessment revealed that the watershed exhibits considerable variability in landforms, slope, soils and land use. This variability critically governs processes like surface runoff generation, soil erosion, moisture availability and the occurrence of groundwater. Soils show corresponding variations in depth, texture, drainage, and fertility status across the terrain.
- Detailed maps and data for critical soil properties (including pH, organic carbon, macro and micro-nutrients like N, P, K, Fe, Mn, Cu, and Zn), hydrological data (rainfall-runoff) and a scientific evaluation of soil-site suitability for crops, which forms the foundation for developing and prioritizing watershed-based alternate land use and soil and water conservation (SWC) plans.

5.2 CONCLUSION

The Land Resource Inventory (LRI) and comprehensive watershed assessment, carried out by the ICAR-National Bureau of Soil Survey and Land Use Planning (ICAR-NBSS&LUP) for the Seloo watershed, delivers an essential technical and scientific foundation for effective planning and execution under the Pradhan Mantri Krishi Sinchayee Yojana - Watershed Development Component (PMKSY-WDC 2.0) framework.

The systematic and integrated analysis of the terrain, soil resources and local hydrological conditions provides a detailed and pragmatic understanding of the existing resource base, potential opportunities and specific resource constraints within the watershed. The assessment confirms the need for scientific interventions to manage the variability in soil and terrain characteristics.

The detailed maps of Soil-Site Suitability and Groundwater Potential Zones, offer a robust, scientific basis for strategic planning and the prioritization of interventions. Successful implementation of the proposed Soil and Water Conservation (SWC) measures is expected to enhance groundwater recharge, mitigate surface runoff and resource degradation, and ultimately ensure the long-term sustainable management of land and water resources for the sustained benefit of the local farming community in the Wardha district.

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 Seloo cluster, Wardha

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 site-specific assessment and practical implementation. However, morphometric analysis was conducted at the watershed level because morphometric parameters are controlled by natural drainage boundaries rather than administrative units.

Morphometric analysis quantitatively evaluates drainage network characteristics, basin geometry, slope, and relief, which influence runoff generation, erosion, and groundwater recharge. These parameters must be derived from a hydrologically closed unit bounded by natural divides. A watershed represents such a unit, where streams develop hierarchically

and drain toward a common outlet, ensuring reliable computation of indices such as drainage density, bifurcation ratio, stream frequency, form factor, and relief ratio.

Village clusters are administrative entities that do not coincide with complete drainage systems. Since streams often cross village boundaries, morphometric analysis at the cluster level would result in truncated stream networks and distorted basin geometry, leading to inaccurate hydrological interpretation.

Therefore, morphometric analysis was intentionally performed at the watershed level to maintain hydrological accuracy, while runoff estimation, GWPZ mapping, and SWC planning were undertaken at the village cluster level for effective local implementation. This integrated framework links natural hydrological processes with decentralized planning for sustainable water resource management.

The Seloo cluster, Wardha, Maharashtra, comprises eight villages. Together, these villages constitute the study cluster having 2 sub-watersheds (Fig. 1).

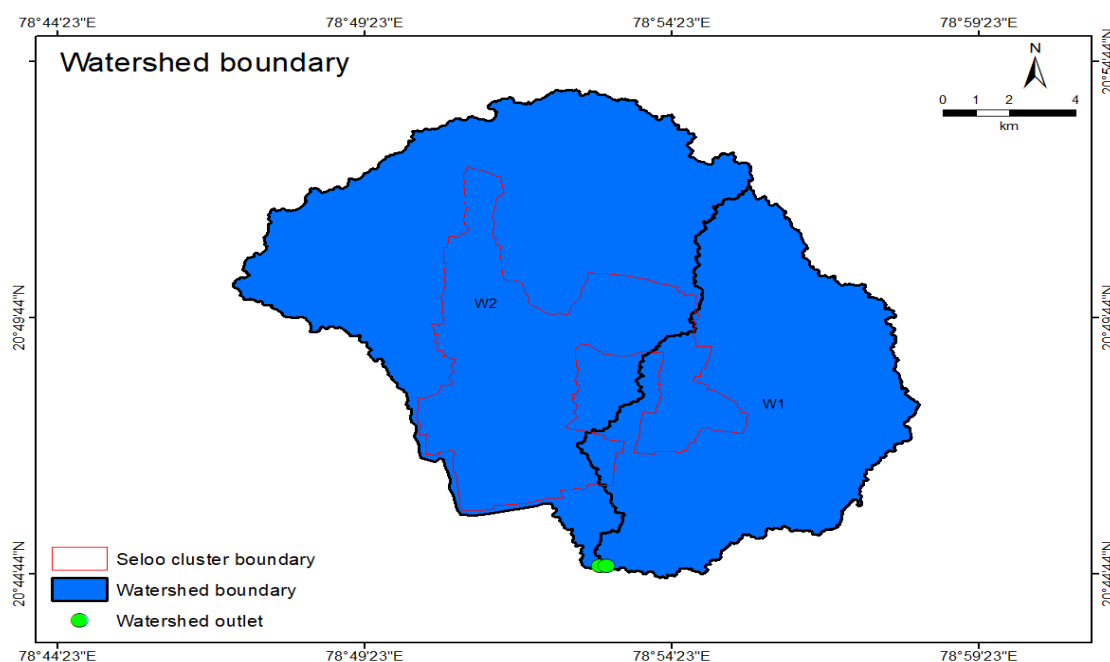


Fig. 1. Map of Seloo cluster, Wardha depicted through sub-watershed

Table 1. Distribution of area under different sub-watershed, Seloo cluster, Wardha

Sr. No.	Sub-watershed name	Sub-watershed order	Elevation (m)	Area (km ²)	Flow origination
1	W1	5 th	154-234	76.71	North-south
2	W2	6 th	154-348	128.85	North-south
	Total			205.56	

The sub-watershed wise area, their order, elevation range 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.

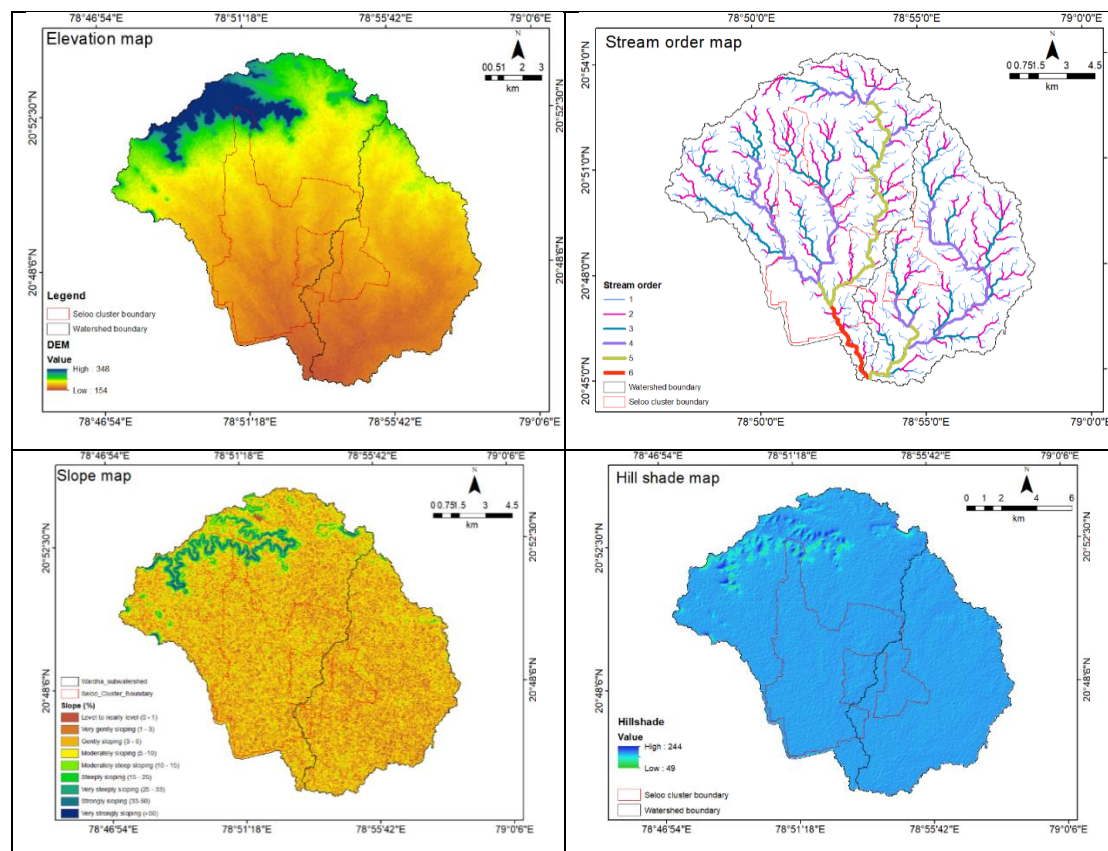


Fig. 2. Elevation, stream network, slope and hill shade map of sub-watershed

Linear aspect

Linear morphometric parameters focus on the stream network characteristics and its influence on runoff and watershed behavior. The morphometric analysis of the two sub-watersheds shows clear variation in drainage characteristics. W2 has the highest number of streams (626) and total stream length (338.04km), indicating a well-developed drainage network, while W1 has the lowest values (Table 2). The bifurcation ratio ranges from 4.2 (W1) to 4.1 (W2), suggesting relatively greater structural influence in W1.

Mean channel length and valley length are highest in W1, reflecting more mature channel development, whereas W2 records the lowest values. Channel index is highest in W1 (1.2), indicating greater sinuosity. Basin perimeter is also largest in W2 (85.04 km), confirming it as the most extensive sub-watershed, while W1 is the smallest.

Table 2. Linear morphometric parameters of sub-watersheds, Seloo cluster, Wardha

Sr. No.	Morphometric parameter	Symbol	Unit	W1
1	No. of streams	Nu	No	384
2	Stream length	Lu	km	214.7
3	Bi-furcation ratio	Rb	-	4.2
4	Mean channel length	Cl	km	23.3
5	Valley Length	Vl	km	21.8
6	Channel Index	Ci	-	1.2
7	Minimum areal distance	Adm	km	19.52
8	Valley Index	Vi	-	1.12
9	Basin perimeter	P	km	64.42

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. The analysis reveals variation in basin shape and drainage characteristics among the two sub-watersheds. Basin area is highest in W2 (128.85 km²) and lowest in W1 (76.71 km²). Mean basin width is also greater in W2 (4.58 km). Form factor (Ff) and elongation ratio (Re) are highest in W2 (0.16 and 0.46), suggesting a comparatively more circular basin, whereas W2 show lower values, indicating elongated shapes. Circularity ratio (Rc) is maximum in W2 (2.13), and compactness coefficient (Cc) is highest in W1 (0.23), reflecting greater basin irregularity. Standard sinuosity index (Ssi) ranges from 1.05 (W1) to 1.07 (W2), indicating relatively higher channel sinuosity in W1.

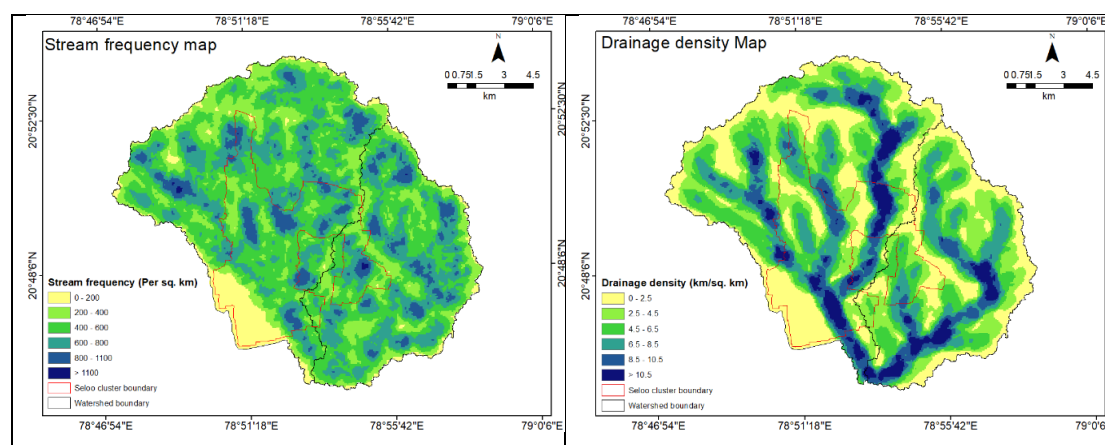


Fig. 3. Steam frequency and drainage density map of sub-watershed

Drainage parameters show that stream frequency (F_s) is highest in W1 (5.01 per km^2) and lowest in W2 (4.86 per km^2). Drainage density (D_d) is W1 (2.80 km/km^2) but lower in W2 (2.62 km/km^2). Drainage intensity (D_i) follows a similar trend, with the highest value in W2 (1.8). Length of overland flow (L_g) in range from 0.18 to 0.31 km, from W1 to W2 indicating shorter runoff travel distance in watershed.

Table 3. Areal morphometric parameters of sub-watersheds, Seloo cluster, Wardha

Sr. No.	Parameter	Symbol	Method/ Formula	Unit	W1
1.	Mean basin width	Wb	$Wb=A/Lb$	km	3.18
2.	Basin area	A	GIS Analysis	km^2	76.71
3.	Relative perimeter	Pr	$Pr= A/P$	km	1.19
4.	Length area relation	Lar	$Lar = 1.4*A^{0.6}$	km^2	18.93
5.	Lemniscate's	k	$K = Lb^2/A$	-	7.57
6.	Form factor	Ff	$Ff = A/Lb^2$	-	0.13
7.	Elongation ratio	Re	$Re = 2/Lb*(A/\pi)^{0.5}$	-	0.41
8.	Circularity ratio	Rc	$Rc = 12.57*(A/P^2)$	-	2.09
9.	Compactness coefficient	Cc	$Cc = 0.2841*P/A^{0.5}$	-	0.23
10.	Standard sinuosity index	Ssi	$Ssi = C_i/V_i$	-	1.07
11.	Stream frequency	F_s	$F_s = N_u/A$	Per km^2	5.01
12.	Drainage Density	D_d	$D_d = L_u/A$	km/km^2	2.80
13.	Drainage Intensity	D_i	$D_i = F_s/D_d$	-	1.79
14.	Length of Overland Flow	L_g	$L_g = A/2*L_u$	km	0.18

Relief Aspects

The maximum basin height (Z) is highest in W2 (348 m) and lowest in W1 (234 m), while total basin relief (H) is also maximum in W2 (194 m) and minimum in W2 (80 m) (Table 4). Relief ratio (R_{hl}) is highest in W2 (6.9), indicating steeper terrain conditions, whereas W1 shows the lowest value (3.3).

Relative relief ratio (R_{hp}) is greatest in W2 (228.1), followed by W1 suggesting higher relief intensity in W2. The ruggedness number (R_n) is maximum in W2 (0.36), reflecting more dissected and erosion-prone terrain, while W1 has the lowest value (0.14). Similarly, the Melton ruggedness number (MR_n) is highest in W2 (17.1), indicating comparatively higher susceptibility to runoff and erosion processes.

Table 4. Relief morphometric parameters of sub-watersheds, Seloo cluster, Wardha

Sr. No	Parameters	Symbol	Methods /Formula	W1
1.	Height of at basin mouth (m)	z	DEM	154
2.	Maximum height of the basin (m)	Z	DEM	234
3.	Total basin relief (m)	H	$H = Z - z$	80
4.	Relief ratio	Rhl	$Rhl = H / Lb$	3.3
5.	Relative relief ratio	Rhp	$Rhp = H * 100 / P$	124.2
6.	Ruggedness number	Rn	$Rn = Dd*(H/1000)$	0.14
7.	Melton Ruggedness number	MRn	$MRn = H / A^{0.5}$	9.1

The slope distribution of the two sub-watersheds (W1 and W2) indicates that the terrain is predominantly gently to moderately sloping, reflecting an undulating landscape. In W1, the gently sloping class (3–5%) occupies the largest portion of the watershed, covering 31.80 km² (41.46%), followed by moderately sloping land (5–10%) with 23.20 km² (30.24%). The level to nearly level (0–1%) and very gently sloping (1–3%) classes account for 10.46 km² (13.63%) and 9.32 km² (12.15%), respectively, indicating the presence of relatively stable and low-gradient areas. In contrast, steeper slope categories such as moderately steep (10–15%), steep (15–25%), and very steep (25–33%) occupy only a small proportion of W1, suggesting limited high-relief terrain. In W2, a similar trend is observed, with gently sloping land (3–5%) covering 43.89 km² (34.06%) and moderately sloping land (5–10%) accounting for 42.52 km² (32.99%), making them the dominant slope classes. The level to nearly level (0–1%) and very gently sloping (1–3%) categories represent 12.59 km² (9.77%) and 12.87 km² (9.99%), respectively. However, compared to W1, W2 shows a relatively greater proportion of steeper slopes, including moderately steep (10–15%), steep (15–25%), very steep (25–33%), and strongly to very strongly sloping areas, indicating more varied relief conditions. Overall, the slope distribution suggests that both watersheds are mainly characterized by gentle to moderate slopes, though W2 contains relatively large areas of steeper terrain, which may influence runoff and erosion processes.

Based on the morphometric characteristics and slope distribution of the two sub-watersheds (W1 and W2), a comprehensive soil conservation and land use planning strategy is required to minimize soil erosion and manage runoff effectively. The morphometric analysis indicates a well-developed drainage network, relatively high stream frequency, drainage density, and higher relief parameters, particularly in W2, which suggest greater runoff generation and higher susceptibility to erosion. The slope analysis shows that a major portion of both watersheds falls under gently sloping (3–5%) and moderately sloping (5–10%) terrain, indicating undulating topography that requires appropriate land management practices. In nearly level and gently sloping areas (0–5%), sustainable agriculture can be promoted through contour bunding, graded bunds, strip cropping, and mulching to reduce runoff and improve soil moisture retention. In moderately sloping lands (5–10%), contour

farming, vegetative hedges, terracing, and conservation tillage should be adopted to control soil loss and enhance infiltration. In areas with steeper slopes (>10%), particularly in parts of W2 where relief and ruggedness are higher, afforestation, agro-forestry, and pasture development are recommended to stabilize the soil and maintain vegetation cover. Additionally, check dams, gully plugs, farm ponds, and percolation tanks should be constructed along drainage lines and valley bottoms to reduce flow velocity, trap sediments, and enhance groundwater recharge. Thus, integrating morphometric analysis with slope-based land capability planning helps identify priority zones for conservation interventions, ensuring improved watershed stability, reduced soil degradation, and sustainable land and water resource management.



