ICAR-NBSSLUP Pub. No. 258 *Technical Report*

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

(WDC-2.0)2/2021-22: Mangalwedha, Dist - Solapur

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.

Citation: H. Biswas, Nirmal Kumar, Sunil B.H., R.K. Naitam, A.O. Shirale, Ch. Jyotiprava Dash, P.C. Moharana, Sirisha Adamala, B. Dash, M.S. Raghuwanshi, H.L. Kharbikar, U. Surendran and N.G. Patil (2026). Land resource inventory for 14 selected watersheds of Maharashtra for land use planning using geo-spatial techniques (PMKSY 2.0). Solapur (WDC-2.0)2/2021-22: Mangalwedha, Dist – Solapur. ICAR-NBSS&LUP Publication No. 258, NBSS&LUP, Nagpur, 61 p.

To obtain copies of this report please write to:

The Director, ICAR-National Bureau of Soil Survey and Land Use Planning (ICAR-NBSS&LUP), Amravati Road, NAGPUR-440 033, India.

Phone : (0712) 2500386, 2500545, 2500664
E-mail : director-nbsslup@icar.org.in, director.nbsslupngp@gmail.com,
Website URL : https://icar-nbsslup.org.in

Project Team

Scientific staff	Technical Staff
Dr. H. Biswas (Principal Investigator)	Dr. D.S. Mohekar
Dr. Nirmal Kumar (Co-PI)	Sh. Vilas Parhad
Dr. Sunil B.H. (Co-PI)	Smt. Nisha A. Lade
Dr. R.K. Naitam (Co-PI)	Dr. P.S. Butte
Dr. A.O. Shirale (Co-PI)	Sh. J.B. Padole
Dr. Ch. Jyotiprava Dash (Co-PI)	Sh. Sunil Meena
Dr. P.C. Moharana (Co-PI)	Atul Kurzekar
Dr. Sirisha Adamala (Co-PI)	Anmol Ukey
Dr. B. Dash (Co-PI)	**Cover page design and Layout**
Dr. M.S. Raghuwanshi (Co-PI)	Sh. Prakash V. Ambekar
Sh. H.L. Kharbikar (Co-PI)	
Dr. U. Surendran (Co-PI)	
Contractual Project Staff (field and laboratory)	
Er. Aniket Rajput	Ms. Shabana Sheikh
Dr. Abhay Gedam	Ms. Vishakha Thakre
Sh. Anantraj Jadhav	Ms. Kalpana Ghate
Sh. Bhushan Deshkar	Ms. Babali Mange
Sh. Prashant Pakhare	Dr. Snehalata Chaware
Sh. Nihal Uike	Ms. Chetana Thawale
Sh. Ravi Warhade	
Sh. Dinesh Sawale	
Sh. Pratik Borkar	
Sh. Saurabh Chinchkhede	
Sh. Yash Raut	
Sh. Deepesh Goswami	
Sh. Aaditya Nimbalkar	
Sh. Umesh Dolaskar	

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.

(N.G. Patil)
Director,
ICAR-NBSS&LUP, Nagpur

ACKNOWLEDGEMENTS

The publication titled "Land resource inventory for 14 selected watersheds of Maharashtra for land use planning using geo-spatial techniques (PMKSY 2.0). Solapur (WDC-2.0)2/2021-22: Mangalwedha, Dist - Solapur" is the result of the collaborative efforts of the officials from the ICAR-National Bureau of Soil Survey and Land Use Planning (ICAR-NBSS&LUP), Nagpur and the Vasundhara Watershed Development Agency (VWDA), Government of Maharashtra.

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

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

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

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

Project Team
ICAR-NBSS&LUP, Nagpur

CONTENTS		Page No.

EXECUTIVE SUMMARY

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

Accordingly, ICAR-NBSS&LUP conducted a Land Resource Inventory and watershed assessment for the Mangalwedha (WDC-2.0) Village Cluster-watershed. It is situated within the Shrinandagi River, specifically located in Mangalwedha Taluka, Solapur District, Maharashtra. Agriculture is the primary land use in this watershed, heavily relying on monsoon rainfall.

The primary objectives of the study were to systematically characterize soil and land resources at watershed level, assess land capability and crop-site suitability, support watershed-based land use planning, and evaluate groundwater potential to aid sustainable watershed development under PMKSY-WDC 2.0.

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

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

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

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

CHAPTER 1

INTRODUCTION

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

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

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

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

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

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

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)3/202 1-22	Tuljapur	25	10	3380.0
Palghar	Palghar (WDC-2.0) 6/2021-22	Dahanu	7	23	3926.2
Parbhani	Parbhani (WDC-2.0/3/2021-22	Gangakhed	8	9	3791.0
Raigad	Raigad (WDC-2.0)/2/2021-22	Roha	3	11	3825.0
Ratnagiri	Ratnagiri (WDC-2.0)/3/2021-22	Chiplun	13	9	2548.0
Sangli	Sangli (WDC-2.0)3/2021-22	Jath	23	5	3200.0
Sindhudurg	Sindhudurg (WDC-2.0)/3/2021-22	Dodamarga	5	5	3604.4
Solapur	Solapur (WDC-2.0)2/2021-22	Mangalwedha	31	7	4198.1
Wardha	Wardha (WDC-2.0)/3/202 1-22	Seloo	12	7	2657.5
Washim	Washim (WDC-2.0)/5/202 1 -22	Malegaon	21	8	3806.1
Total			**192**		**48626.9**

Note-MWS-Micro Watershed

This report presents the Land Resource Inventory (LRI) conducted in the Mangalwedha (WDC-2.0/4/2021-22) sub-watershed of Mangalwedha 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.

CHAPTER 2

MANGALWEDHA WATERSHED AT A GLANCE

2.1 Location and Extent

The watershed (Fig. 2.1) is located in Mangalwedha Taluka, one of the administrative divisions of Solapur District in the Pune Revenue Division of Maharashtra. Solapur district lies in the southern part of the state, predominantly within the Bhima and Sina river basins, and is officially classified as a drought-prone region due to low and erratic rainfall. Geographically, the watershed lies between 75.42° to 75.61° longitude and 17.35° to 17.23° latitude. The cluster watershed receives an average annual rainfall of 653 mm, typical of the semi-arid conditions of the region.

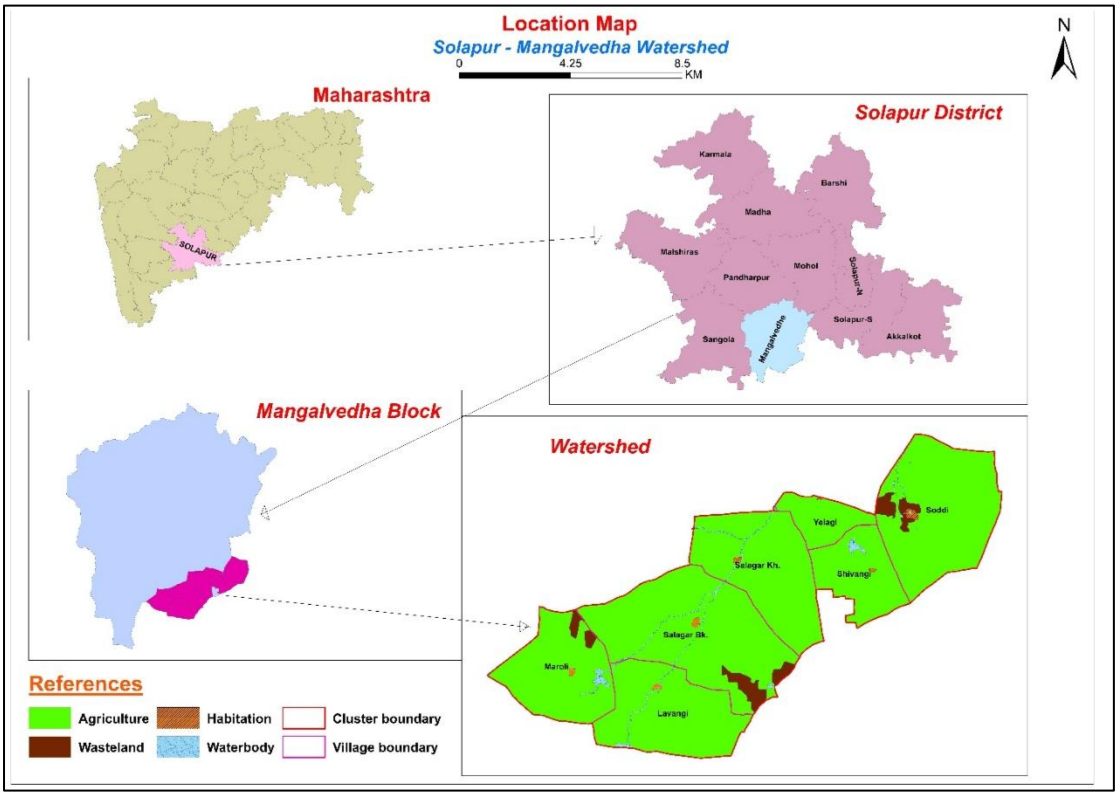


Fig. 2.1: Location map of the Mangalwedha watershed

Mangalwedha Taluka is predominantly rural, comprising dispersed villages with an agrarian economy largely dependent on rainfed agriculture. The landscape varies from gentle slopes in most areas to moderate relief. Table 2.1 provides the general profile in respect of the watershed.

Table 2.1: Geographical and Administrative Profile

Sr. No.	Particulars	Details
1	District	Solapur
2	Taluka	Mangalwedha
3	Revenue Division	Pune
4	Total sub-watershed Area	Approx. 10458 hectares
5	Villages	07 (Lavangi, Maroli, Salagar Bk., Salagar Kh., Shivangi, Soddi, and Yelagi)
6	Major River	Shrinandagi River
7	Climate	Semi-arid
8	Average annual Rainfall	653 mm

2.2 Geology

The geology of the Mangalwedha watershed is mainly represented by the Deccan Trap basalt, which is the principal rock formation across Solapur district. The area is covered by basaltic lava flows that belong to the Deccan volcanic province. These basalt flows occur in layers and include both massive and vesicular types. Massive basalt is generally compact, while vesicular basalt contains small cavities formed during the cooling of lava. Weathering and fracturing of these basalt rocks influence the development of soils in the area. The basalt formation also controls the movement and storage of groundwater in the region. Groundwater generally occurs in weathered and fractured zones of the basalt. The nature of the basaltic rocks also affects infiltration and runoff within the watershed. Overall, the geological setting of the area is typical of the basaltic terrain.

2.3 Geomorphology

The geomorphology of the Mangalwedha watershed has developed over the Deccan Trap basalt that forms the dominant geological formation of Solapur district. The terrain of the area includes a combination of pediment surfaces, plateau regions and pediplain areas, along with limited patches of plains and eroded land. These features have formed due to long-term weathering and erosion processes acting on the basaltic rocks under semi-arid climatic conditions. Such terrain characteristics influence the drainage pattern, soil development and land use distribution within the watershed. The presence of these landform units reflects the gradual denudation of basaltic terrain typical of the Deccan Plateau region.

2.4 Physiography and Soil

The terrain is flat to gently undulating, with slopes ranging from 0 to 27% rise. Elevation varies between 455 m and 540 m above mean sea level. The major landforms present are pediment, pediplain, and low plateau, consistent with the geomorphology of watershed.

The soils within the watershed cluster are derived from basalt and show variation in texture, arranged in decreasing areal extent as clay, clay loam, sandy clay loam, and loam. This distribution reflects the natural heterogeneity of the area, with heavier clay soils occupying the largest portion and lighter textured soils occurring in smaller pockets.

2.5 Climate

The watershed in Mangalwedha taluka experiences a semi-arid climate, which is typical of Solapur district located in the rain-shadow region of the Western Ghats. The climate of the area is largely controlled by the southwest monsoon, which brings most of the rainfall between June and September. The average annual rainfall is about 653 mm, indicating relatively low rainfall conditions compared to many other parts of Maharashtra. A major portion of the annual rainfall is received during the monsoon months, while the remaining part of the year remains comparatively dry. Summers, extending from March to May, are generally hot and dry, whereas the winter season from November to February is relatively cooler. Due to the limited and variable rainfall, agriculture in the area is largely dependent on monsoon precipitation.

2.6 Drainage

The drainage of the watershed is mainly governed by the Shrinandagi River, which forms the principal drainage channel in the area. The river and its associated natural drainage lines form the surface drainage network of the watershed. Several small seasonal streams and local drainage channels join the Shrinandagi River and carry runoff during the monsoon season. These streams generally flow during periods of rainfall and remain dry during the non-monsoon months. The drainage network thus plays an important role in conveying surface runoff generated during the monsoon period across the watershed.

2.7 Cropping Patterns, and Demography and Socioeconomics

2.7.1 Cropping Pattern

The watershed area of the Mangalvedhe cluster in the Solapur district is characterized by a semi-arid climate with low and erratic rainfall ranging between 300–450 mm annually. Historically, agriculture in the region has been predominantly rainfed, with kharif crops such as bajra, arhar (tur), and maize, along with rabi jowar, forming the principal cropping system. These crops have traditionally supported household consumption and local food security.

2.7.2 Demographic and Socioeconomic Status

The watershed villages of the Mangalvedhe cluster are entirely rural and agrarian in nature. Agriculture remains the primary occupation, supported by allied activities such as livestock rearing. Landholdings are generally small and fragmented, influencing the scale and nature of farming operations. Educational levels, access to institutional credit, and infrastructure facilities vary across villages, shaping the socio-economic structure of the farming community.

2.8 Water Resources

2.8.1 Surface Water

Surface water in the watershed is mainly governed by the Shrinandagi River, its non-perennial tributaries, and smaller nala streams, which flow predominantly during the monsoon season. Maroli Talav serves as a small storage structure, capturing runoff from the surrounding catchment. These water bodies are essential for local irrigation and domestic water supply; however, their availability is limited due to their seasonal nature. Additionally, numerous ponds within the watershed contribute to irrigation support.

2.8.2 Groundwater

Groundwater occurs mostly in weathered and fractured zones of basalt rock. According to the Dynamic Ground Water Resources of Solapur District (CGWB), 2024, annual extractable ground water resources place the region under the "semi critical" category, with the groundwater extraction level is 78.8%

2.8.3 Irrigation and Water Management

Given the semi-arid climatic conditions of the Solapur district, rainfall alone is generally insufficient to meet crop water requirements. Irrigation therefore plays an important role in stabilizing agricultural production within the watershed. Groundwater, mainly through borewells, constitutes the major source of irrigation in the cluster, supplemented by open wells and farm ponds in certain locations.

2.9 Constraints

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

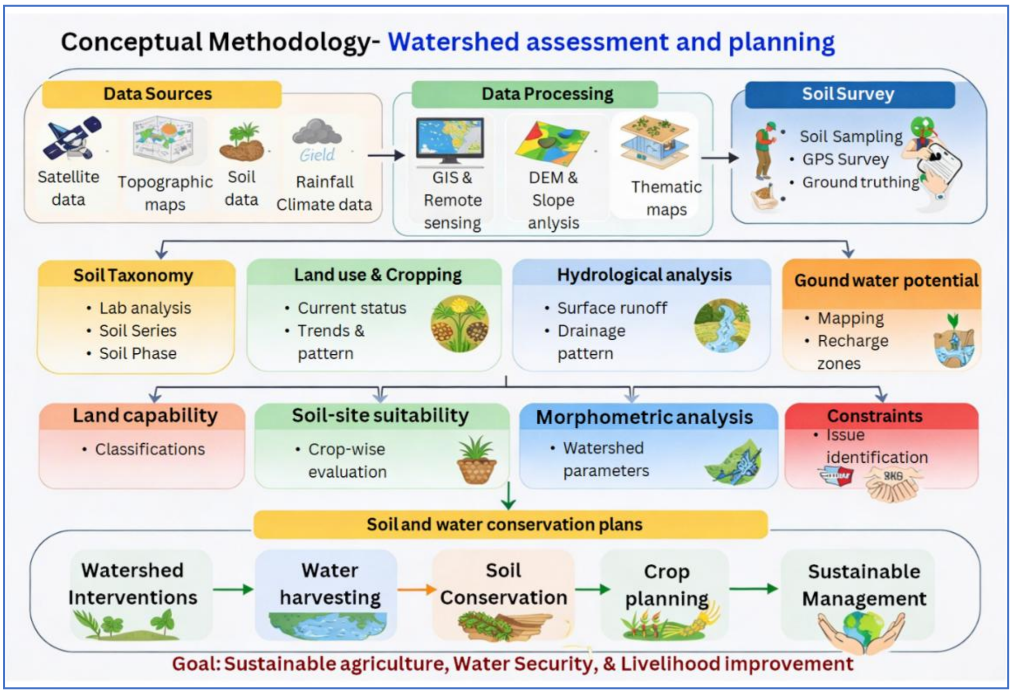
a. Low Recharge: Hard basaltic strata restrict infiltration, limiting aquifer recharge.
b. Declining Water Availability: Wells and handpumps show reduced yield after monsoon.
c. Silted Surface Structures: Existing tanks and reservoirs require desilting and maintenance.
d. Non-perennial Surface Water Sources: The River and seasonal stream flow only during the monsoon, limiting year-round surface water availability.
e. Stress on Agricultural Water Supply: Due to the combination of low rainfall, limited irrigation support, and declining groundwater availability, agricultural activities face water stress.

CHAPTER 3

METHODOLOGY

3.1 Overview of activities

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



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

A. Pre-field

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

B. Soil Survey

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

- Mapping of current land use/land cover, existing soil and water conservation structures etc.

C. Post-field phase

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

3.2 Preparation of Base Maps

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

3.3 Ground-truth Verification

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

3.4 Soil Sampling and Analysis

Soil samples from each horizon of all of the representative soil series were collected for laboratory studies. The soil samples collected during the fieldwork were initially air dried in the laboratory at room temperature, ground using a wooden pestle and mortar, screened through a 2 mm sieve, properly labelled, and stored in polythene bags for laboratory analysis. The soil samples were analysed in the laboratory for physical and chemical parameters using standard procedures. The particle size analysis was done by international pipette method. A combined glass-calomel electrode was used to determine the pH measured (1:2.5 soil/solution ratio). Soil organic carbon (SOC) was determined using the wet digestion method of Walkley and Black (1934). Available nitrogen (N) was measured by the alkaline permanganate method as described by Subbiah and Asija (1956). Available phosphorus (P) was determined by the Bray II method (Bray and Kurtz 1945). Cation exchange capacity (CEC) of soil was measured as per the procedure outlined by Jackson (1976). Exchangeable cations [calcium (Ca), potassium (K), and magnesium (Mg)] were extracted with 1 M ammonium acetate (NH4Oac) (pH 7.0). Potassium content was determined by flame photometry (Rich 1965), while Ca and Mg were determined in ethylene diamine tetra acetic acid (EDTA) titration. Exchangeable Al was extracted with 1 N potassium chloride (KCl) solution and titrated with 0.1 N sodium hydroxide (NaOH) solution. Available micronutrient content [copper (Cu), manganese (Mn), iron (Fe), and zinc (Zn)] were determined by diethylene triamine penta-acetic acid (DTPA) extraction (Lindsay and Norvell 1978), followed by atomic absorption spectrophotometry. Soils were classified according to Keys to Soil Taxonomy (Soil Survey Staff 2010).

3.5 Development of Soil Mapping Legend

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

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

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

3.6 Surface runoff estimation

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

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

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

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

CHAPTER 4
RESULTS AND INTERPRETATIONS

4.1 Irrigation, Cropping Patterns, and Demography and Socioeconomics

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

4.1.1 Irrigation and water management

The irrigation pattern of the watershed cluster presented in Table 4.1 indicates seasonal dominance of irrigation sources. During the Kharif season, borewells contributed 75.8% of the total seasonal irrigation, indicating the primary source of irrigation. Wells contributed 16.2%, while ponds contributed 8.1%. Rainfed areas recorded 0% irrigation, indicating complete dependence on rainfall without supplemental irrigation support. This clearly reflects the strong reliance on groundwater sources during the monsoon cropping season.

In the Rabi season, borewells dominated irrigation with a contribution of 73.9% to the total seasonal irrigated area. Ponds contributed 22.6%, while wells contributed only 3.4%. Rainfed lands remained entirely unirrigated. Compared to Kharif, the contribution of ponds increased in Rabi, indicating the importance of surface water during the post-monsoon period.

During the summer season, the irrigation pattern shifted significantly. Ponds are the major source, contributing 84.76% of total summer irrigation, whereas borewells accounted for 15.2%. Wells and rainfed sources had no irrigation contribution during this season.

Borewells are the important source of irrigation in Kharif and Rabi seasons, while ponds become the important source in summer.

Table 4.1 Seasonal Distribution of Irrigation Sources in the Mangalwedha Watershed

Sr. No.	Number of Farmers Interviewed (n)	Irrigation Source	Seasonal Water Availability	Contribution to Season's Total Irrigation (%)
1	132	Borewell	Kharif	75.8
2	129	Borewell	Rabi	73.9
3	6	Borewell	Summer	15.2
4	36	Well	Kharif	16.2
5	12	Well	Rabi	3.4
6	12	Pond	Kharif	8.1
7	34	Pond	Rabi	22.6
8	23	Pond	Summer	84.7
9	20	Rainfed	Kharif	0
10	10	Rainfed	Rabi	0

4.1.2 Cropping Pattern

The cropping pattern of the Mangalwedha cluster has a seasonal diversification across Kharif, Rabi and perennial crops. The net sown area of the surveyed villages is 398.00 ha, while the gross cropped area is 460.60 ha, the cropping intensity was calculated by the following formula.

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

$$Cropping\ intensity(\%) = \frac{460}{398} \times 100 = 115.7\%$$

The cropping intensity of 115.7% indicates moderate land use efficiency, with partial double cropping practiced under irrigated conditions. However, it indicates constraints in crop cultivation across different season.

Table 4.2 Crop-wise Distribution in the Mangalwedha watershed

Sr. No.	Season	Crop	No. of Farmers Interviewed (n)	Irrigation Type	Total Cropped Area (%)	Productivity (kg/ha)
1	Kharif	Bajra	53	Irrigated	8.0	630
2	Rabi	Bajra	19	Irrigated	3.2	911
3	Perennial	Grapes	30	Irrigated	6.1	5426
4	Kharif	Jowar	67	Irrigated	12.0	700
5	Rabi	Jowar	50	Irrigated	6.7	736
6	Kharif	Jowar	5	Rainfed	1.4	419
8	Kharif	Maize	55	Irrigated	7.8	2563
9	Rabi	Maize	13	Irrigated	1.6	2535
10	Perennial	Pomegranate	63	Irrigated	12.4	2779
11	Kharif	Tur	78	Irrigated	15.9	899
12	Rabi	Tur	35	Irrigated	7.5	833
13	Kharif	Tur	7	Rainfed	2.8	273
14	Rabi	Wheat	14	Irrigated	1.1	810
1	Kharif	Bajra	53	Irrigated	8.0	630

As presented in Table 4.2, the cropping pattern is predominantly irrigation-based across all seasons, with only a small proportion of crops cultivated under rainfed conditions.

During Kharif, major crops include tur (15.9%), jowar (12.0%), bajra (8.0%), and maize (7.8%). Irrigated maize records high productivity (2,563 kg/ha), while irrigated tur yields 899 kg/ha. Rainfed crops such as jowar (419 kg/ha) and tur (273 kg/ha) show significantly lower productivity, highlighting the impact of irrigation on yield performance.

Rabi crops include jowar (6.7%), bajra (3.2%), maize (1.6%) and wheat (1.1%). Productivity remains relatively stable under irrigation, with maize yielding 2,535 kg/ha and wheat 810 kg/ha.

With respect to perennial crops, pomegranate cultivated in 12.4% of the cropped area with a productivity of 2,779 kg/ha, while grapes cover 6.1% with a productivity of 5,426 kg/ha.

4.1.3 Socioeconomic Status

4.1.3.1 Land holding pattern

The distribution of land holdings in the study area reveals a dominance of small and semi-medium farmers. From Table 4.3 it was observed that among the total farmers interviewed, the highest number of farmers were observed in the small farmer category (1-2 ha), having 98 respondents (52.69%) with an average land holding of 1.52 ha, which is followed by semi-medium farmers (2-4 ha) having 45 respondents (24.19%) with an average land holding of 2.91 ha. Marginal farmers (<1 ha) having 28 respondents (15.05%) with an average land holding of 0.63 ha. Medium farmers (4-10 ha) had 12 respondents (6.45%) with an average land holding of 6.25 ha, while only 3 respondents (1.61%) were reported in the large farmer category (>10 ha) with an average land holding of 13.33 ha.

The average land holding size of the study area was found to be 2.22 ha, which indicates that the farmers mostly possess small to semi-medium agricultural land holdings. The predominance of smaller farm sizes may result in low capital investment capacity, irrigation development, and adoption of improved agricultural technologies in the watershed area.

Table 4.3 Land holding pattern in Mangalwedha watershed

Category	Criteria Land (ha)	No. of Farmers Interviewed (n)	Farmers (%)	Average Land Holding (ha)
Marginal Farmers	<1	28	15.0	0.63
Small Farmers	1-2	98	52.6	1.52
Semi-Medium Farmers	2-4	45	24.1	2.91
Medium Farmers	4-10	12	6.4	6.25
Large Farmers	>10	3	1.6	13.33
Average land holding				**2.22**

4.1.3.2 Income distribution

The income distribution in the study area is presented in Table 4.4, which indicates the contribution of both field and horticultural crops to farmers' income. The results show considerable variation in income generated from different crops cultivated in the area.

Tur occupies has the highest cropped area (27.6%) with an average income of 95,015 Rs, indicating its importance as a major field crop. Jowar has 21.0% of the cropped area with an average income of 27,273 Rs, reflecting relatively lower income returns. Maize covered 10.0% of the cropped area with an average income of 56,534 Rs.

Among the horticultural crops, pomegranate covers 12.9% of the cropped area generating an average income of 3,25,195 Rs, which is considerably higher than most field crops. Grapes cover 7.3% of the cropped area with the highest average income of 10,53,417 Rs.

The income pattern indicates that horticultural crops, particularly grapes and pomegranate, significantly enhance farmers' income compared to traditional field crops such as tur, maize and jowar. Although field crops occupy a larger proportion of the cropped area, high-value horticultural crops contribute to overall farm income.

Table 4.4 Average annual income of farmers in Mangalwedha watershed.

Name of Crops	No. of Farmers Interviewed (n)	Crop Area (%)	Average Income (Rs.)
Tur	67	27.6	95015
Pomegranate	40	12.9	325195
Grapes	30	7.3	1053417
Maize	27	10.0	56534
Jowar	11	21.0	27273
Tur	44	2.0	0
Sesamum	28	2.4	0
Sugarcane	22	5.1	0
Gram	10	1.1	0
Moong	9	0.5	0

4.1.3.3 Education

The educational profile of respondents in the study area is presented Table 4.5. The results indicate that a large proportion of the population is illiterate, reflecting generally low educational attainment across most villages in the watershed.

Village Shivangi recorded the highest illiteracy rate, where 100% of the respondents were illiterate, indicating extremely poor educational status in the village. Similarly, high illiteracy were observed in Soddi (87%), Lavangi (84%), Yelagi (82%), and Salgar Kh (81%), showing that a majority of the respondents in these villages have not received formal education. Maroli also recorded a high illiteracy rate of 77%, while a small number of respondents were educated up to primary (4%), secondary (6%), higher secondary (10%), and higher studies (3%).

Salgar Bk shows comparatively better educational attainment among the villages. Only 4% of the respondents were illiterate, while 8% had primary education, 12% secondary education, and 23% higher secondary education. Significantly, the highest proportion of respondents with higher studies (54%) was recorded in this village.

The watershed is characterized by high illiteracy levels in most villages, with the exception of Salgar Bk which demonstrates a better educational status. This educational condition may influence farmers' awareness levels, adoption of improved agricultural practices, and participation in extension programs in the watershed area.

Table 4.5 Education profile of villages in Mangalwedha watershed by population

Village	No Education (%)	Primary (%)	Secondary (%)	Higher Secondary (%)	Higher Studies (%)
Lavangi	84	2	2	5	7
Maroli	77	4	6	10	3
Salgar Bk	4	8	12	23	54
Salgar Kh	81	7	3	7	2
Shivangi	100	0	0	0	0
Soddi	87	1	6	4	2
Yelagi	82	3	8	6	1

4.2 Land-use/Land-cover

The Land Use Land Cover (LULC) (Fig. 4.1) pattern of the Mangalwedha watershed indicates that most of the area is under agricultural use, accounting for about 95.5 percent of the total area. This clearly shows that farming is the primary land use and plays a major role in shaping the landscape and livelihood activities in the watershed. Wasteland forms a small portion of the area (3.0%), representing relatively less productive lands that may require suitable soil and water conservation measures for improvement. Water bodies constitute about 1.1 percent of the watershed and contribute to local water availability for various uses. Habitation occupies a very small share of the total area (0.5%), indicating limited built-up development within the watershed. Overall, the land use pattern reflects a landscape that is largely utilized for agriculture, with only small areas under other land uses.

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

Land use	Area(ha)	Percent (%)
Agriculture	9985.4	95.5
Wasteland	309.3	3.0
Waterbody	116.1	1.1
Habitation	47.5	0.5
	10458.2	**100.0**

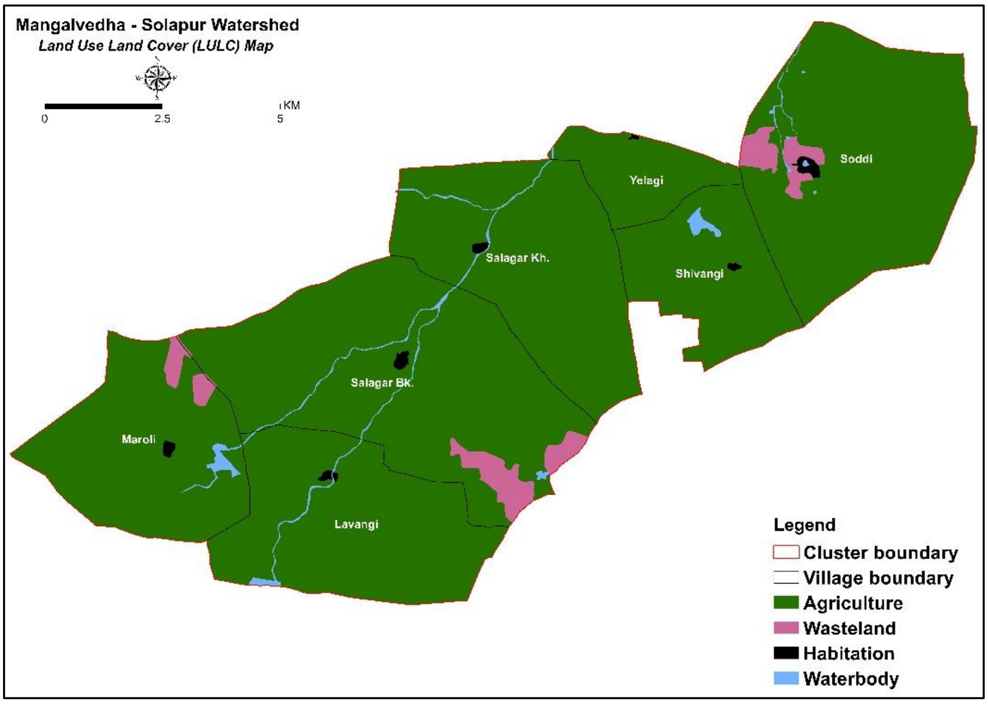


Fig. 4.1: Land-use/land-cover map

4.3 Landform Delineation

The landform pattern of the Mangalwedha watershed shows the presence of several terrain features that shape the overall landscape of the area. Pediment occupies the largest share of the watershed, covering about 37.2 percent of the total area. These areas generally occur as gently sloping surfaces developed over hard rock and are commonly used for agricultural activities where soil depth permits. The upper plateau and lower plateau together form a considerable part of the watershed, accounting for 19.9 percent and 19.7 percent respectively, and represent relatively elevated and stable surfaces. Pediplain covers about 15.2 percent of the area and occurs as comparatively level land formed through long-term weathering and erosion. Plains occupy around 3.5 percent of the watershed and usually represent flatter areas suitable for cultivation. Eroded land accounts for about 3.0 percent, indicating locations where soil has been affected by erosion. Water bodies and habitation occupy only a small portion of the watershed, contributing about 1.1 percent and 0.5 percent of the area respectively. Overall, the landscape is largely composed of pediment and plateau areas with smaller patches of plains and eroded land. The landform map of the watershed is presented in Fig. 4.2.

Table 4.7: Landform features existing in Mangalwedha watershed

Landform	Area(ha)	Percent (%)
Pediment	3890.9	37.2
Upper Plateau	2077.1	19.9
Lower Plateau	2059.4	19.7
Pediplain	1590.8	15.2
Plain	367.2	3.5
Eroded land	309.3	3.0
Waterbody	116.1	1.1
Habitation	47.5	0.5
	10458.2	**100.0**

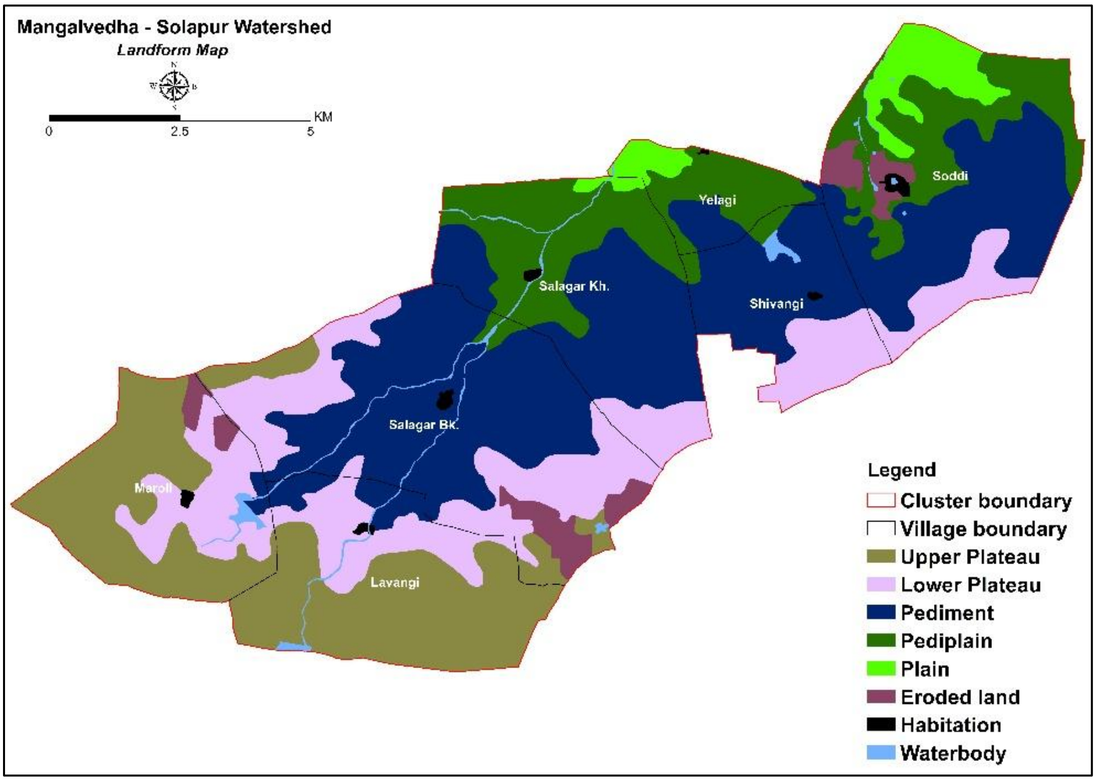


Fig. 4.2: Landform map of Mangalwedha watershed.

4.4 Soil series and phases

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

Table 4.8. Dominant soil series identified in the watershed.

Sr. No.	Series	Area (ha)	Percent (%)
1	Shivangi	2797.6	26.8
2	Lavangi	2429.5	23.2
3	Yelagi	1571.1	15.0
4	Salghar-Kh	904.3	8.6
5	Salghar-Bk	639.0	6.1
6	Maroli	572.5	5.5
7	Maroli1	537.5	5.1
8	Soddi	533.9	5.1
9	Eroded land	309.3	3.0
10	Waterbody	116.1	1.1
11	Habitation	47.5	0.5
	Total	**10458.2**	**100.0**

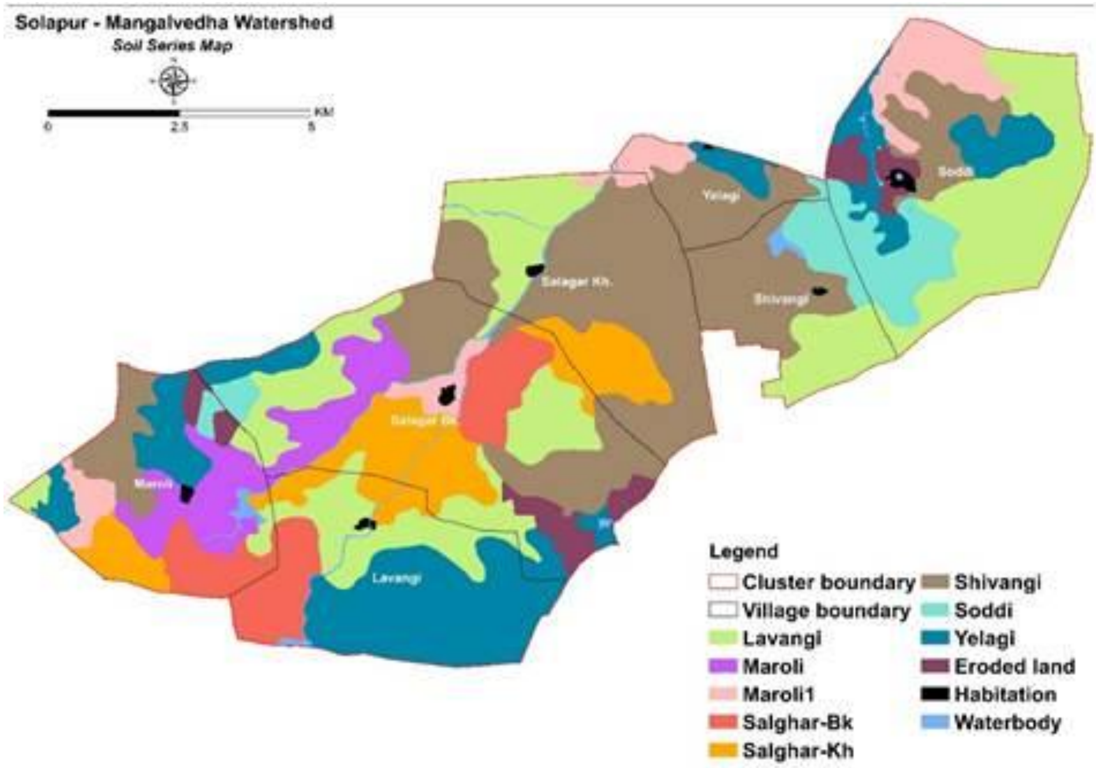


Fig. 4.3: Soil series map of Mangalwedha watershed.

Table 4.9. Soil phases existing in Mangalwedha watershed.

Sr. No.	Phase	Area(ha)	Percent (%)
1	Lav2dA1g2	282.0	2.7
2	Lav2fA2g4	203.4	1.9
3	Lav2hA1g3	456.6	4.4
4	Lav2mA1g1	303.8	2.9
5	Lav2mA1g3	29.6	0.3
6	Lav2mA2g1	416.0	4.0
7	Lav2mB2g2	347.7	3.3
8	Lav2mB2g3	390.4	3.7
9	Mao2fA1g1	79.1	0.8
10	Mao2fA1g2	91.1	0.9
11	Mao2mA2g2	367.2	3.5
12	Mar5mA1g1	298.0	2.8
13	Mar5mB2g1	274.5	2.6
14	Sab4hA1g2	416.6	4.0
15	Sab4mB2g1	222.4	2.1
16	Sak6cA1g1	570.8	5.5
17	Sak6cA1g2	133.0	1.3
18	Sak6fA1g1	200.4	1.9
19	Shi1fA1g3	564.9	5.4
20	Shi1fB2g2	575.5	5.5
21	Shi1hB2g2	516.9	4.9
22	Shi1hB2g3	262.3	2.5
23	Shi1mA2g3	453.1	4.3
24	Shi1mB1g3	424.9	4.1
25	Sod3fB2g3	459.6	4.4
26	Sod3hB1g2	74.3	0.7
27	Yel3mA1g2	936.6	9.0
28	Yel3mA1g3	260.9	2.5
29	Yel3mA2g1	373.6	3.6
30	Eroded land	309.3	3.0
31	Habitation	47.5	0.5
32	Waterbody	116.1	1.1
	Total	**10458.2**	**100.0**

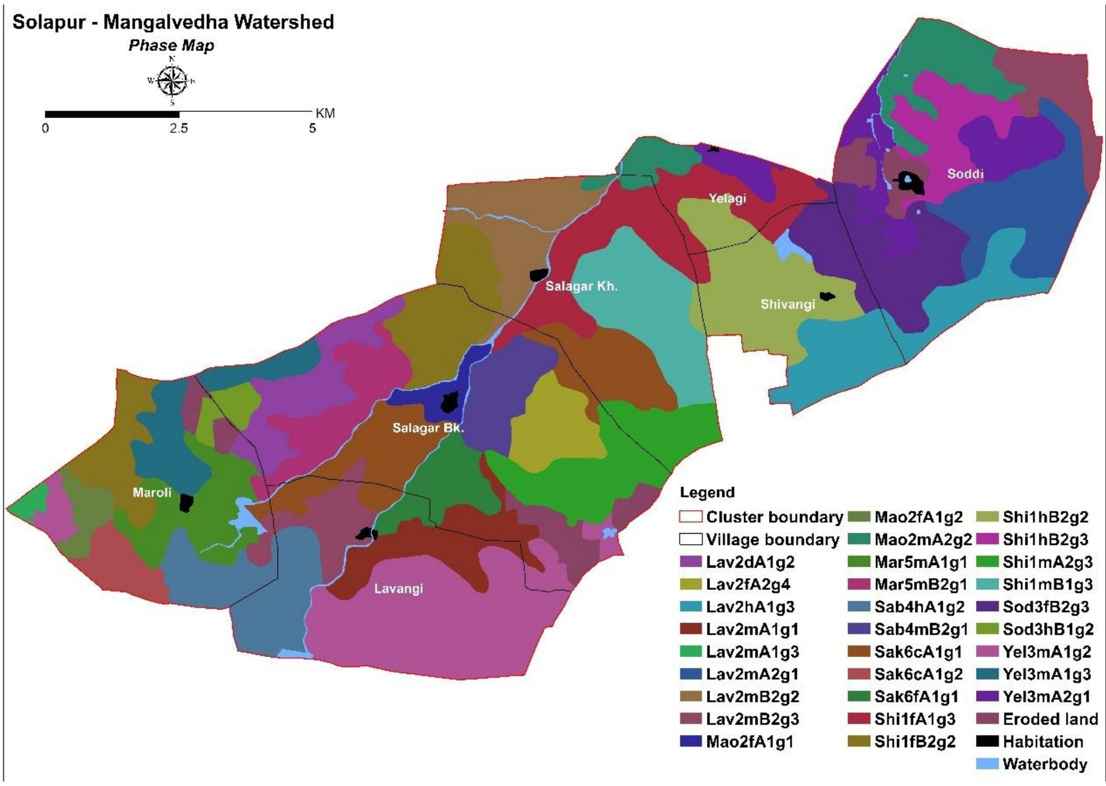


Fig. 4.4: Soil Phase map of Mangalwedha watershed.

4.5 Soil Survey Interpretation

4.5.1 Slope

Land slope plays a crucial role in agriculture, as it affects water drainage, soil erosion, and the ease with which crops can be cultivated. Gentle slope tends to have higher rates of surface runoff, which can lead to soil erosion and loss of valuable topsoil, reduce soil fertility and compromise crop yields. On the other hand, very gently sloping lands allow for better water retention, easier mechanization, and more efficient irrigation practices, leading to higher productivity. The slope also influences the microclimate of the area, with sloped terrains potentially being more prone to temperature extremes or frost in certain regions. By considering the slope of land, farmers can implement soil conservation techniques, such as terracing, bunding or contour farming, to reduce erosion and optimize land use, ensuring more sustainable agricultural practices. Among the different slope classes (Table 4.10, Fig. 4.5) the maximum area of watershed is under level to nearly level (0-1%), covering 59.6% followed by very gently sloping (1-3%), covering 35.9% and eroded land covering 3%. The analysis indicates that no steep slope categories are present in the watershed, suggesting that the area is primarily characterized by gentle terrain, which is favorable for agricultural activities and reduces the risk of severe soil erosion.

Table: 4.10. Land slope classes in Mangalwedha watershed.

Sr. No.	Slope Class	Area (ha)	TGA (%)
1	Level to nearly level (0 - 1)	6233.5	59.6
2	Very gently sloping (1 - 3)	3751.9	35.9
3	Eroded land	309.3	3.0
4	Habitation	47.5	0.5
5	Waterbody	116.1	1.1
	Total	**10458.2**	**100.0**

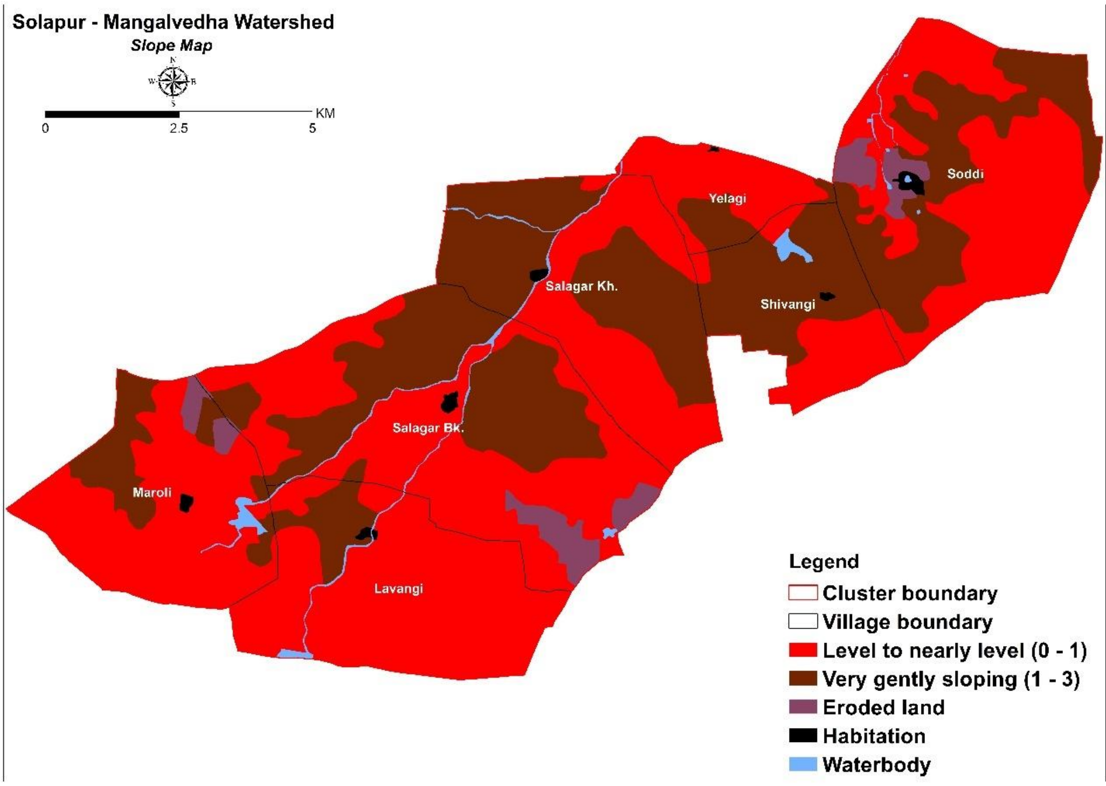


Fig. 4.5: Slope map of Mangalwedha watershed

4.5.2 Soil Erosion

Soil erosion, caused by water, wind, or human activity, strips away the nutrient-rich layers of soil, reducing its ability to retain water and support plant roots. This depletion of soil quality can result in decreased agricultural productivity, making crops more vulnerable to drought, nutrient deficiencies, and pests. Additionally, soil erosion can lead to the sedimentation of nearby water bodies, affecting water quality and ecosystems. Reduce soil erosion through crop cover, mulching and residue management, crop rotation, bunding, terracing, etc. helps maintain soil structure and prevent further degradation. As per the watershed area erosion classification levels largely varied from very slow to eroded land (Table 4.11), followed by moderate is 4862.6 ha (46.5%) indicating moderate erosion hazard in Solapur watershed, eroded land 3% of the area, which suffers from high erosion (Fig. 4.6), particularly parts of the 49% of the watershed is very slow soil erosion.

Table 4.11: Soil erosion status in Mangalwedha watershed.

Sr. No.	Erosion class	Area (ha)	Percent (%)
1	Very Slight	5122.8	49.0
2	Moderate	4862.6	46.5
3	Eroded land	309.3	3.0
4	Habitation	47.5	0.5
5	Waterbody	116.1	1.1
	Total	**10458.2**	**100.0**

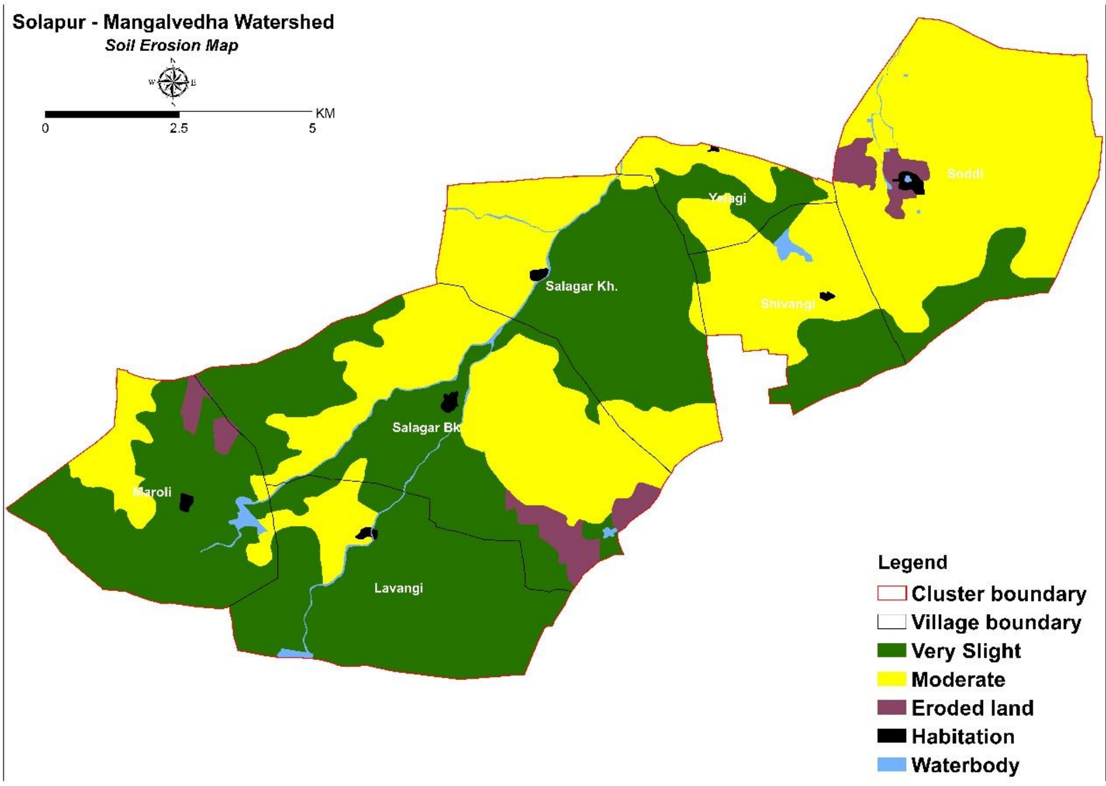


Fig. 4.6: Erosion map of Mangalwedha watershed

4.5.3 Soil Depth

Soil depth is a crucial factor in agriculture as it acts as an integrative proxy for several other soil properties and functions, including soil moisture retention, organic carbon storage, effective rooting depth, nutrient availability and overall profile development. These properties are intrinsically linked to paedogenic processes such as weathering, translocation, erosion-deposition dynamics, and biological activity, all of which are strongly modulated by landscape position and hydrological condition. As a result, spatial variability in soil depth reflects not only physical soil thickness but also broader gradients in soil fertility, water holding capacity, and ecosystem functioning across the terrain. Deeper soils generally provide more space for roots to penetrate, access water, and take up essential nutrients, which supports healthier plant growth and higher crop yields. Shallow soils, on the other hand, can restrict root development and limit the availability of nutrients and moisture, especially during dry periods. This can result in stunted plant growth, lower productivity, and increased vulnerability to drought stress. In regions with shallow soils, farmers may need to implement practices such as deep ploughing, irrigation, or the addition of organic matter to improve soil depth and enhance crop performance. Understanding soil depth helps farmers make better decisions on crop selection, irrigation, and soil management, promoting more efficient and sustainable agricultural practices. The soil depth in the watershed (Fig. 4.7) varies from shallow (<25 cm) to very deep (>100 cm). Area wise distribution of the data showed that maximum area was under moderate (28.4%) followed by shallow (26.8%), moderately deep (20.1%), very deep (11.5%) and deep soils (8.7%).

Table 4.12. Soil depth classes in Mangalwedha watershed.

Sr. No.	Depth Class	Area (ha)	TGA (%)
1	Shallow (< 25)	2797.6	26.8
2	Moderate (25 - 50)	2967.0	28.4
3	Moderately Deep (50 - 75)	2105.0	20.1
4	Deep (75 - 100)	913.5	8.7
5	Very Deep (> 100)	1202.2	11.5
6	Eroded land	309.3	3.0
7	Habitation	47.5	0.5
8	Waterbody	116.1	1.1
	Total	**10458.2**	**100.0**

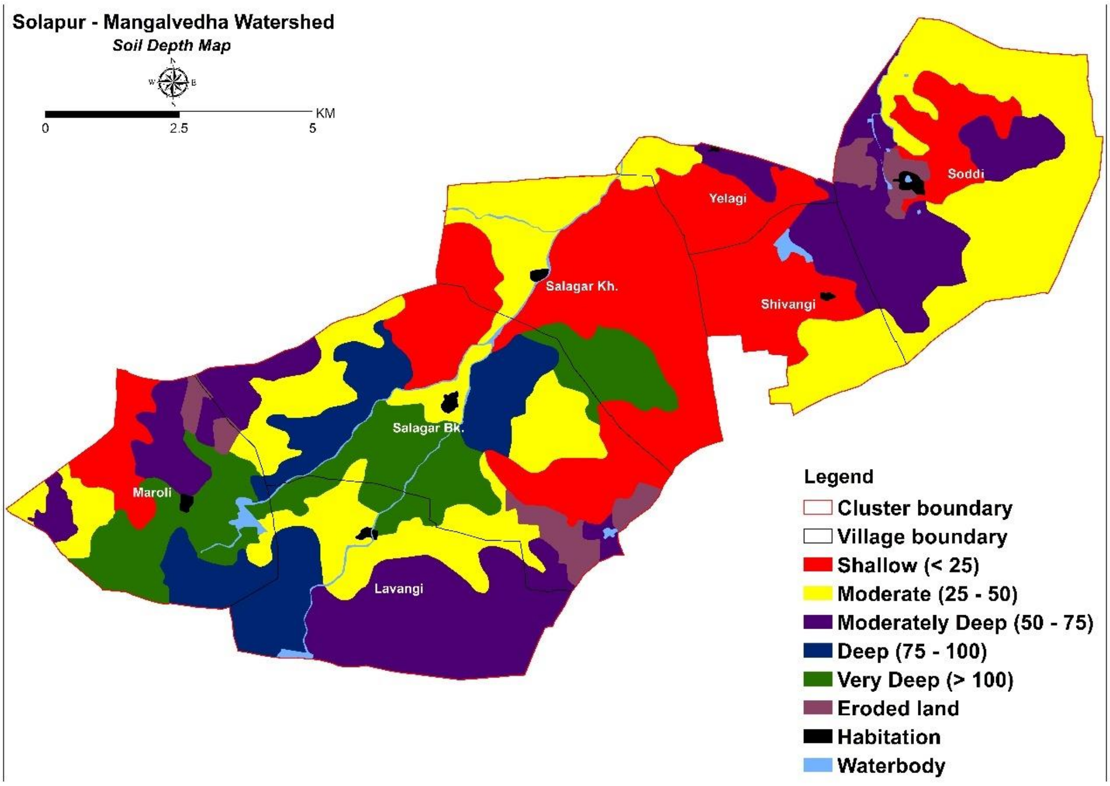


Fig. 4.7: Depth map of Mangalwedha watershed

4.5.4 Surface texture

Soil texture plays a vital role in agriculture by directly influencing water retention, root development, and nutrient availability to plants. Soils with a balanced texture, such as loam, provide optimal conditions for plant growth by allowing good water drainage while retaining enough moisture for the roots. Clay soils, though rich in nutrients, can become compacted and poorly drained, while sandy soils may drain too quickly and lack essential nutrients. Understanding texture helps farmers make informed decisions about irrigation practices, crop selection, and the appropriate use of soil amendments. The texture of the watershed area soils was grouped into four classes (Table 4.13, Fig. 4.8). Among the different classes clay texture was found in 55.5% area followed by clay loam (20.8%), sandy clay loam (16.5%) and loam (2.7%). Based on the texture, the soils of the watershed particularly the highly soils are expected to be fertile and produce good crops.

Table 4.13. Soil texture distribution in Mangalwedha watershed.

Sr. No.	Texture	Area (ha)	TGA (%)
1	Clay	5802.6	55.5
2	Clay Loam	2174.1	20.8
3	Loam	282.0	2.7
4	Sandy Clay Loam	1726.7	16.5
5	Eroded land	309.3	3.0
6	Habitation	47.5	0.5
7	Waterbody	116.1	1.1
	Total	**10458.2**	**100.0**

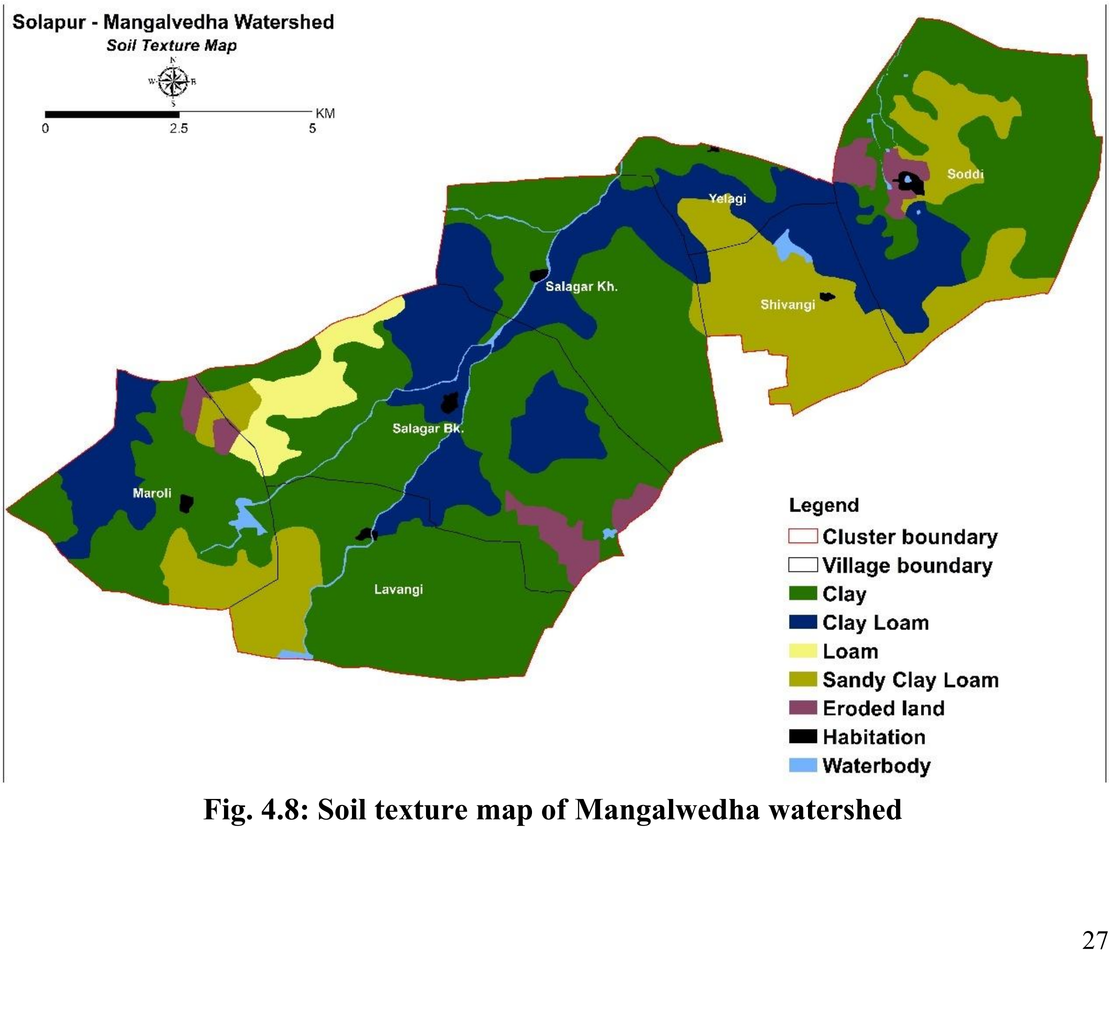


Fig. 4.8: Soil texture map of Mangalwedha watershed

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 4.14, Fig. 4.9). The data revealed that soils in watershed are primarily moderately alkaline in reaction (pH 8.0 - 9.0) covering an area of about 80% followed by strongly alkaline (pH 9.0 - 10.0) and Slightly Alkaline (pH 7.5-8.0).

Table 4.14. Soil pH distribution in Mangalwedha watershed.

Sr. No.	Soil pH	Area (ha)	TGA (%)
1	Slightly Alkaline (7.5 - 8.0)	800.4	7.7
2	Moderately Alkaline (8.0 - 9.0)	8366.1	80.0
3	Strongly Alkaline (9.0 - 10.0)	818.8	7.8
4	Eroded land	309.3	3.0
5	Habitation	47.5	0.5
6	Waterbody	116.1	1.1
	Total	**10458.2**	**100.0**

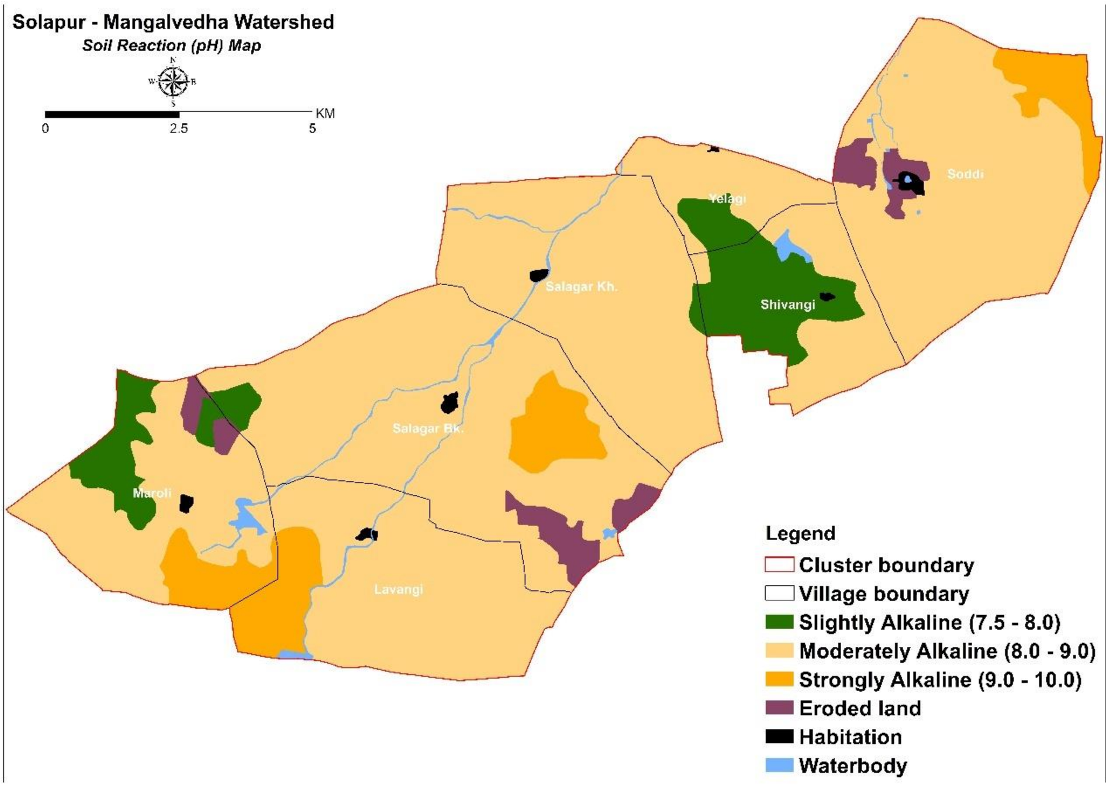


Fig. 4.9: Soil pH map of Mangalwedha watershed

4.5.6 Soil salinity

Soil salinity, measured through the electrical conductivity of a solution within a unit distance, represents the content of soluble salts in the matrix. Soil conductivity is an index to measure soil water-soluble salt, which is an important indicator of mineral nutrients in the topsoil that can be quickly utilized by plants and is a factor to determine whether salt ions in soil limit crop growth. The EC of the soils of the watershed were well within the permissible limit of salinity (Table 4.15) and will Fig 4.10. The soil salinity status of the watershed (Table 4.15) shows that the majority of the area, 95.5%, falls under the normal salinity class (EC < 1 dS/m), indicating minimal risk of salt-induced crop stress. The predominance of normal soils suggests that salinity is not a major constraint for agricultural activities in the Solapur watershed and most areas are suitable for crop cultivation without additional salinity management measures.

Table 4.15. Soil salinity classes in Mangalwedha watershed.

Sr. No.	Electrical conductivity (dSm^{-1})	Area (ha)	TGA (%)
1	Normal (0 - 1)	9985.4	95.5
2	Eroded land	309.3	3.0
3	Habitation	47.5	0.5
4	Waterbody	116.1	1.1

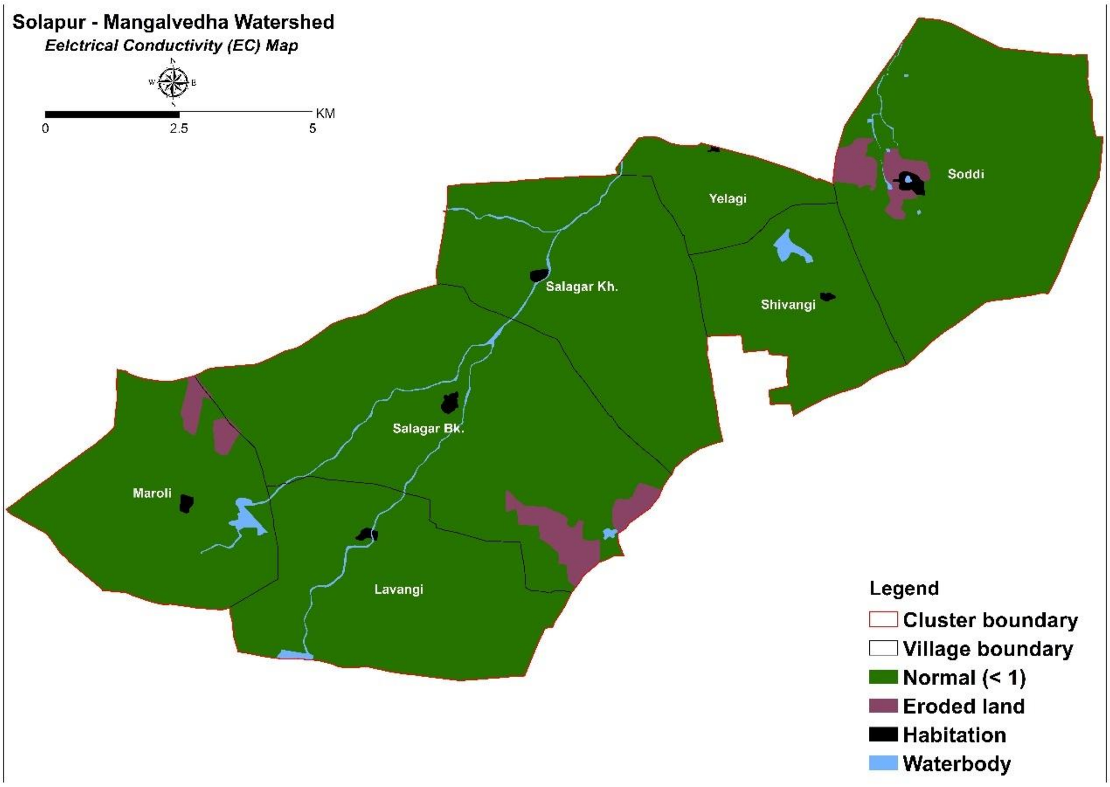


Fig. 4.10: Soil EC map of Mangalwedha watershed

4.5.7 Calcium carbonate ($CaCO_3$) content

The soils of the watershed are generally calcareous in nature with the $CaCO_3$ content ranging from moderate to very high (>10%). Semi-arid climatic features with low rainfall and high PET favour release of substantial amount of alkali bicarbonates and carbonates into the soil solution, thereby rendering the soils calcareous. As can be inferred from Table 4.16 and Fig. 4.11, a large part of the watershed area (46.1%) contains more than 10% $CaCO_3$ in soil, which could pose problems to normal crop growth. Soils with high (5–10%)

$CaCO_3$ occupy 24.1%, while moderately high (2–5%) soils cover 23.3% of the area. Medium (1–2%) calcareous soils account for 2.0% of the watershed.

Table 4.16. Extent of calcareousness in soils of Mangalwedha watershed.

Sr. No.	$CaCO_3$ content (%)	Area (ha)	TGA (%)
1	Medium (1.0 - 2.0)	209.2	2.0
2	Moderately High (2.0 - 5.0)	2439.9	23.3
3	High (5.0 - 10.0)	2516.4	24.1
4	Very High (> 10.0)	4819.9	46.1
5	Eroded land	309.3	3.0
6	Habitation	47.5	0.5
7	Waterbody	116.1	1.1
	Total	**10458.2**	**100.0**

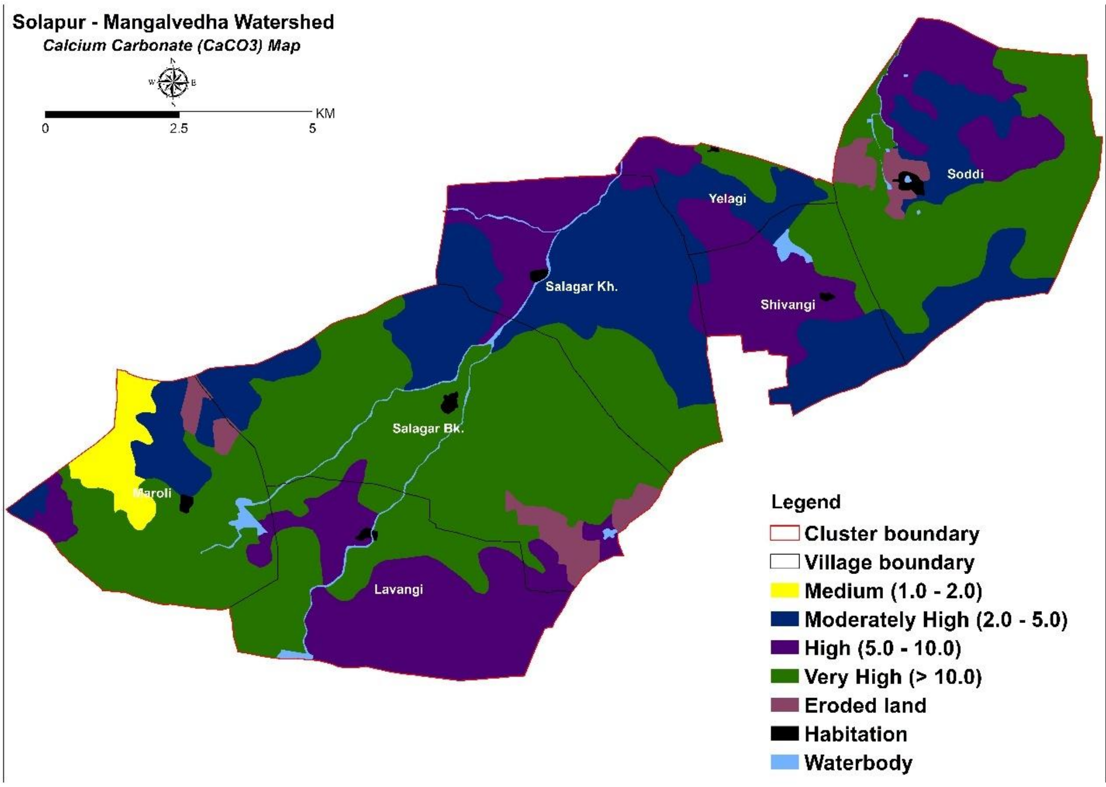


Fig. 4.11: Status of soil calcareousness in Mangalwedha watershed

4.5.8 Soil organic carbon

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

Monitoring SOC levels is crucial for sustainable land use and management. The loss of SOC through practices like deforestation and intensive agriculture can result in degraded soils leading to reduced agricultural productivity and enhanced greenhouse gas emissions. Promotion of climate-smart practices that increase SOC can ensure healthier and productive soils. Soils of Solapur watershed supported medium to moderately high SOC content, which can be inferred from Table 4.17 and Fig. 4.12. This is also indicated by the moderate-deep soils and sandy texture prevalent in the watershed. However, maximum area 43.0% under the low (0.21 - 0.40) OC class followed by moderately high (0.61–0.80%) soils covering 23.9%, medium (0.41–0.60%) soils covering 20.3% of the watershed and high (0.81 - 1.00) soil covering 6.2% of the watershed. Very low (<0.20%) OC soils account for 2% of the area. It is indicated that low and moderately high organic carbon for good fertility in the watershed.

Table 4.17. Soil organic carbon status of Mangalwedha watershed.

Sr. No.	Organic carbon (%)	Area (ha)	TGA (%)
1	Very Low (< 0.20)	209.2	2.0
2	Low (0.21 - 0.40)	4499.9	43.0
3	Medium (0.41 - 0.60)	2124.6	20.3
4	Moderately High (0.61 - 0.80)	2500.1	23.9
5	High (0.81 - 1.00)	651.5	6.2
6	Eroded land	309.3	3.0
7	Habitation	47.5	0.5
8	Waterbody	116.1	1.1
	Total	**10458.2**	**100.0**

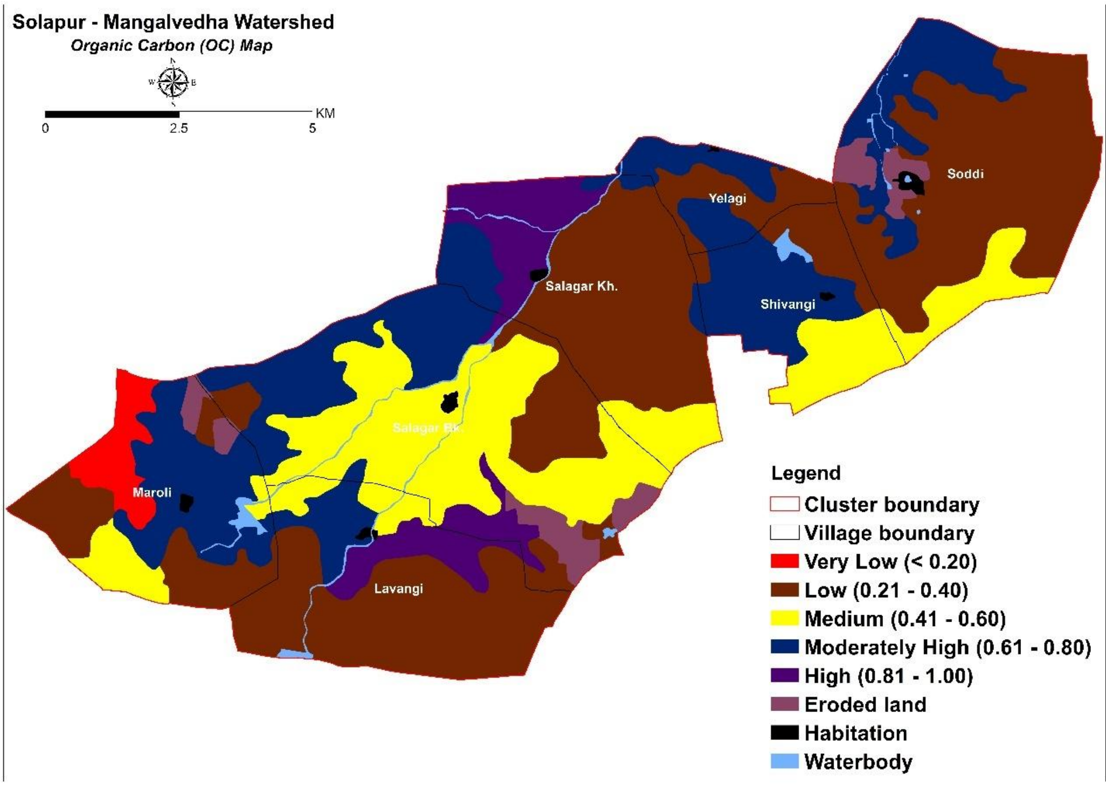


Fig. 4.12: Soil organic carbon map of Mangalwedha watershed

4.5.9 Available nitrogen (N)

Available nitrogen content in soils is crucial as it forms the primary building block for plant growth, is essential for producing proteins, amino acids, and chlorophyll to support photosynthesis, plant health and yield. The agricultural soils of watershed are inherently deficient in available N content. As seen from Table 4.18 and Fig. 4.13, 45.4% of the watershed area registered low N values (140-280 kg ha^{-1}) whereas in 50.1% area is very low N content (<140 kg ha^{-1}) is a matter of concern. Therefore, it is advocated to apply the nitrogenous fertilizers as per crop needs to maximize crop yields in the watershed area.

Table 4.18: Available N content in soils of Mangalwedha watershed.

Sr. No.	Available N (kg ha^{-1})	Area (ha)	TGA (%)
1	Very Low (< 140)	5237.3	50.1
2	Low (141 - 280)	4748.1	45.4
3	Eroded land	309.3	3.0
4	Habitation	47.5	0.5
5	Waterbody	116.1	1.1
	Total	**10458.2**	**100.0**

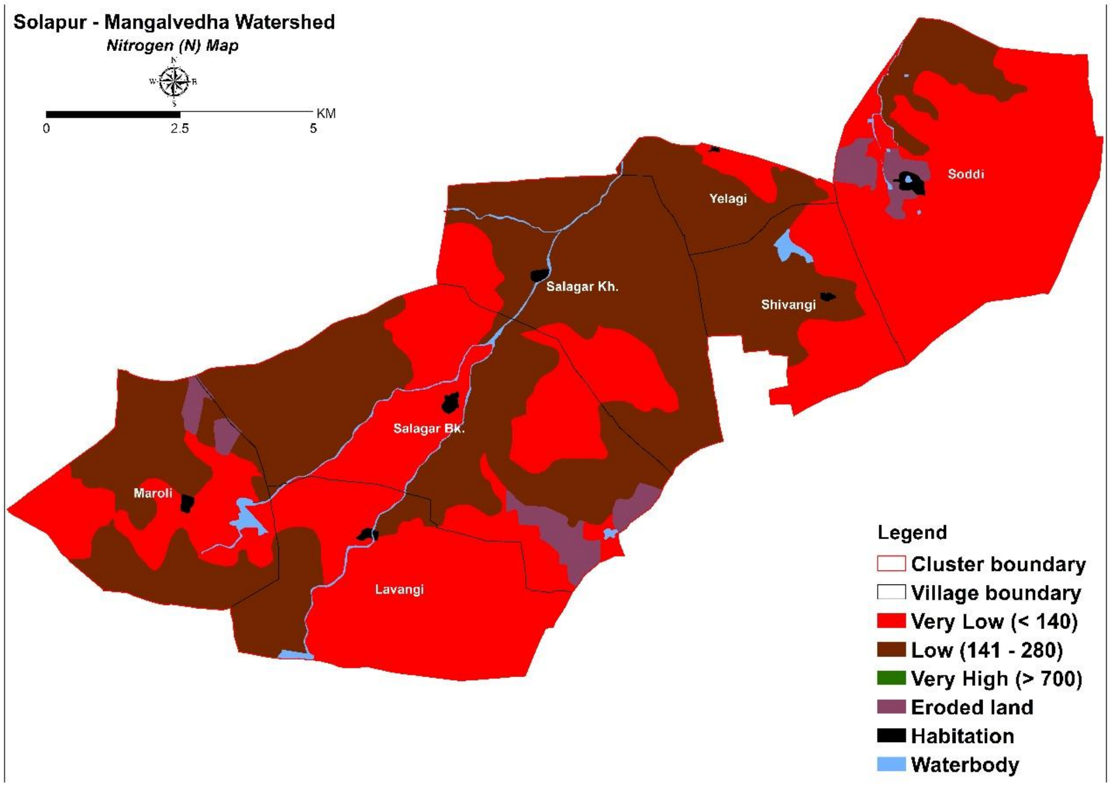


Fig. 4.13: Available soil nitrogen map of Mangalwedha watershed

4.5.10 Available Phosphorous (P)

Among the three major nutrients, phosphorus (P) plays an important role to complete the life cycle of a plant; its functions start right from the stimulation of root growth to proper seed filling and seed setting. It also plays a vital role in photosynthesis, carbohydrate breakdown and transfer of energy in the form of ATP and ADP compounds in various metabolic processes. The P content of the agricultural soils of the watershed (Table 4.19, Fig. 4.14) ranged from very low (<15 kg ha-1) to medium (31-50 kg ha-1), with the highest area was under very low and medium both have P status 34.7% followed by low (26.1%). The vast majority (three-fifth) of the area under very low to low 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 4.19: Available P content in soils of Mangalwedha watershed.

Sr. No.	Available P (kg ha^{-1})	Area (ha)	TGA (%)
1	Very Low (< 15)	3630.5	34.7
2	Low (16 - 30)	2726.4	26.1
3	Medium (31 - 50)	3628.4	34.7
4	Eroded land	309.3	3.0
5	Habitation	47.5	0.5
6	Waterbody	116.1	1.1
		10458.2	**100.0**

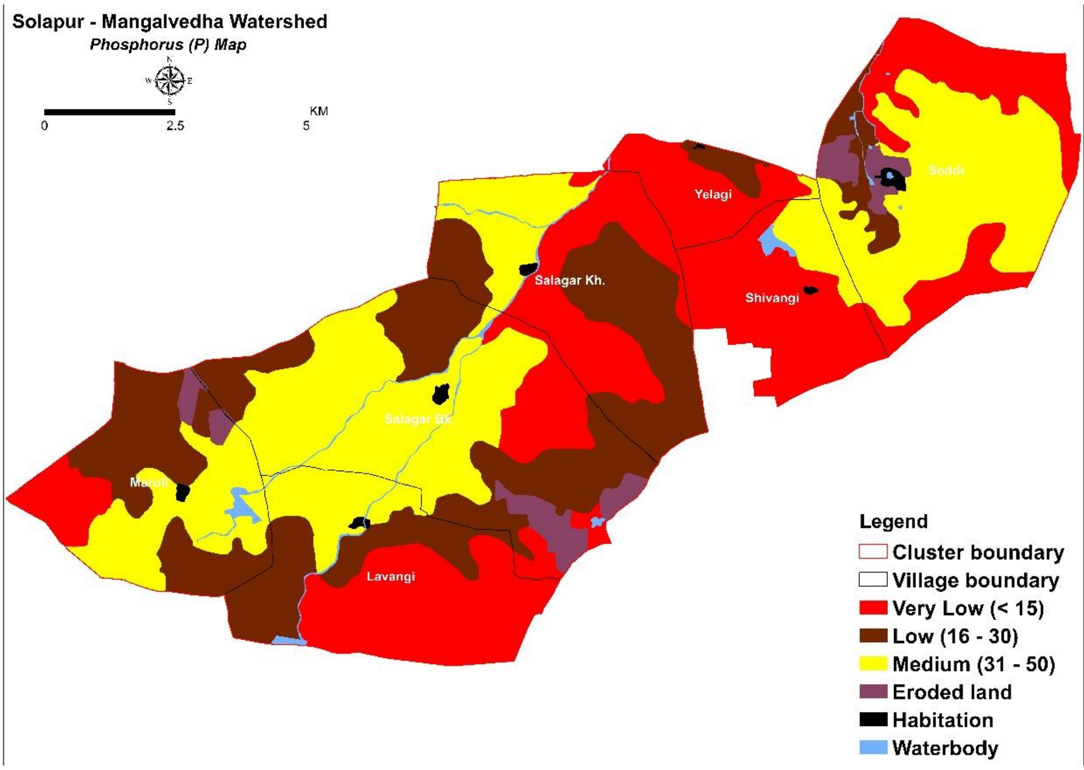


Fig.4.14: Available soil Phosphorus map of Mangalwedha watershed

4.5.11 Available Potassium (K)

The importance of potassium (K) is well recognized in agriculture. Exchangeable K or available K is widely used to evaluate the soil K status and to predict the crop K requirements. Six classes of available K status (Table 4.20, Fig. 4.15) were observed in the watershed soils. Surprisingly, largest area 38.7% under the very low (<120 kg/ha) K class. This is followed by low (121–180 kg/ha) soils covering 24.4%, Very High (> 360) soils at 11%, medium (181–240 kg/ha) soils at 9.8%. Moderately high (241–300 kg/ha) and high (301–360 kg/ha) K soils account for 9.8% and 5.5%, respectively. It is indicated that large portions of the watershed have inadequate potassium for crop growth, targeted fertilization may be required in areas with low or very low K to optimize agricultural productivity.

Table 4.20: Available K content of soils of Mangalwedha watershed

Sr. No.	Available K (kg ha^{-1})	Area (ha)	TGA (%)
1	Very Low (< 120)	4044.1	38.7
2	Low (121 - 180)	2552.0	24.4
3	Medium (181 - 240)	1022.6	9.8
4	Moderately High (241 - 300)	647.3	6.2
5	High (301 - 360)	570.8	5.5
6	Very High (> 360)	1148.7	11.0
7	Eroded land	309.3	3.0
8	Habitation	47.5	0.5
9	Waterbody	116.1	1.1
	Total	**10458.2**	**100.0**

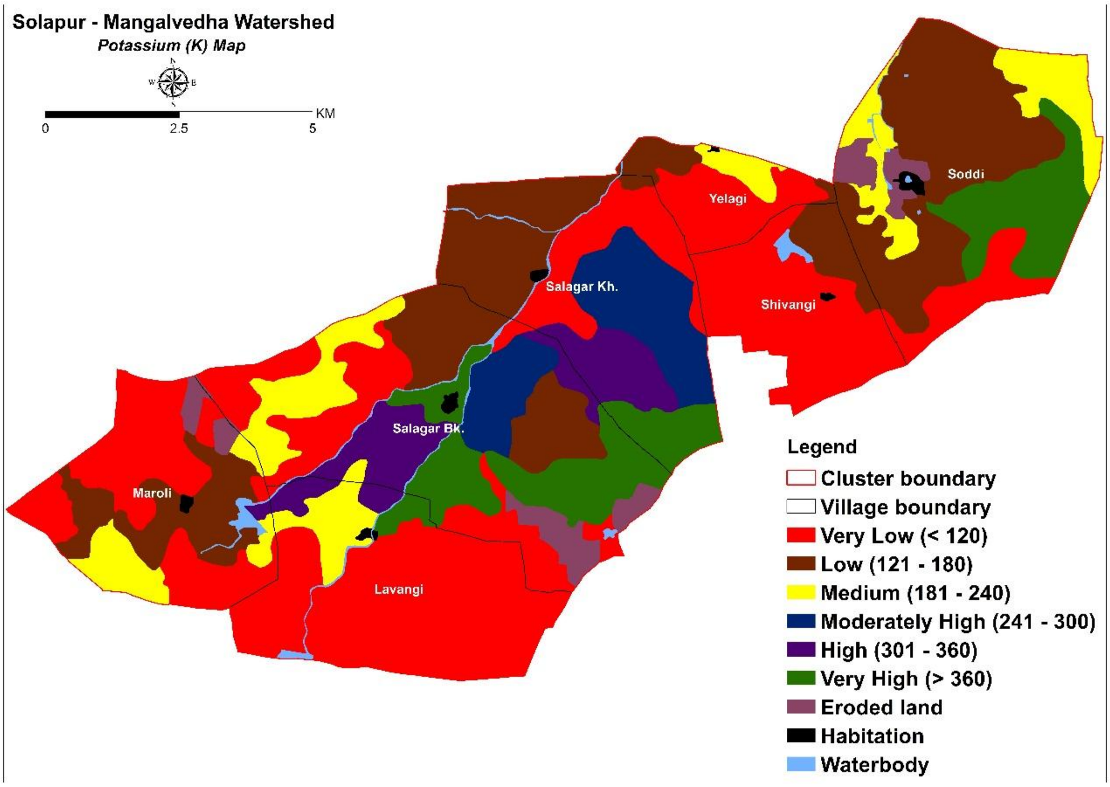


Fig. 4.15: Available soil Potassium map of Mangalwedha watershed

4.5.12 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. Five classes of available Fe were found in the watershed. Table 4.21 and Fig. 4.16 indicate that about 36% of the watershed area is very low Fe. This is Followed 29.5% is low Fe, 14.8% moderately high Fe, 8.9% is medium and 6% is high Fe calling for immediate attention in terms of its soil or foliar application through different fertilizer products. On the other hand, about a quarter of the watershed area was categorized as very high (>10.5 mg kg-1) in DTPA-extractable Fe. Approximately 37% of the watershed was found to be deficient in plant-available Mn content, while majority of the area is adequately supplied with Mn (Table 4.22, Fig. 4.17). Soils of the entire watershed are sufficient with respect to DTPA-extractable Cu (Table 4.23, Fig. 4.18), whereas more than 68% of the soils exhibit deficiency in available Zn (Table 4.24, Fig. 4.19), necessitating external Zn fertilization by the farmers.

Table 4.21: Available Fe content in the soils of Mangalwedha watershed.

Sr. No.	Available Fe (mg kg^{-1})	Area (ha)	TGA (%)
1	Very Low (< 2.5)	3786.2	36.2
2	Low (2.5 - 4.5)	3083.4	29.5
3	Medium (4.5 - 6.5)	932.1	8.9
4	Moderately High (6.5 - 8.5)	1551.9	14.8
5	High (8.5 - 10.5)	631.7	6.0
6	Eroded land	309.3	3.0
7	Habitation	47.5	0.5
8	Waterbody	116.1	1.1
	Total	**10458.2**	**100.0**

Table 4.22: Available Mn content in the soils of Mangalwedha watershed.

Sr. No.	Available Mn (mg kg^{-1})	Area (ha)	TGA (%)
1	Very Low (< 1.0)	3877.3	37.1
2	Low (1.0 - 1.3)	2250.0	21.5
3	Medium (1.3 - 5.0)	1674.4	16.0
4	Moderately High (5.0 - 7.0)	1551.9	14.8
5	High (7.0 - 9.0)	631.7	6.0
6	Eroded land	309.3	3.0
7	Habitation	47.5	0.5
8	Waterbody	116.1	1.1
	Total	**10458.2**	**100.0**

Table 4.23: Available Cu content in the soils of Mangalwedha watershed.

Sr. No.	Available Cu (mg kg^{-1})	Area (ha)	TGA (%)
1	High (0.8 - 1.0)	456.6	4.4
2	Very High (> 1.0)	9528.8	91.1
3	Eroded land	309.3	3.0
4	Habitation	47.5	0.5
5	Waterbody	116.1	1.1
	Total	**10458.2**	**100.0**

Table 4.24: Available Zn content in the soils of Mangalwedha watershed.

Sr. No.	Available Zn (mg kg^{-1})	Area (ha)	TGA (%)
1	Very Low (< 0.3)	7079.0	67.7
2	Low (0.3 - 0.6)	2773.3	26.5
3	Medium (0.6 - 0.9)	133.0	1.3
4	Eroded land	309.3	3.0
5	Habitation	47.5	0.5
6	Waterbody	116.1	1.1
	Total	**10458.2**	**100.0**

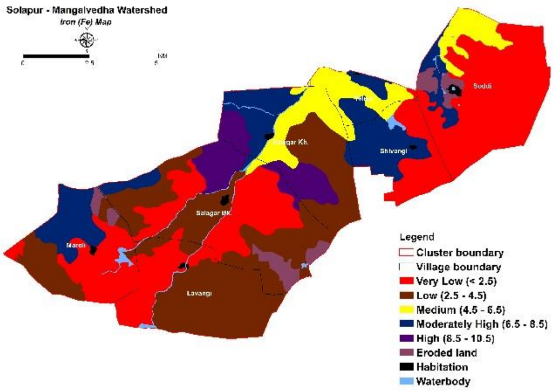


Fig. 4.16: DTPA-extractable soil Fe map of Mangalwedha watershed

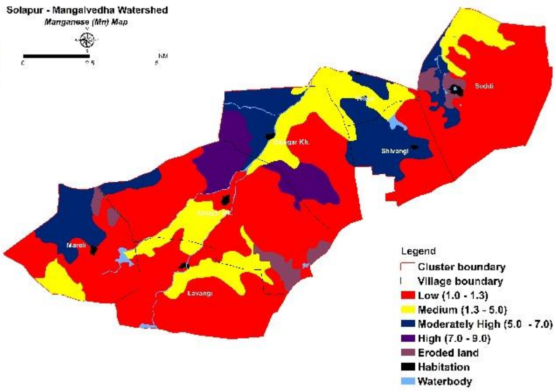


Fig. 4.17: DTPA-extractable soil Mn map of Mangalwedha watershed

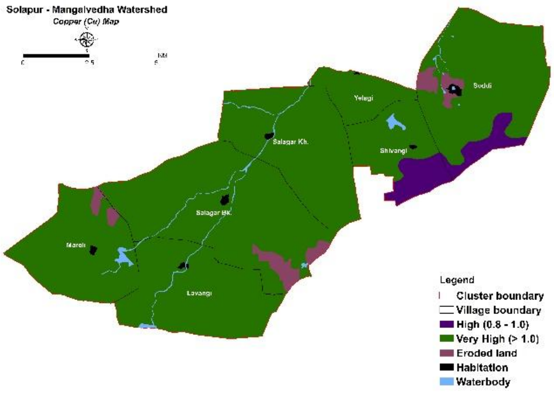


Fig. 4.18: DTPA-extractable soil Cu map of Mangalwedha watershed

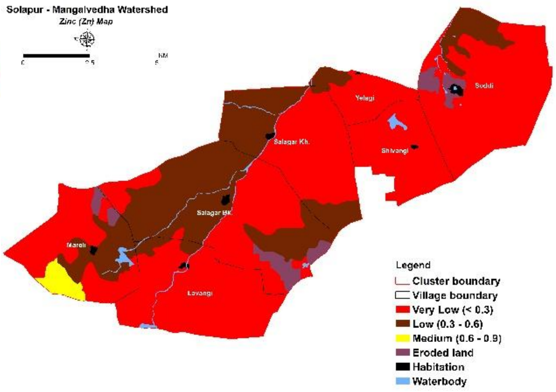


Fig. 4.19: DTPA-extractable soil Zn map of Mangalwedha watershed

4.6 Surface Runoff

Runoff estimation is a key step in understanding water movement in Mangalwedha Taluka, which experiences variable rainfall and semi-arid conditions typical of Solapur District. The conversion of rainfall into surface runoff determines water availability for storage, groundwater recharge, and irrigation in the watershed. Analysis of rainfall and runoff data from 2014 to 2024 provides insights into the seasonal and annual patterns of surface water in this region.

Runoff quantifies the portion of rainfall that flows over the land surface rather than infiltrating into the soil. In semi-arid basaltic regions such as Mangalwedha, understanding runoff patterns is important for identifying areas where water can be conserved, erosion can be minimized, and groundwater recharge can be enhanced. Rainfall data alone cannot explain water scarcity; runoff analysis shows how much water leaves the landscape and how much can potentially be retained through interventions.

Runoff estimation is also essential for watershed planning. High runoff percentages highlight zones where rainwater harvesting or storage structures are needed, while low runoff areas indicate better infiltration potential that can be enhanced further. By identifying seasonal peaks and inter-annual variability, planners can prioritize interventions during critical months, such as October, which consistently shows higher runoff in the Mangalwedha watershed. Runoff assessment also helps estimate erosion risk, as high quick-flow events often coincide with soil loss and degradation, supporting long-term land and water management.

For this study, the SCS–Curve Number (CN) method was applied to estimate runoff. This method links runoff depth to rainfall, land use, soil type, and antecedent moisture conditions. CN values range from 30 to 100, with lower values representing permeable soils and vegetated cover and higher values representing impervious or degraded surfaces. Soils were classified into hydrologic groups (A, B, C, D), and CN values were assigned to each land use–soil combination. Daily rainfall data from 2014 to 2024 were aggregated into storm events, and runoff depth was calculated using the SCS equation. Monthly and annual runoff values were then derived, providing both seasonal and long-term averages

Monthly rainfall and runoff for June to October during 2014-2024 are presented in Table 4.25. The data show substantial variability in runoff across months and years.

Table 4.25 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	56.0	0.0	123.7	15.3	214.5	57.1	46.3	0.3	44.2	0.0
2015	102.1	8.0	23.3	0.0	111.5	0.0	142.2	7.8	53.0	0.4
2016	90.7	0.0	153.4	16.8	27.7	0.1	128.7	7.4	31.1	0.0
2017	214.7	60.1	21.4	0.0	176.7	5.7	232.6	17.6	195.2	71.7
2018	63.7	0.0	36.4	0.0	86.3	0.0	60.5	0.0	4.5	0.0
2019	109.4	6.4	56.0	0.0	61.2	0.0	140.2	12.1	215.4	19.6
2020	173.3	5.6	150.1	2.0	61.1	0.0	192.8	18.9	196.0	68.6
2021	111.8	0.0	141.1	0.1	124.9	0.0	116.5	0.0	59.5	0.0
2022	108.0	0.0	186.4	1.5	107.0	13.7	151.8	23.3	202.8	36.5
2023	48.7	0.0	143.4	0.6	54.1	2.1	85.5	0.5	5.9	0.0
2024	139.0	36.6	83.1	0.0	153.0	30.8	158.4	10.7	47.6	0.0
Average	**110.7**	**10.6**	**101.7**	**3.3**	**107.1**	**10.0**	**132.3**	**9.0**	**95.9**	**17.9**

Analysis of Table 4.25 indicates that October generally records the highest average runoff (17.9 mm), followed by selective high-runoff years in June and September. June and July runoff is usually low despite moderate rainfall, suggesting substantial early-season infiltration. August shows moderate runoff in specific years. The monthly variation is illustrated in Fig 4.20.

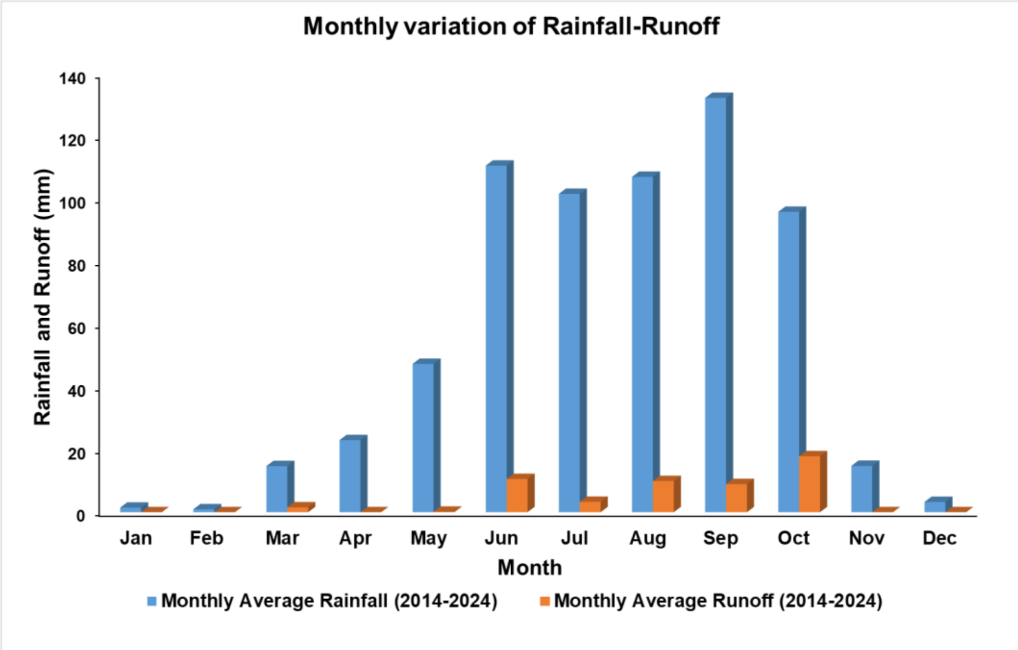


Fig 4.20: Monthly variation of rainfall-runoff in Mangalwedha watershed

Table 4.26. Relationship between rainfall and runoff.

Year	Rainfall (mm)	Runoff (mm)	No. of Runoff Events	Runoff (%)
2014	691.4	89.6	14	13.0
2015	549.9	16.2	6	2.9
2016	528.6	24.3	8	4.6
2017	870.6	155.0	19	17.8
2018	325.4	38.1	13	11.7
2019	640.8	95.1	10	14.8
2020	856.1	0.1	1	0.0
2021	734.8	75.6	15	10.3
2022	871.4	3.3	4	0.4
2023	445.8	79.1	14	17.7
2024	670.7	0.0	0	0.0
Average	**653.2**	**52.4**	**9**	**8.0**

Table 4.26 shows an average annual runoff of 52.4 mm, about 8.0% of the average annual rainfall. High runoff years include 2017, 2019, and 2023, while years such as 2020, 2022, and 2024 record very low runoff despite significant rainfall. Runoff events range from zero to nineteen, showing strong inter-annual variation.

In conclusion, the runoff estimation for Mangalwedha Taluka cluster watershed from 2014-2024 shows an average annual runoff of 52.4 mm, approximately 8.0% of rainfall. The SCS-Curve Number method application confirms that runoff generation varies strongly with monthly rainfall distribution and intensity. These results provide a factual reference for watershed planning, water harvesting design, and sustainable water resource management in Solapur District.

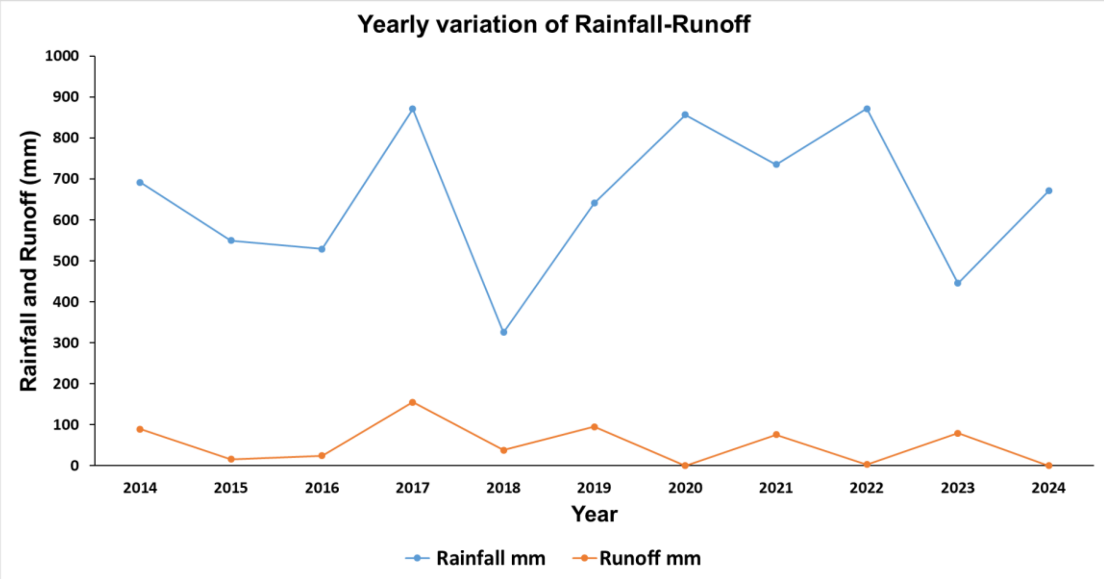


Fig 4.21: Yearly variation of rainfall-runoff in Mangalwedha watershed

4.7 Mapping of Groundwater Potential Zones

Groundwater has emerged as one of the most critical natural resources in contemporary times, particularly in semi-arid regions of India where surface water availability is limited and rainfall is highly erratic. The increasing dependence on groundwater for agriculture, drinking, and domestic purposes has placed immense stress on aquifers, leading to depletion and declining water quality. In this context, delineation of Groundwater Potential Zones (GWPZ) has become an essential scientific exercise to ensure sustainable utilization and management of groundwater resources. Mangalweda Taluka in Solapur District, Maharashtra, represents a drought-prone landscape where groundwater serves as the primary source of livelihood security. The taluka has faced recurrent challenges in recent years, including declining rainfall, over-extraction of groundwater, soil degradation, and migration of rural populations. To counter these challenges, a systematic study was undertaken to delineate GWPZ in an identified 8-village cluster watershed. The resulting classification delineated five distinct categories of groundwater potential zones: very poor, poor, moderate, good, and very good.

The findings reveal that large portions of the watershed fall under moderate to poor categories, reflecting the inherent limitations of the semi-arid environment and the anthropogenic pressures on water resources. However, small pockets of good and very good potential zones were identified, particularly in areas with favorable fractured lithology, gentle slopes, and near to the stream. These zones represent opportunities for targeted interventions such as recharge structures, check dams, and sustainable irrigation practices. Conversely, the very poor zones highlight regions where groundwater extraction should be minimized and alternative livelihood strategies promoted.

This delineation provides a benchmark for future extension work in Mangalweda Taluka. By identifying spatial variability in groundwater potential, the study offers a scientific basis for planning water resource management, agricultural diversification, and climate resilience strategies. The classification into five potential categories enables policymakers, local institutions, and farmers to prioritize interventions according to resource availability and vulnerability. In the broader context, the study demonstrates the utility of integrating GIS, remote sensing, and AHP in watershed-level planning, offering replicable methodology for other drought-prone regions of Maharashtra and beyond.

In conclusion, the delineation of GWPZ in the 8-village cluster watershed of Mangalweda Taluka underscores the importance of scientific planning in addressing contemporary water challenges. The integration of thematic factors and multi-criteria decision analysis has produced actionable insights that can guide sustainable groundwater management. As climate variability intensifies and water scarcity deepens, such studies will serve as critical benchmarks for ensuring long-term resilience and livelihood security in vulnerable rural landscapes.

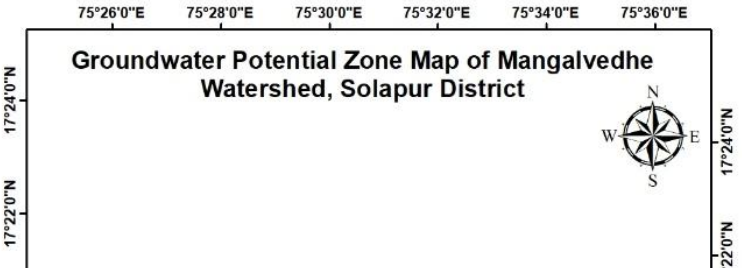


Fig. 4.22. Ground water potential zones in Mangalwedha watershed.

4.8 Evaluation of Soil-Site Suitability for Crops

Soil and climate are the prime factors governing optimum crop growth. Soil physicochemical properties and crop micro-environment control the availability of water and essential plant nutrients. Therefore, key soil attributes, *viz.* soil depth, texture, fertility status and drainage conditions are carefully assessed during soil-site evaluation. This enables meaningful interpretation of soil maps in terms of their suitability for field and horticultural crops and contributes to the formulation of scientific land-use plans for watershed development.

The suitability of soils for crop cultivation was determined based on the criteria proposed by Naidu et al. (2006). The concept of land utilization types and the classification system for land evaluation categorizes land into different hierarchical levels, namely orders, classes, sub-classes, and units. Two major orders are recognized: ‘S’ (Suitable) and ‘N’ (Not suitable), representing the general suitability status of land. Under the suitable order (S), three classes S1, S2, and S3 indicate high, moderate, and marginal suitability, respectively, while the not suitable order (N) includes two classes N1 and N2 representing current and permanent unsuitability. The assignment of these classes is based on the degree of land limitations affecting crop production.

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

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

4.8.1 Soil-Site Suitability for Wheat Cultivation

Soil site suitability analysis for wheat shown in Table 4.27 and Fig 4.23 suggests that nearly half of the cluster, 5510.3 ha (52.7%), is marginally suitable (S3) for cultivation. This cluster is characterized by steep slopes and hot climate and shallow soils which reduce the overall suitability for cultivation. About, 1939.8 ha (18.5%) of the land is highly suitable(S1) for wheat cultivation. This region has adequate soil depth and well-drained soil. A small proportion, 24.2% (2535.3 ha) of land is not suitable for wheat cultivation. overall, short duration heat tolerant cultivars of wheat would grow well in this region.

Table 4.27 Area under suitability sub-classes for Wheat Cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Highly Suitable (S1)	1939.8	18.5
2	Marginally Suitable (S3)	5510.3	52.7
3	Not Suitable (N)	2535.3	24.2
4	Eroded land	309.3	3.0
5	Habitation	47.5	0.5
6	Waterbody	116.1	1.1
		Total	**10458.2**

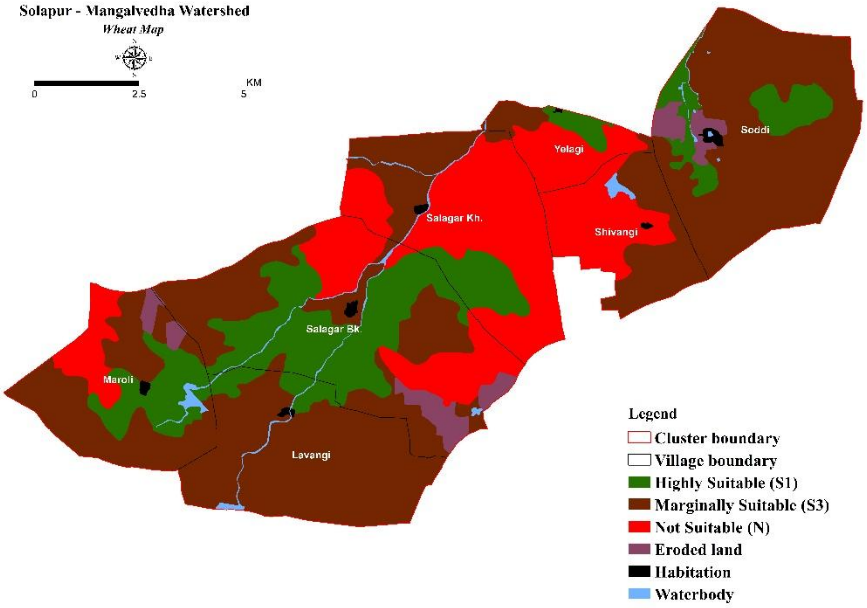


Fig. 4.23 Soil site suitability map for Wheat Cultivation

4.8.2 Area under suitability sub-classes for Maize Cultivation

The assessment of soil site suitability for maize cultivation reveals that major proportion of the cluster is Marginally Suitable (S3), accounting for 5,510.3 ha (52.7%) of the area. This cluster is limited by low rainfall and steep slopes. Moderately Suitable (S2) region is 1,939.8 ha (18.5%). These zones generally offer more favorable topography and sufficient soil depth with well drained soils. However, a considerable portion, 2,535.3 ha (24.2%) is deemed Not Suitable (N). it is due to the combined adverse effects of steep slopes and shallow and calcareous soil (Table 4.28) (Fig 4.24).

Table 4.28 Area under suitability sub-classes for Maize Cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Moderately Suitable (S2)	1939.8	18.5
2	Marginally Suitable (S3)	5510.3	52.7
3	Not Suitable (N)	2535.3	24.2
4	Eroded land	309.3	3.0
5	Habitation	47.5	0.5
6	Waterbody	116.1	1.1
		Total	**10458.2**

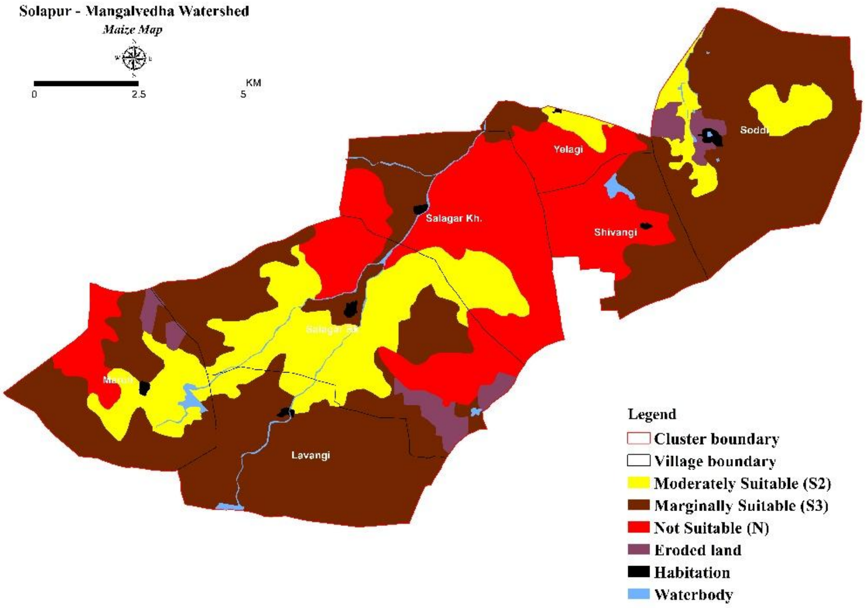


Fig. 4.24 Soil site suitability map for Maize Cultivation

4.8.3 Soil-Site Suitability for Sorghum (Jowar) Cultivation

Sorghum, a drought-tolerant crop, demonstrates moderate to marginal suitability for cultivation in the Solapur cluster. A marginally suitable (S2) area, spanning 3,949.7 hectares (37.7%), is limited by low organic carbon content, a constraint that can be mitigated by applying farmyard manure. A moderately suitable (S3) area covers 3,500.3 hectares (33.5% of the cluster), benefiting from a highly conducive clay to clay loam soil composition, though crop growth is impeded by a pronounced slope. Finally, 2,535.3 hectares (24.2% of the cluster) are "Not Suitable (N)" due to very shallow soil depth and steep slopes (Table 4.29) (Fig 4.25).

Table 4.29 Area under different suitability sub-classes for Sorghum Cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Moderately Suitable (S2)	3500.3	33.5
2	Marginally Suitable (S3)	3949.7	37.8
3	Not Suitable (N)	2535.3	24.2
4	Eroded land	309.3	3.0
5	Habitation	47.5	0.5
6	Waterbody	116.1	1.1
		Total	**10458.2**

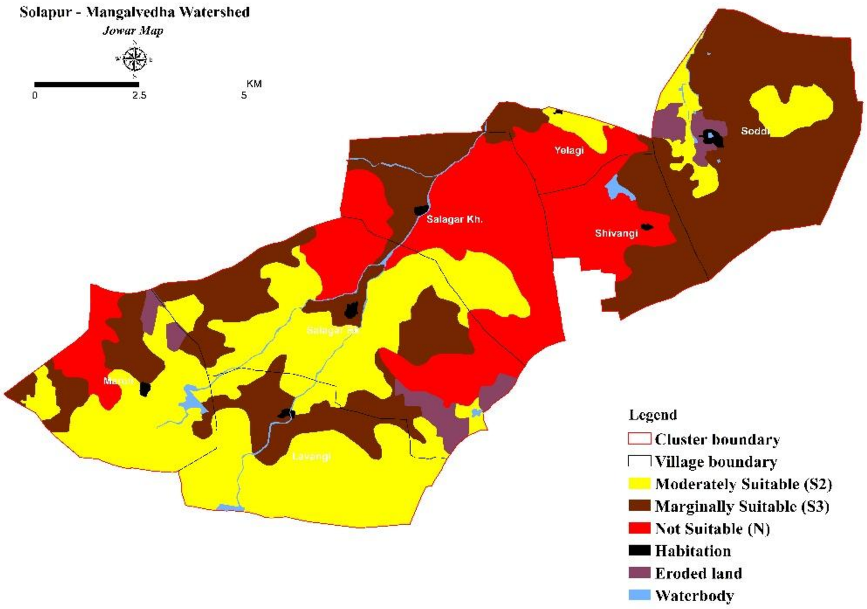


Fig. 4.25 Soil site suitability map for Sorghum (jowar) Cultivation

4.8.4 Soil-Site Suitability for Pearl millet (Bajra*)* Cultivation

Soil site suitability analysis for bajra is shown in Fig 4.26 and Table 4.30. Most of the region in the cluster, 5510.3 ha (52.7%) is marginally suitable (S3) for cultivation. The Solapur cluster features very steep gradients, which is a limiting factor for bajra cultivation. moderately suitable (S2) region is nearly 16.6% (1739.3 ha). This region has a lower organic carbon content, which can be mitigated by adding farmyard manure. Highly suitable region is of 200.4 ha (1.9%). This region has adequate soil depth, topography, well-drained soil.

Table 4.30 Area under suitability sub-classes for Pearl millet (Bajra) Cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Highly Suitable (S1)	200.4	1.9
2	Moderately Suitable (S2)	1739.3	16.6
3	Marginally Suitable (S3)	5510.3	52.7
4	Not Suitable (N)	2535.3	24.2
5	Eroded land	309.3	3.0
6	Habitation	47.5	0.5
7	Waterbody	116.1	1.1
	Total	**10458.2**	**100.0**

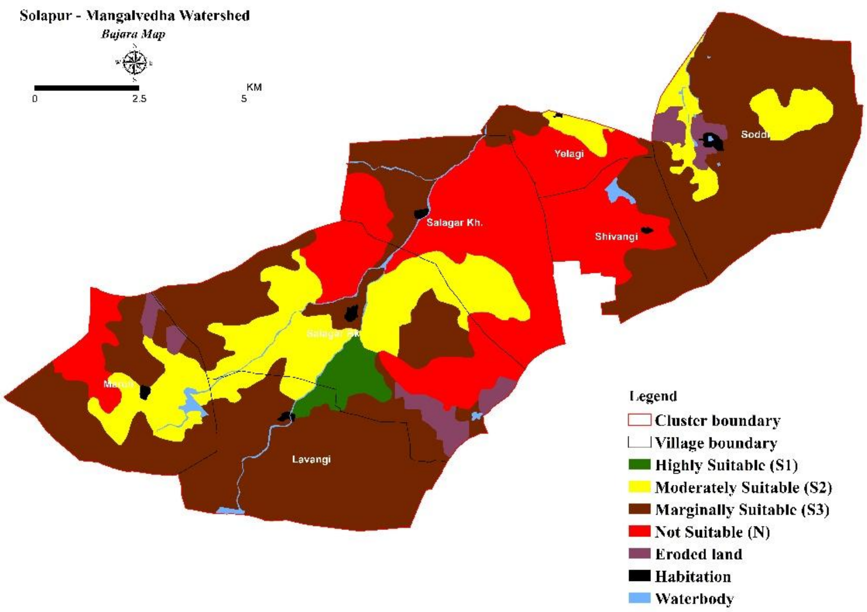


Fig. 4.26 Soil site suitability map for Pearl millet (Bajra) Cultivation

4.8.5 Soil-Site Suitability for Green gram Cultivation

Based on the soil site suitability analysis of green gram suitability assessment, the largest portion of the area is classified as Marginally Suitable (S3), covering 4,960.6 ha (47.4%). This is followed by land that is Not Suitable (N), accounting for 2,535.3 ha (24.2%), and Moderately Suitable (S2) land, which spans 2,288.9 ha (21.9%). The smallest fraction of the region is designated as Highly Suitable (S1), representing 200.4 ha (1.9%). The cluster has adequate rainfall, well-drained soil but steep slopes reduce the overall suitability of green gram cultivation (Table 4.31) (Fig 4.27).

Table 4.31 Area under suitability sub-classes for Green gram Cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Highly Suitable (S1)	200.4	1.9
2	Moderately Suitable (S2)	2288.9	21.9
3	Marginally Suitable (S3)	4960.6	47.4
4	Not Suitable (N)	2535.3	24.2
5	Eroded land	309.3	3.0
6	Habitation	47.5	0.5
7	Waterbody	116.1	1.1
	Total	**10458.2**	**100.0**

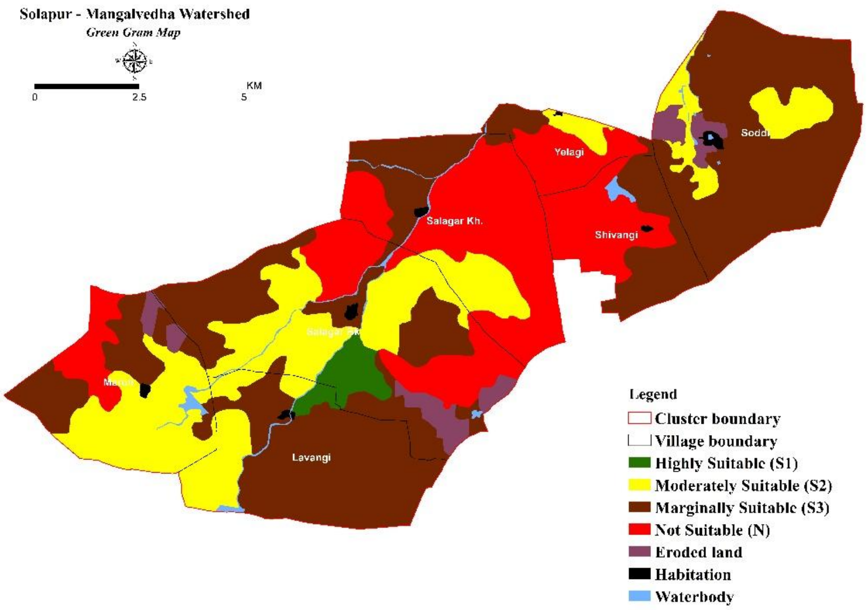


Fig. 4.27 Soil site suitability map for Green gram Cultivation

4.8.6 Soil-Site Suitability for Black gram Cultivation

The land suitability assessment for tomato cultivation reveals that more than half of the region is classified as Marginally Suitable (S3), covering 5,510.3 ha (52.7%). This is followed by Not Suitable (N) land, which accounts for 2,535.3 ha (24.2%), while Moderately Suitable (S2) areas represent 1,939.8 ha (18.5%) of the total. The cluster has adequate rainfall, well-drained soil but high temperature impedes in cultivation of black gram (Table 4.32) (Fig 4.28).

Table 4.32 Area under suitability sub-classes for Black gram Cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Moderately Suitable (S2)	2489.4	23.8
2	Marginally Suitable (S3)	4960.6	47.4
3	Not Suitable (N)	2535.3	24.2
4	Eroded land	309.3	3.0
5	Habitation	47.5	0.5
6	Waterbody	116.1	1.1
	Total	**10458.2**	**100.0**

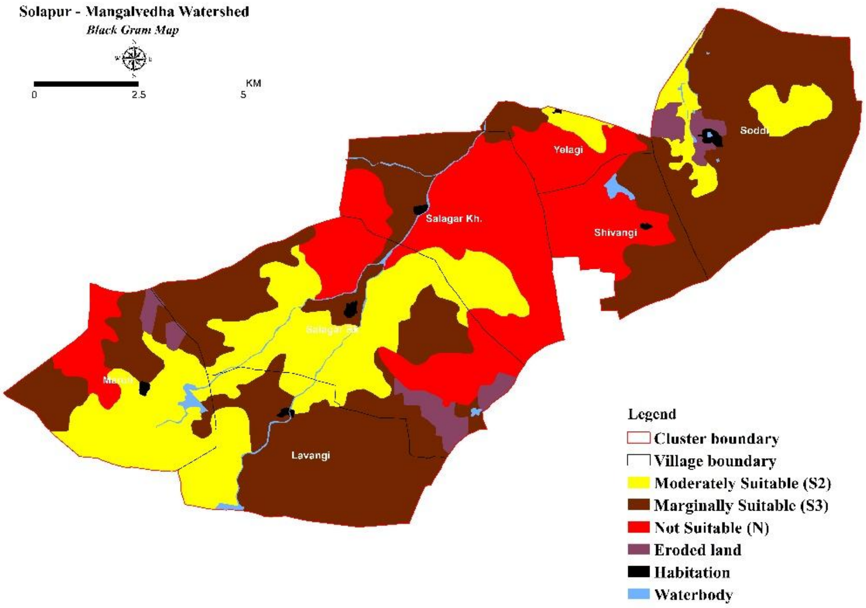


Fig. 4.28 Soil site suitability map for Black gram Cultivation

4.8.7 Soil-Site Suitability for Groundnut Cultivation

Soil site suitability assessment map for groundnut is depicted in Fig 4.29 and its details are shown in Table 4.33. The majority of the area in the cluster, 5510.3 ha (52.7%), is marginally suitable (S3) for the cultivation of groundnut. Groundnut cultivation in this area is primarily restricted by the steep slope of the land. This limitation could be addressed by leveling the land and using reclaimed soil sediments to increase the soil depth and mitigate the challenges posed by the steep terrain. About 1939.8 ha (18.5%) is moderately suitable (S2) for cultivation; applying farmyard manure to increase the organic carbon would improve the yield of groundnut. The not suitable (N) region for cultivation is 2535.3 ha (24.2%), it would require numerous interventions.

Table 4.33 Area under suitability sub-classes for Groundnut Cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Moderately Suitable (S2)	1939.8	18.5
2	Marginally Suitable (S3)	5510.3	52.7
3	Not Suitable (N)	2535.3	24.2
4	Eroded land	309.3	3.0
5	Habitation	47.5	0.5
6	Waterbody	116.1	1.1
	Total	**10458.2**	**100.0**

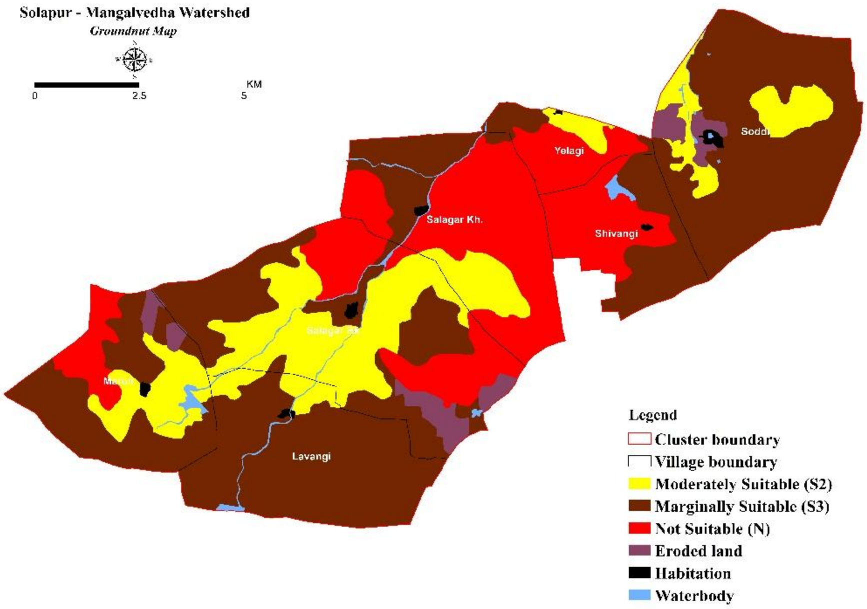


Fig. 4.29 Soil site suitability map for Groundnut Cultivation

4.8.8 Soil-Site Suitability for Sugarcane Cultivation

The assessment of crop site suitability for sugarcane reveals that a significant area (5764.6 ha, 55.1%) is classified as Not Suitable (N) for cultivation, primarily attributed to insufficient rainfall. Sugarcane necessitates a high, well-distributed annual rainfall ranging from 2000 to 2500 mm. Consequently, for sugarcane production within the cluster, the requisite crop water demand must be met through irrigation. This substantial irrigation water requirement renders the region unsuitable for sugarcane cultivation. The Marginally Suitable (S2) region comprises approximately 2281.0 ha (21.8%) and is characterized by a relatively level topography compared to the not suitable area. Furthermore, this region possesses deep, well-drained, stable loam to clay loam soils. The smallest proportion of the cluster, 1939.8 ha (18.5%), is deemed moderately suitable (S2) for sugarcane cultivation. Overall, the region is generally not suitable for sugarcane production (Table 4.34) (Fig 4.30).

Table 4.34 Area under suitability sub-classes for Sugarcane Cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Moderately Suitable (S2)	1939.8	18.5
2	Marginally Suitable (S3)	2281.0	21.8
3	Not Suitable (N)	5764.6	55.1
4	Eroded land	309.3	3.0
5	Habitation	47.5	0.5
6	Waterbody	116.1	1.1
	Total	**10458.2**	**100.0**

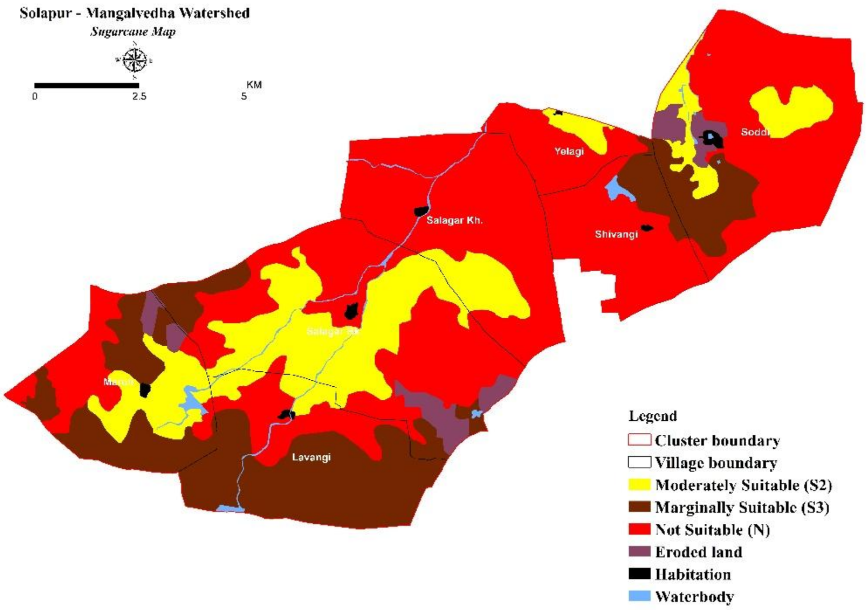


Fig. 4.30 Soil site suitability map for Sugarcane Cultivation

4.8.9 Soil-Site Suitability for Lemon Cultivation

Soil site suitability assessment for lemon is shown in Table 4.35 and presented in Fig 4.31. The assessment suggests that nearly half of the cluster, 5764.6 ha (55.1%), is not suitable (N) for the cultivation of lemon. This is due to steep slopes and shallow soil. About, 21.8% of the cluster is marginally suitable (S3) due to inadequate rainfall. Implementation of efficient irrigation systems could enable good crop yields in the cluster. Moderately suitable (S2) land for cultivation is 1939.8 ha (18.5%). Adding reclaimed soil sediments to the field and adequate agronomic measures to stabilize the soil would increase the soil depth resulting in better yields.

Table 4.35 Area under suitability sub-classes for Lemon Cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Moderately Suitable (S2)	1939.8	18.5
2	Marginally Suitable (S3)	2281.0	21.8
3	Not Suitable (N)	5764.6	55.1
4	Eroded land	309.3	3.0
5	Habitation	47.5	0.5
6	Waterbody	116.1	1.1
	Total	**10458.2**	**100.0**

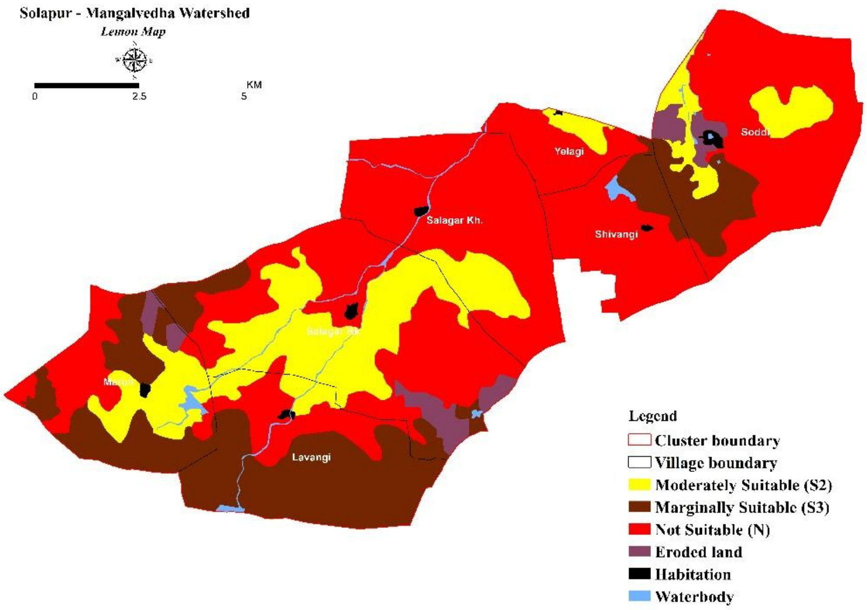


Fig. 4.31 Soil site suitability map for Lemon Cultivation

4.8.10 Soil-Site Suitability for Pomegranate Cultivation

Soil site suitability for the Solapur cluster shows that the Solapur cluster due to steep slope and shallow soil, 5764.6 ha (55.1%) of area is not suitable (N) for cultivation. About, 3018.6 ha (28.9%) of land is marginally suitable(S3) for cultivation. To overcome the limitation of shallow soil in this cluster, reclaimed soil sediments could be added to the land. About 11.5% (1202 ha) of land is moderately suitable(S2) for cultivation. Overall the cluster has high intrinsic suitability particularly its climate and needs minimal interventions for good cultivation (Table 4.36) (Fig 4.32).

Table 4.36 Area under suitability sub-classes for Pomegranate Cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Moderately Suitable (S2)	1202.2	11.5
2	Marginally Suitable (S3)	3018.6	28.9
3	Not Suitable (N)	5764.6	55.1
4	Eroded land	309.3	3.0
5	Habitation	47.5	0.5
6	Waterbody	116.1	1.1
	Total	**10458.2**	**100.0**

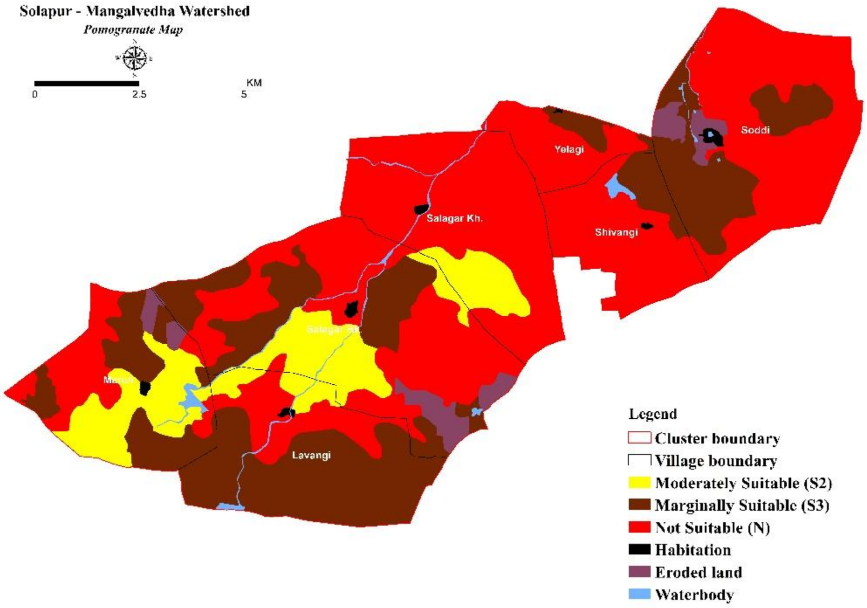


Fig. 4.32 Soil site suitability map for Pomegranate Cultivation

4.8.11 Soil-Site Suitability for Onion Cultivation

Based on the soil site suitability assessment for onion cultivation, the majority of the cluster falls under the Marginally Suitable (S3) category, covering 7,246.6 ha (69.3%). This is followed by Moderately Suitable (S2) land, which accounts for 2,538.3 ha (24.3%), while only a small fraction of the area is classified as Highly Suitable (S1) at 200.4 ha (1.9%) (Table 4.37, Fig 4.33). The cluster has steep slopes and inadequate rainfall, reducing overall suitability for onion cultivation.

Table 4.37 Area under suitability sub-classes for Onion Cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Highly Suitable (S1)	200.4	1.9
2	Moderately Suitable (S2)	2538.3	24.3
3	Marginally Suitable (S3)	7246.6	69.3
4	Eroded land	309.3	3.0
5	Habitation	47.5	0.5
6	Waterbody	116.1	1.1
Total		**10458.2**	**100.0**

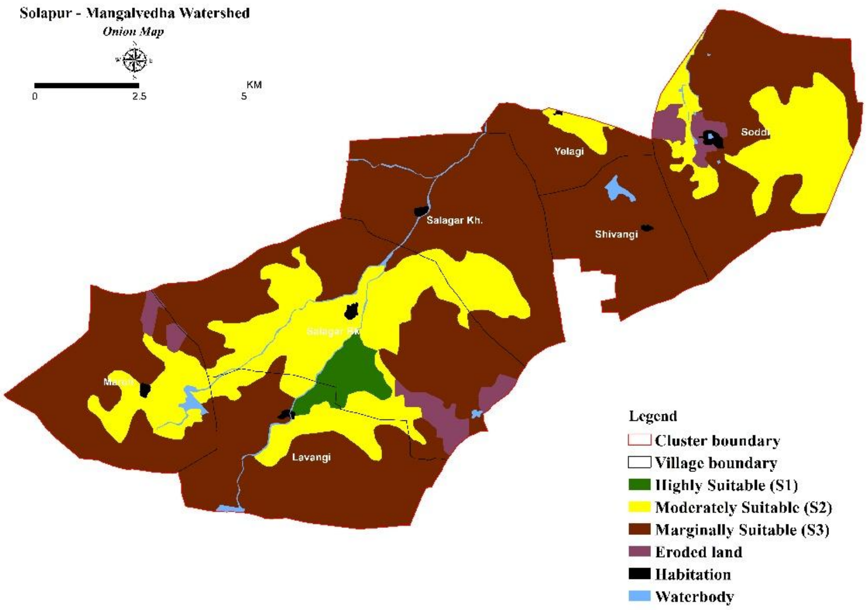


Fig. 4.33 Soil site suitability map for Onion Cultivation

4.8.12 Soil-Site Suitability for Tomato Cultivation

The soil site suitability assessment for tomato cultivation reveals that more than half of the cluster is classified as Marginally Suitable (S3), covering 5,510.3 ha (52.7%). This is followed by Not Suitable (N) land, which accounts for 2,535.3 ha (24.2%), while Moderately Suitable (S2) areas represent 1,939.8 ha (18.5%) of the total. High temperatures, low rainfall steep slopes and calcareous soil affect the cultivation of tomato negatively (Table 4.38) (Fig 4.34).

Table 4.38 Area under suitability sub-classes for Tomato Cultivation

Sr. No.	Suitability class	Area (ha)	Percent (%)
1	Moderately Suitable (S2)	1939.8	18.5
2	Marginally Suitable (S3)	5510.3	52.7
3	Not Suitable (N)	2535.3	24.2
4	Eroded land	309.3	3.0
5	Habitation	47.5	0.5
6	Waterbody	116.1	1.1
	Total	**10458.2**	**100.0**

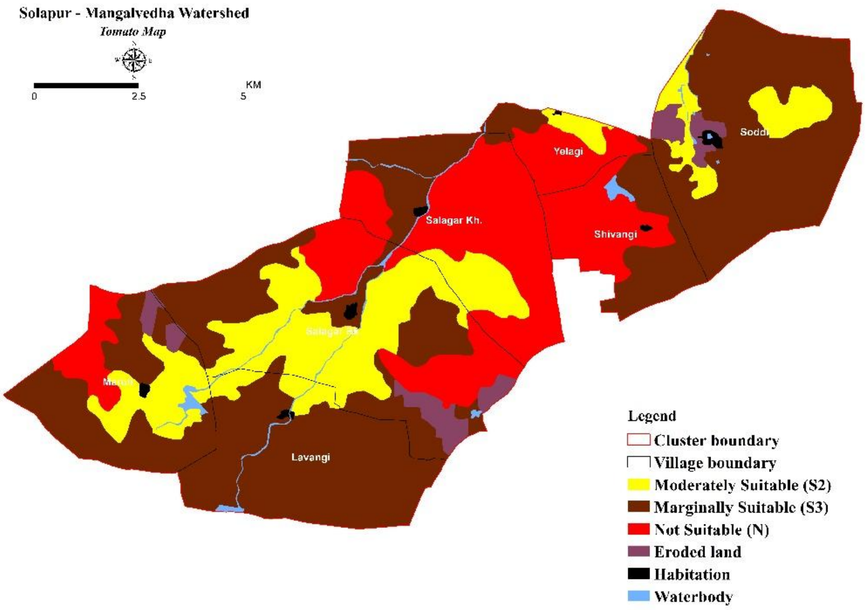


Fig. 4.34 Soil site suitability map for Tomato Cultivation

4.9 Soil and Water Conservation measures

Mangalwedha Taluka in Solapur District is recognized as a drought-prone region where soil erosion, erratic rainfall, and limited groundwater recharge have long affected agricultural productivity. To address these challenges, a detailed plan has been drawn up for the village cluster watershed, focusing on interventions that match the land capability and local conditions. The plan covers a wide range of measures, each identified with its specific area of application, ensuring that conservation practices are practical and site-specific.

The watershed area is predominantly cultivable, with very shallow to Deep soil depth and slopes suitable for bunding and moisture conservation practices. The largest share of interventions is devoted to field bunding and strengthening of existing bunds with safe disposal of runoff water. In several locations, bunds are combined with farmponds, and in some cases lined farmponds are proposed to reduce seepage and improve durability. These measures are critical for stabilizing fields and conserving soil moisture within the cluster.

Conservation bench terraces are planned in unbunded fields to minimize erosion and retain water on sloping lands. The Broad Bed and Furrow system is introduced across multiple patches, both independently and in combination with bunds and farmponds, including lined structures where suitable. These practices are particularly suited to dryland farming within the watershed and will improve in-situ moisture conservation.

Vegetative measures are included to complement structural works. Afforestation with in-situ moisture conservation is proposed in areas with scrub and tree cover, while horticultural plantations are planned with supporting moisture conservation practices. In some locations, these plantations are combined with farmponds, including lined structures, to ensure long-term sustainability. Stream bank plantation is also recommended to stabilize waterways and reduce erosion within the watershed boundary.

Water harvesting and renovation works are emphasized throughout the cluster. Rooftop rainwater harvesting is suggested for built-up areas, while renovation and desilting of farmponds will restore their storage capacity. Larger waterbodies are also earmarked for renovation, ensuring improved water availability across the watershed. Structural measures such as cement and earthen nala bunds, along with repair and desilting of existing nallas, are included to regulate runoff and recharge groundwater. Road-related works are proposed to improve drainage and prevent erosion along transport routes. Localized in-situ moisture conservation measures are also included, ensuring that even small plots benefit from conservation practices.

The plan integrates bunding, terraces, farmponds, afforestation, horticulture, water harvesting, and nala bunds into a single watershed management framework. The following recommended plan is already shown in the table provided, which details each measure and its coverage for the village cluster watershed under Mangalwedha Taluka.

Table 4.39 Proposed soil and water conservation (SWC) plan for Mangalwedha watershed.

Sr. No.	Proposed SWC Plan
1	Field bund/Strengthening of existng bund with safe disposal of runoff water, Farmpond
2	Converation Bench Terrace in Unbunded Field/Field bund/Strengthening of existng bund with safe disposal of runoff water
3	Broad Bed and Furrow (BBF) system/Field bund/Strengthening of existng bund with safe disposal of runoff water
4	Field bund/Strengthening of existng bund with safe disposal of runoff water
5	Broad Bed and Furrow (BBF) system/Field bund/Strengthening of existng bund with safe disposal of runoff water, Farmpond
6	Field bund/Strengthening of existng bund with safe disposal of runoff water, Farmpond with Lining
7	Afforestation, In-situ Moisture Conservation Measures
8	Afforestation, In-situ Moisture Conservation Measures, Farmpond
9	Broad Bed and Furrow (BBF) system/Field bund/Strengthening of existng bund with safe disposal of runoff water, Farmpond with Lining
10	Road
11	Rooftop Rainwater Harvesting
12	Renovation/Desilting of Farmpond as per the site condition
13	Stream Bank Plantation
14	Renovation of Waterbody as per the site condition
15	Horticultural Plantation, In-situ Moisture Conservation Measures
16	Afforestation, In-situ Moisture Conservation Measures, Farmpond with Lining
17	Horticultural Plantation, In-situ Moisture Conservation Measures, Farmpond
18	Cement Nala Bund, Earthen Nala Bund / Repairing of Cement Nala Bund and Desilting of Nallas
19	In-situ Moisture Conservation Measures

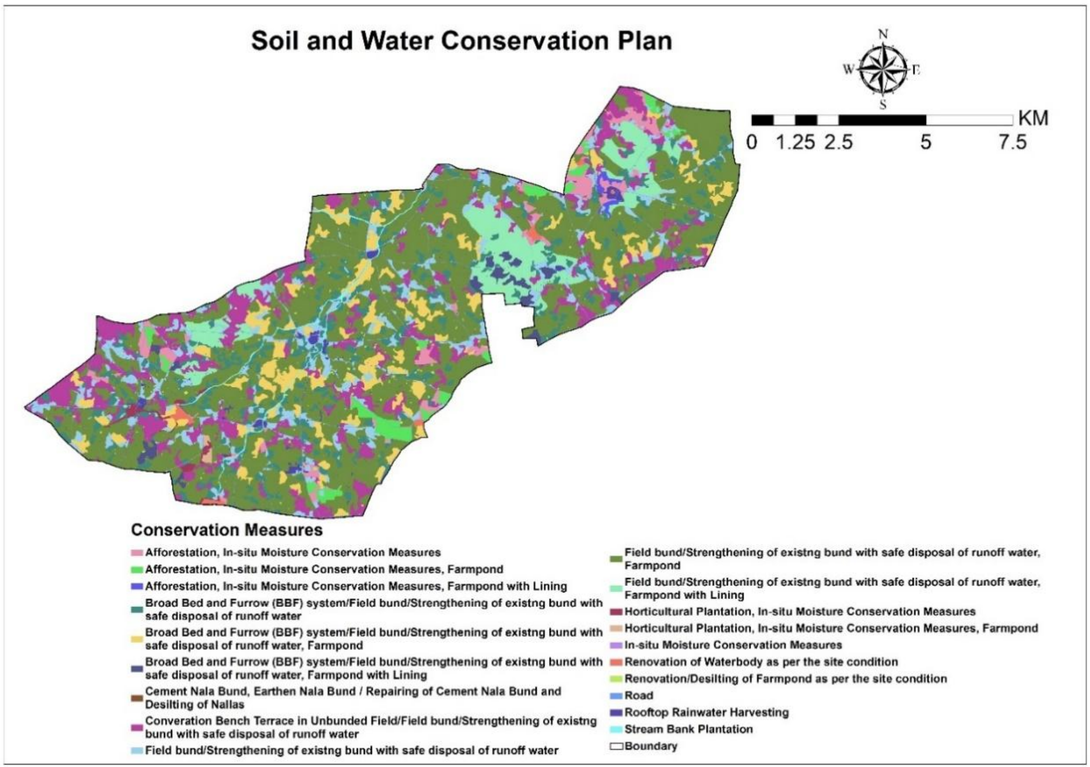


Fig. 4.35: Soil and Water Conservation measures proposed for Mangalwedha watershed.

CHAPTER 5

SUMMARY AND CONCLUSION

5.1 SUMMARY

- The watershed is located in the semi-arid, drought-prone Solapur District, a rain-shadow region, with a average annual rainfall of 653 mm. Agriculture is largely dependent on monsoon rainfall.
- Agriculture is the primary occupation, and the socio-economic structure is influenced by small and fragmented landholdings.
- Groundwater, mainly through borewells, constitutes the major source of irrigation. The groundwater resource is classified as semi critical.
- Key issues include low groundwater recharge due to hard basaltic strata, declining water availability in wells post-monsoon, silted surface structures, and resulting stress on agricultural water supply.
- Geology is dominated by Deccan Trap basalt. Major landforms are pediment, pediplain, and low plateau. Agriculture is the primary land.
- The terrain is flat to gently undulating (slopes 0 to 27%). Soils are basalt-derived.
- The research generated detailed maps and data for soil properties (pH, organic carbon, N, P, K, micronutrients), hydrological data (rainfall-runoff), and the Evaluation of Soil-Site Suitability for 12 crops, for development of watershed-based alternate land use and Soil and Water Conservation (SWC) plans.

5.2 CONCLUSION

The Land Resource Inventory (LRI) and comprehensive watershed assessment, conducted by ICAR-NBSS&LUP, provides an essential technical and scientific foundation for effective planning and implementation under the PMKSY-WDC 2.0 framework.

The systematic analysis of the terrain, soil resources, and hydrological conditions establishes a detailed understanding of the resource constraints in the Mangalwedha watershed. The assessment confirms that the agricultural system is highly vulnerable due to the semi-arid climate, non-perennial water sources and "semi critical" groundwater status.

The technical outputs, particularly the detailed maps of Soil-Site Suitability and Groundwater Potential Zones, offer a robust scientific basis for strategic planning. 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 benefit of the local farming community.

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 Mangalwedha Cluster

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 Mangalvedhe village cluster, Solapur, Maharashtra, comprises seven villages. Together, these villages constitute the study cluster having 2 sub-watersheds (Fig. 1).

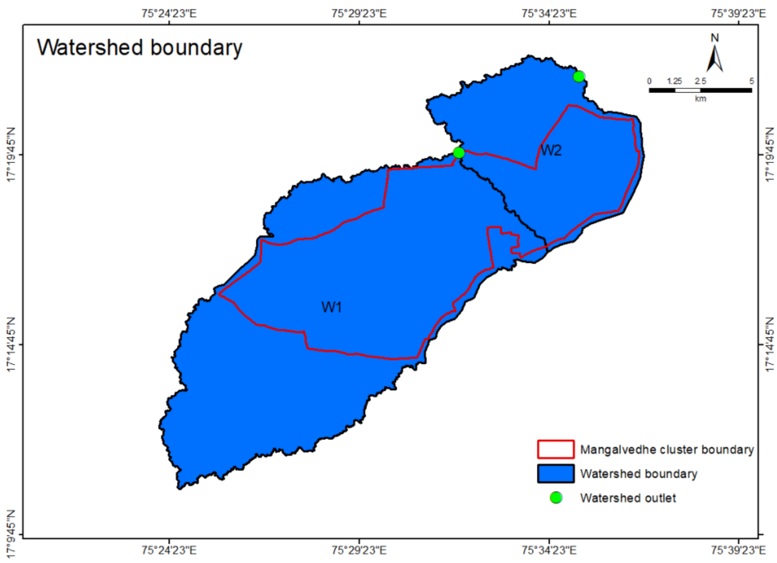


Fig. 1. Map of Mangalwedha Cluster depicted through sub-watershed

Table 1. Distribution of area under different sub-watershed, Mangalwedha

Sr. No.	Sub-watershed name	Sub-watershed order	Elevation (m)	Area (km^2)	Flow origination
1	W1	5^{th}	383-525	154.01	South-west to west
2	W2	5^{th}	448-599	55.86	South-west to west
			Total	**209.87**	

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.

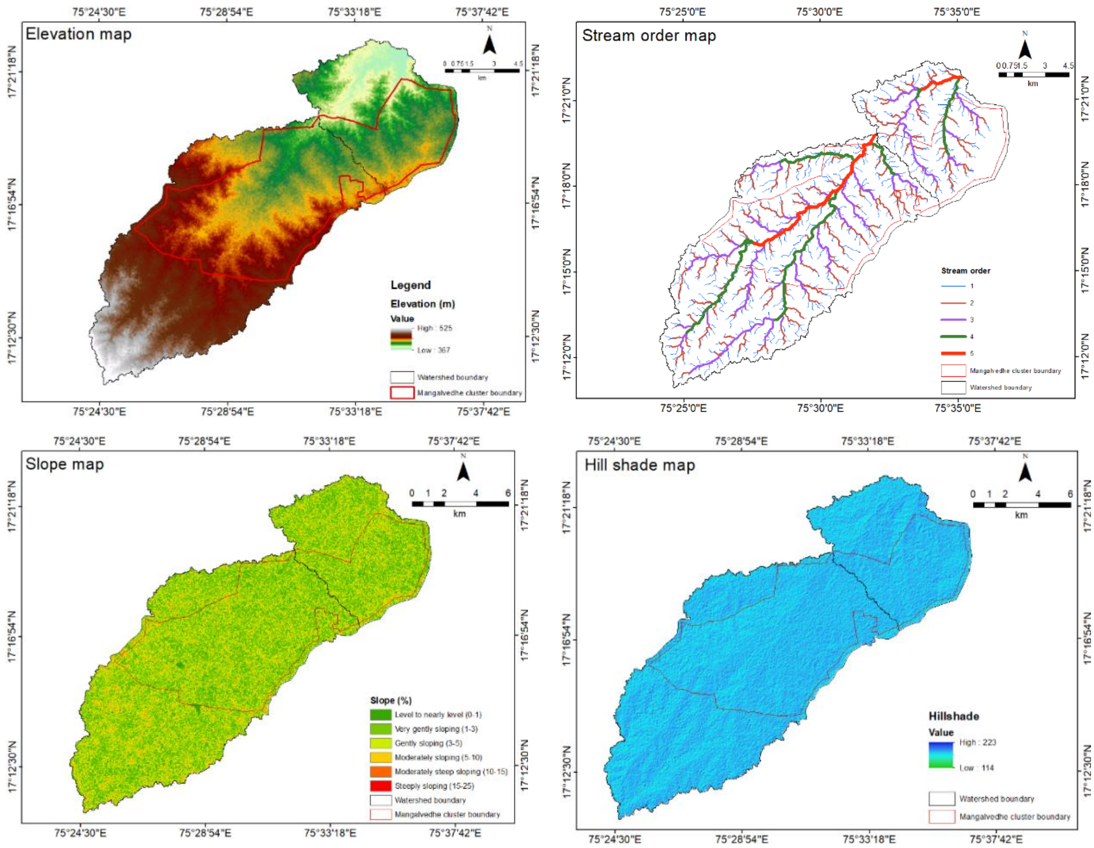


Fig. 2: Elevation, stream network, slope and hill shade map of sub-watershed

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. W1 has the highest number of streams (743) and total stream length (394.81 km), indicating a well-developed drainage network, while W2 has the lowest values (Table 2). The bifurcation ratio ranges from 4.9 (W1) to 3.7 (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 W2 (1.3), indicating greater sinuosity. Basin perimeter is also largest in W1 (86.15 km), confirming it as the most extensive sub-watershed, while W2 is the smallest.

Table 2. Linear morphometric parameters of sub-watersheds, Mangalwedha Cluster

Sr.no.	Morphometric parameter	Symbol	Unit	W1	W2
1	No. of streams	Nu	No	743	234
2	Stream length	Lu	km	394.81	124.3
3	Bi-furcation ratio	Rb	-	4.9	3.7
4	Mean channel length	Cl	km	25.46	9.12
5	Valley Length	Vl	km	24.0	8.65
6	Channel Index	Ci	-	1.1	1.3
7	Minimum areal distance	Adm	km	23.56	7.1
8	Valley Index	Vi	-	1.02	1.22
9	Basin perimeter	P	km	86.15	43.44

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 W1 (154.01 km²) and lowest in W2 (55.86 km²). Mean basin width is also greater in W1 (5.8 km). Form factor (Ff) and elongation ratio (Re) are highest in W1 (0.22 and 0.52), suggesting a comparatively more circular basin, whereas W2 show lower values, indicating elongated shapes. Circularity ratio (Rc) is maximum in W1 (0.26), and compactness coefficient (Cc) is highest in W1 (1.97), reflecting greater basin irregularity. Standard sinuosity index (Ssi) ranges from 1.06 (W1) to 1.05 (W2), indicating relatively higher channel sinuosity in W1.

Drainage parameters show that stream frequency (Fs) is highest in W1 (4.82 per km²) and lowest in W2 (4.19 per km²). Drainage density (Dd) is W1 (2.6 km/km²) but lower in W2 (2.2 km/km²). Drainage intensity (Di) follows a similar trend, with the highest value in W1 (1.8). Length of overland flow (Lg) is nearly same in W1 and W2 as (0.20 km), indicating shorter runoff travel distance in watershed.

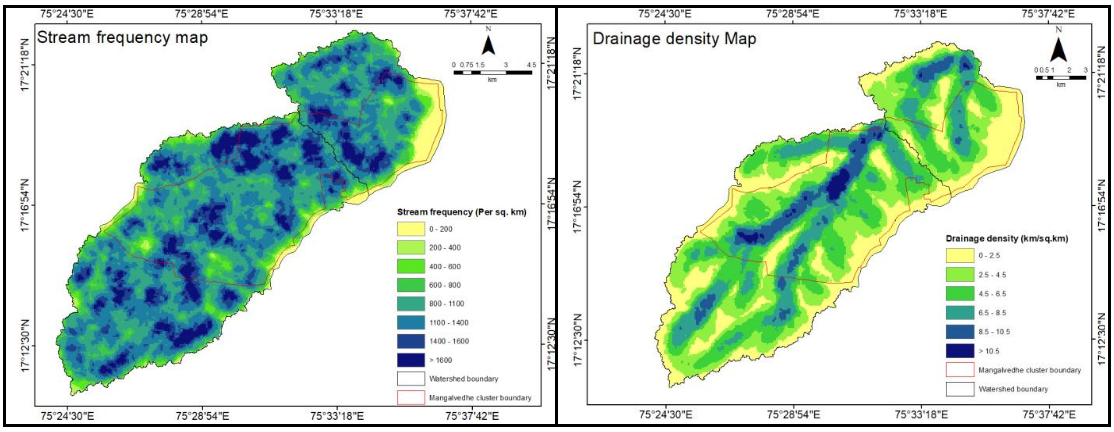


Fig. 3: Steam frequency and drainage density map of sub-watershed

Table 3. Areal morphometric parameters of sub-watersheds, Mangalwedha Cluster

Sr. No.	Parameter	Symbol	Method/Formula	Unit	W1	W2
1.	Mean basin width	Wb	Wb=A/Lb	km	5.8	5.37
2.	Basin area	A	GIS Analysis	km^2	154.01	55.86
3.	Relative perimeter	Pr	Pr= A/P	km	1.79	1.29
4.	Length area relation	Lar	Lar = 1.4*A0.6	km^2	28.75	15.65
5.	Lemniscate's	k	K = Lb2/A	-	4.6	1.9
6.	Form factor	Ff	Ff = A/Lb2	-	0.22	0.52
7.	Elongation ratio	Re	Re = 2/Lb*(A/π)0.5	-	0.52	0.81
8.	Circularity ratio	Rc	Rc = 12.57*(A/P2)	-	0.26	0.37
9.	Compactness coefficient	Cc	Cc = 0.2841*P/A0.5	-	1.97	1.65
10.	Standard sinuosity index	Ssi	Ssi = Ci/Vi	-	1.06	1.05
11.	Stream frequency	Fs	Fs = Nu/A	Per km^2	4.82	4.19
12.	Drainage Density	Dd	Dd = Lu/A	km/km^2	2.6	2.2
13.	Drainage Intensity	Di	Di = Fs/Dd	-	1.8	1.52
14.	Length of Overland Flow	Lg	Lg = A/2*Lu	km	0.20	0.22

Relief Aspects

The maximum basin height (Z) is highest in W2 (599 m) and lowest in W1 (525 m), while total basin relief (H) is also maximum in W2 (151 m) and minimum in W2 (142 m) (Table 4**).** Relief ratio (Rhl) is highest in W2 (14.5), indicating steeper terrain conditions, whereas W1 shows the lowest value (5.3).

Relative relief ratio (Rhp) is greatest in W2 (347.6), followed by W1 suggesting higher relief intensity in W2. The ruggedness number (Rn) is maximum in W2 (0.28), reflecting more dissected and erosion-prone terrain, while W1 has the lowest value (0.27). Similarly, the Melton ruggedness number (MRn) is highest in W2 (20.2), indicating comparatively higher susceptibility to runoff and erosion processes.

Table 4. Relief morphometric parameters of sub-watersheds, Mangalwedha Cluster

Sr. no.	Parameters	Symbol	Methods/Formula	W1	W2
1.	Height of at basin mouth	z	DEM	383	448
2.	Maximum height of the basin	Z	DEM	525	599
3.	Total basin relief	H	H = Z - z	142	151
4.	Relief ratio	Rhl	Rhl = H / Lb	5.3	14.5
5.	Relative relief ratio	Rhp	Rhp = H * 100 / P	164.8	347.6
6.	Ruggedness number	Rn	Rn = Dd*(H/1000)	0.27	0.28
7.	Melton Ruggedness number	MRn	MRn = H / A^0.5	11.4	20.2


REDMI NOTE 8 PRO
AI QUAD CAMERA


REDMI NOTE 8 PRO
AI QUAD CAMERA


MW/WD/P40
REDMI NOTE 8 PRO
AI QUAD CAMERA


Latitude: 17.259494
Longitude: 75.448469
Elevation: 517.07±5 m
Accuracy: 3.8 m
Time: 26-02-2025 11:10
Note: तुकाराम आप्पाराया जमखंडी मारोळी
Powered by NoteCam


Latitude: 17.277609
Longitude: 75.521443
Elevation: 560.67±64.00 m
Accuracy: 28.90 m
Time: 02-26-2025 11:58:03
Note: MAHANANDA MAHADEV TIKKE salgar bk


Latitude: 17.275319
Longitude: 75.524256
Elevation: 497.15±4.00 m
Accuracy: 4.23 m
Time: 02-26-2025 12:07:02
Note: Subash pandurang TIKKE salgar bk


Latitude: 17.276202
Longitude: 75.522917
Elevation: 498.24±4.00 m
Accuracy: 14.00 m
Time: 02-26-2025 12:03:34
Note: Mahesh bhausaheb TIKKE salgar bk


Latitude: 17.274485
Longitude: 75.470994
Altitude: 440.2±8 m
Accuracy: 4.4 m
Time: 26-02-2025 09:36
Note: भिवदास धोंडिबा होनमुखे मारोळी
Powered by NoteCam


Latitude: 17.258165
Longitude: 75.465771
Altitude: 444.88±4 m
Accuracy: 3.8 m
Time: 26-02-2025 10:42
Note: मल्हारी भागाप्पा करे मारोळी
Powered by NoteCam