FIELD GUIDE FOR LAND RESOURCE INVENTORY REWARD

(Rejuvenating Watershed for Agricultural Resilience through Innovative Development)

PROJECT, KARNATAKA

ICAR - NATIONAL BUREAU OF SOIL SURVEY AND LAND USE PLANNING

REGIONAL CENTRE, HEBBAL, BENGALURU – 560 024

ICAR - NBSS & LUP

WATERSHED DEVELOPMENT DEPARTMENT

GOVERNMENT OF KARNATAKA, BENGALURU – 560 024

ACKNOWLEDGEMENTS

The Field Guide reflects the wisdom of hundreds and thousands of field staff, technical officers and scientists, who have toiled in the past at national and state levels and continue to do so at present in characterizing and mapping soil and other land resources of the country. But for this and their readiness to share their expertise which has helped immensely in finalizing this Field Guide, which is gratefully acknowledged. It is difficult to place on record the contributions received from many individuals, institutions and departments in the preparation of the Guide, but the constant help and assistance rendered by the staff members from NBSS&LUP, LRI Partner Institutions and Watershed Development Department in various stages of preparation of the Guide are gratefully acknowledged. The support and guidance received from the World Bank team in the preparation of this Manual is gratefully acknowledged.

Citation: Rajendra Hegde, A. Natarajan, R. S. Reddy, K.V. Niranjana, R. Srinivasan, S. Dharumarajan, S. Srinivas, B.A. Dhanorkar R. Vasundhara and B.S. Dwivedi (2021) "Field Guide for Land Resource Inventory under REWARD Project, Karnataka" NBSS Publ. No. ICAR – NBSS&LUP, Bengaluru, 160p.

For copies of the Field Guide, Contact

ICAR-National Bureau of Soil Survey & Land Use Planning

Regional Centre, Hebbal, Bengaluru-560024

Phone: 080-23412242, 23410993. Fax : 080-23510350

E-Mail:nbssrcb@gmail.com

Field Guide for Land Resource Inventory Rejuvenating Watersheds for Agricultural Resilience through Innovative Development (REWARD –SUJALA-IV) Karnataka

Rajendra Hegde, A. Natarajan, R.S. Reddy, K.V. Niranjana, R. Srinivasan, S. Dharumarajan, S. Srinivas, B.A. Dhanorkar R. Vasundhara and B.S. Dwivedi

ICAR – NATIONAL BUREAU OF SOIL SURVEY AND LAND USE PLANNING
REGIONAL CENTRE, HEBBAL, BENGALURU

ICAR - NBSS & LUP

WATERSHED DEVELOPMENT DEPARTMENT,
GOVT. OF KARNATAKA, BENGALURU

2022

FOREWORD

The World Bank funded Rejuvenating Watersheds for Agricultural Resilience through Innovative Development Sujala IV project is under implementation in Karnataka from 2021-26 onwards to provide site specific farm level soil, water, land use, weather, socio-economic and other information to enable planning, execution and monitoring of various land based schemes and programmes (like PMKSY, Krishi Bhagya etc) in the state. The project is executed by a consortium of 13 partners in the state with varied background and expertise under the guidance of National Bureau of Soil Survey and Land use Planning, Bengaluru.

A Field Guide for executing Land Resource Inventory in the state is felt necessary not only to guide the partners in their data collection but also to maintain standards and uniformity in the data base generation among the project partners. This "Field Guide for Land Resource Inventory" provides step by step sequence of activities to be followed in base map preparation, interpretation of imagery, field investigations, soil-site characterization, sample collection, finalization of soil and other maps, and post field activities pertaining to the implementation of LRI activities.

The Field Guide is prepared by compiling the state of knowledge available from various sources, and based mainly on the earlier version of the Field Guide brought out by NBSS&LUP (2009) and also the latest version of the Field Book for describing and sampling soils from NRCS (2012) and Field guide for Land Resources Inventory Sujal III Project Karnataka (2016). It is hoped that this Field Guide will be an useful tool, particularly to the hundreds of field staffs involved in the execution of Sujala IV project in the state and as a reference guide to students, scientists, line departments and to all those who are interested in studying, understanding and managing the land resources, particularly the soil resources of the state.

CONTENTS

Chapter

INTRODUCTION

Karnataka has the second largest area under rain-fed agriculture in the country. Recurrence and severity of drought due to spatial and temporal variations in rainfall causes colossal loss to crop and lives of distressed farmers every year. The situation is aggravated by the continuing land degradation, competing land uses and unsustainable farming practices.

Out of the total geographical area of 19.17 m ha, the net sown area is about 54 per cent and out of this, more than 70 per cent is under rainfed cultivation. The vast stretch of rainfed area (about 10 m ha) is affected by severe soil loss due to erosion, salinity, low and uncertain productivity, low rainwater retention and use efficiency, poor recharge, which is compounded by rapid depletion of groundwater, low level of technological penetration, acute fodder shortage, poor livestock productivity and poor marketing facilities and livelihood opportunities.

Among the various forms of land degradation, soil erosion is very widespread in the rainfed areas, affecting the productivity of most of the crops and sustainability of the cropping pattern (Fig 1.1). The impact of erosion is more pronounced in black soils due to their finer texture, higher rate of dispersion and slow permeability. The uncontrolled sheet, rill and gully erosion has resulted in the occurrence of vast tracts of barren lands with exposed lime nodules from the substratum and in places only with patches of thin layer of surface soil. Similar situation is observed in the red and lateritic soils, where the finer soil particles have been eroded by the sheet and rill erosion, leaving only the coarser materials like gravel and stones at the surface. Continuation of this process leads to the development of wastelands, which is a common feature in the undulating or even gently sloping black soil areas of the state (Fig 1.2).

The uncontrolled erosion and severe soil loss from the uplands and its subsequent deposition in the lower slopes, lowland areas and valleys have resulted in the widespread development of inland salinity, an offsite impact of erosion witnessed in the arid and semi-arid rainfed areas of the state. The deposition of finer clay materials in the

lowlands reduces the permeability of the soil, which results in the rise of water table and development of waterlogged condition and subsequently the development of salinity in the rainfed tracts due to the prevailing arid situation, particularly during the summer months. Due to this, the low lying areas particularly in the black soil regions have slowly turned into unproductive areas and lying barren in almost all the districts (Fig 1.3).

Fig.1.1 Severity of sheet, rill and gully erosion in black soils (Kalmali village, Raichur district)

Fig. 1.2 Wastelands due to sheet erosion in Bilakunti village, Belgaum district

Fig.1.3 Fertile lands turned to barren due to salinity in Kalkeri village, Koppal district

Apart from large scale degradation witnessed in the rainfed areas, the facing severe salinity and alkalinity problems. Further, there is a widespread deficiency of both macro and micro nutrients observed both in the rainfed as well as in the irrigated areas of the state. The situation is compounded by the lack of site-specific cropping pattern and situation specific package of practices which has significantly affected the factor productivity of the crops. The situation is further exacerbated by the mismatch between the ground reality and planning due to lack of reliable datasets at the grassroots level.

The challenges posed by the continuing degradation and declining factor productivity of the resource base are very site specific in nature and can be tackled only by addressing the concerned issues at the farm or watershed level by evolving a rational, site-specific and viable land use options suitable for each and every land holding at the village level. To achieve this, the first and foremost thing needed is a detailed site-specific database on all land resources at the farm/ watershed/village level. The lack of such a database was mainly responsible for the failure of most of the conservation structures built over a period of time in the state, due to the mismatch between the conservation needs of the area and the programmes planned and implemented by various line departments.

The required data for watershed or farm or micro level planning can be obtained by carrying out detailed characterization and mapping of all the existing land resources like soils, weather and climate, rock types, surface and groundwater, vegetation, crops, land use, socio-economic conditions, infrastructure, marketing facilities etc. At present, the information available in the state, particularly on soil and site characteristics and land use, is of general nature (1:250,000 soil maps for the entire state and a few district maps at 1: 50,000 scale) and suitable for planning at taluk or district level only. For farm or watershed level planning, detailed site- specific cadastral level information is needed.

Appreciating the importance of site-specific database, advisories, digital tools, decision support systems etc. in planning and implementing appropriate interventions at farm/watershed level in the state, Sujala 3 project was planned and implemented in the state from 2013 to 2019 with the support of the World Bank which is extended to cover the remaining rainfed areas of the state under the REWARD program from 2022. The Field Guide for REWARD is brought out to facilitate data collection by project partners engaged in the execution of LRI and hydrological activities in the project districts.

Chapter 2

REWARD (SUJALA – IV) Project

Watershed Approach for Sustainable Development

To address the challenges of land degradation, recurring drought, increasing food production for ensuring equity, gender participation and optimum utilization of natural resources to achieve optimum and sustainable crop yields, an integrated, holistic approach of watershed development covering both land based and non-land based interventions on scientific approach is a pre-requisite. Treatment of watersheds from ridge to valley on a saturation approach with community participation helps not only the sustainability of the watershed interventions but also the community ownership for achieving the desired results.

Karnataka is the first State in India to create watershed development department during the year 2000. Since then the department has implemented many watershed projects, including the World Bank assisted projects and emerged as the best model in the country as far as watershed development is concerned.

World Bank Support for Watershed Development in Karnataka

Karnataka Watershed Development Project-I, popularly known as Sujala I, was an innovative watershed development project with the World Bank assistance was executed in 6 rainfed districts of the State from the year 2002 to 2009. The project was first of its kind in the history of India's watershed Development which was acknowledged as success story; where the natural resources, the existing institutions and people's participation in decision making on the nature of development they perceive and their involvement in the development strategies have been integrated and harmonized. Sujala watershed project ushered a new era of hope and confidence into the hearts of rural habitats of 1350 villages covering about 4 lakh households spread over 5.2 lakh ha. Area; by evolving and implementing development plans with a high level of community participation, utilizing technology inputs such as Remote Sensing, GIS etc. to help the local people to build a sustainable future in their own hands. These innovative practices had yielded very positive impacts and World Bank acknowledges Sujala project as "Model of Excellence" and "Global Best practice". The project had received five national awards and three International awards, and this model is being replicated at State, National and International levels.

Significant results were I, including: Cropping intensity increased from 129 to 144%, Crop yield increase by 24%, shift from agriculture to agro-horticulture / agro-forestry by 22%, average increase in the ground water level by 66 ft and yield(discharge) by 21%. The number of employment generated was 16,000 to 21,000 man days per micro watershed reducing the out migration by 70%. There was an increase in the household income by 30% and milk yield by 22% at the end of the project. About 10.43 million tonne of biomass build-up was estimated after the intervention with sequestration of 5.21 million tonne of carbon. Thus, the biophysical and social interventions in Sujala project had resulted in positive changes in the treated watersheds and yielded significant benefits with respect to all the dimensions of the sustainable development viz. economic, social, institutional & environmental aspects.

KWDP-II project (known locally as Sujala-III) is being implemented in 12 districts of the State, with a consortium of 14 scientific and other institutions. Project is implemented from 2013-2019 with a financial outlay of USD 40 million (Rs.412.59 Cr.). In this project, through the scientific partners micro watershed-wise land resource inventory up to parcel achieved for sujala level in 2534 rainfed micro watersheds over 1.4 million ha. Area has been carried out. Out of these, based on LRI recommendations 11 pilot watersheds development projects have been taken up in 89 micro watersheds under saturation mode. The project has emerged as the best watershed model in the field of application of Science and technology-based inputs in watershed development and crop production for doubling and sustaining farm income. Many States across the country and even people outside the country have visited the project for replicating the Sujala-III model.

Site specific scientific advisories to farmers through Land Resource Inventory, under KWDP-II (Sujala-III) have helped the farming community to experience the utility of technological application in agriculture for effective farm management and soil & water conservation. The scientific information generated under the project is not only helping the farmers in their effort to increase their income but also helping the other developmental programs such as MGNREGA and PM Kisan Samman scheme of Government of India (GoI) for better utilisation of income support to use only specified inputs in required quantity for reducing cost of cultivation and thereby to increase income and protect soil health, among the marginalised and resource poor farming community.

Sujala III has already generated significant benefits. The project is the first of its kind in the country, where 0.9 million (9 lakh) farmers are getting farm specific scientific recommendations through Land resource inventory for crop and resources management. Sujala-III hydrological data is contributing for bringing out a State Water Policy. Sujala-III has created infrastructure in all its State Agriculture and Horticulture Universities for carrying out soil and water analysis and digitize the same information using GIS. The rich data generated by these universities is not only used by Watershed Development Department and other line departments, but also used by the agriculture students perusing masters and doctorates. So far about 39 MSc and 12 PhD students have effectively used the scientific information generated under Sujala-III for research and preparing their thesis. The inputs of Sujala-III project have also contributed for preparing the Karnataka State FPO policy for organising farmers into commercial entities; which will enable them to collectivise agri. input, machineries and output business of agri. produce and value chain development. Sujala-III project has been so far conferred with one National and two International awards for application of science and technology in the field of Agriculture and its utility to the farming community in enhancing the productive potential of watersheds.

Need for Further Support

Karnataka State has about 5.2 million ha (52.31 lakh ha) rainfed watersheds still to be scientifically treated on watershed approach. The Sujala III project has created improved infrastructure, skilled manpower and other knowledge. In order to disseminate the scientific information generated and to make efficient use of the created infrastructure and to scale up the Sujala-III interventions in the State, Watershed Development Department, Government of Karnataka proposes to participate as light house partner, in the multi-state watershed project called REWARD (Rejuvenating Watersheds for Agriculture Resilience through Innovative Development**)** being formulated by the World Bank.

This project with special emphasis on 'Agriculture Resilience 'through Innovative Development' for providing end to end solutions to farmers right from production, post harvest management and processing to marketing through formation of Farmer Producer Organisations (FPOs). With this background, the present proposal is very much essential to extend, demonstrate and up-scale the LRI technology for helping generation of parcel wise scientific input to the rainfed farmers. Hence the Government of Karnataka wishes to make the following proposal for participating in the multi-state Watershed project from the World Bank.

Proposed Financing

The State of Karnataka has 12.9 million ha. (129 lakh ha.) geographical area, with 5.23 million ha. (52.31 lakh ha.) of rainfed area still to be systematically treated. Under Sujala-III project, Land Resource Inventory (LRI) has been done in 1.4 million ha. (14 lakh ha.) benefiting about 9 lakh farm families. A remaining 3.83 million ha. (38.30 lakh ha.) area covering about 2.55 million (25.53 lakh) farm families, is still requiring LRI treatment and development of integrated watershed development plans. The Government of Karnataka is keen to optimally utilise the knowledge gained and infrastructure created under KWDP-II (Sujala-III project) for up-scaling LRI to other parts of the State and to roll-out LRI technology to other States as a light house partner.

The Objectives

- To scale up and disseminate the LRI &Hydrology based scientific information to build climate resiliency in Agriculture.
- To demonstrate field research driven planning and implementation to improve productivity and income through demonstrations and dissemination of innovative watershed development practices.
- Institution and capacity building for end to end solution to farmers to organise and collectivise their produce to cope up with climate variability and market fluctuations.

The partners participating in the implementation of REWARD project are

1. ICAR-National Bureau of Soil Survey and Land Use Planning (ICAR-NBSS&LUP), Bengaluru (Lead Institute for the Project)
2. Indian Institute of Science (IISc), Bengaluru
3. Universitity of Agricultural Sciences (UAS), Bengaluru
4. University of Agricultural Sciences (UAS), Dharwad
5. University of Agricultural Sciences (UAS), Raichur
6. University of Horticultural Sciences (UHS), Bagalkot
7. University of Agriculture and Horticultural Sciences (UAHS), Shivamogga
8. Karnataka Veterinary, Animal and Fishery Sciences University (KVAFSU), Bidar
9. Karnataka State Remote Sensing Applications Centre (KSRSAC), Bengaluru
10. Karnataka State Natural Disaster Management Centre (KSNDMC), Bengaluru

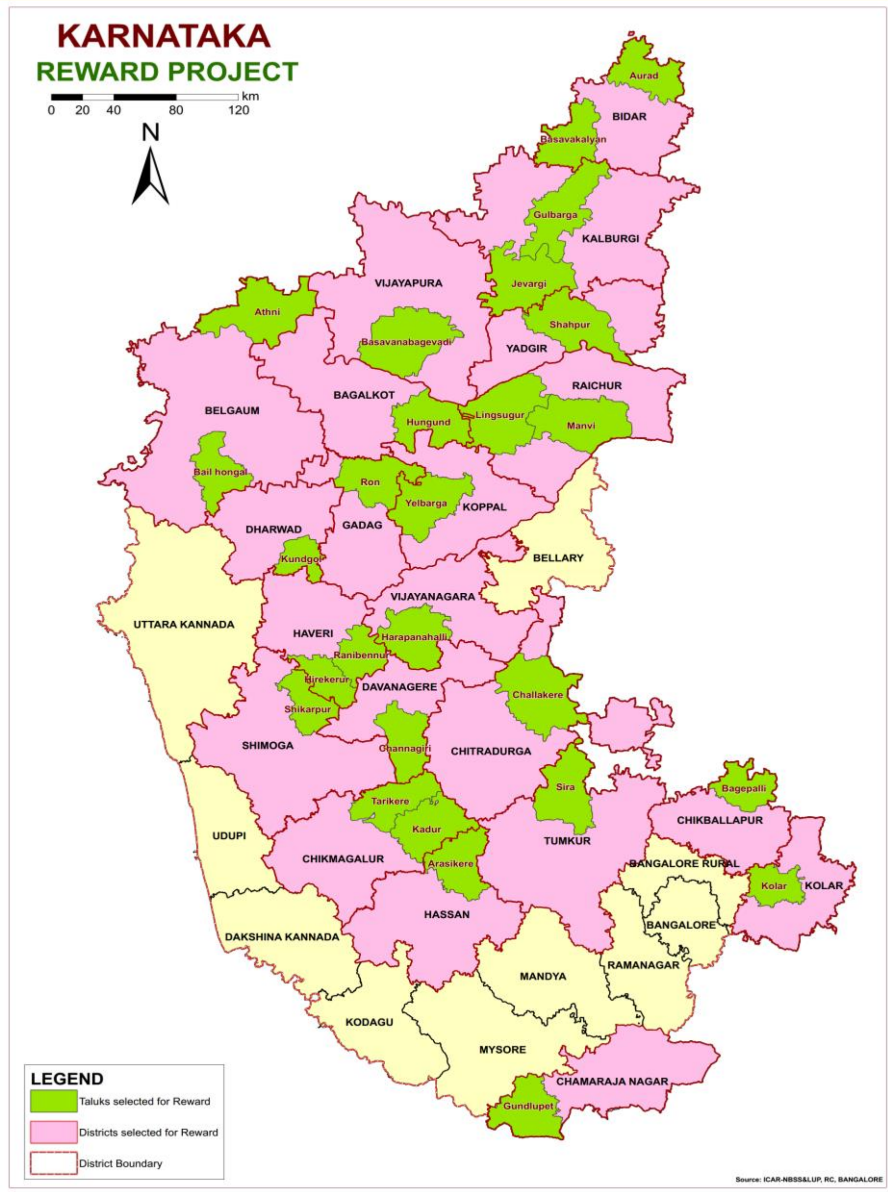


Fig. 2.1 Location of project districts and taluks to be covered initially under REWARD Project

2.1 Land Resource Inventorisation

Detailed database pertaining to the nature of the land resources, their constraints, inherent potentials and suitability for various land-based rural enterprises, crops and other uses is a prerequisite for preparing location-specific action plans, which are in tune with the inherent capability of the resources. Land Resource Inventory (LRI), executed as a part of the Component 1, provides the required information for farm/watershed level planning. For site-specific needs and for developmental works, we need detailed farm level database at 1: 7920 scale, which is not available at present and REWARD aims to bridge this vital gap in the preparation of farm level plans in the state.

The cadastral level resource map is generated by studying all the site characteristics like slope, erosion, drainage, salinity, rock fragments etc. and soil characteristics like depth, texture, colour, structure, consistence, gravel, porosity, soil reaction etc. followed by grouping of similar areas based on soil-site characteristics relatively into homogeneous (management) units and showing their area extent and geographic distribution on the cadastral map. This is accomplished effectively by using georeferenced digital cadastral base in conjunction with high resolution remote sensing data products like Worldview/Quickbird imagery available for the state.

Apart from this, the required hydrological, climatic and socio-economic datasets are collected from the watershed/village areas by the partners by adopting standard protocols. From the LRI database generated, the required thematic outputs can be generated through the use of GIS and based on the above information, viable and sustainable land use options and conservation plans suitable for each and every land holding can be identified (Fig 2.2).

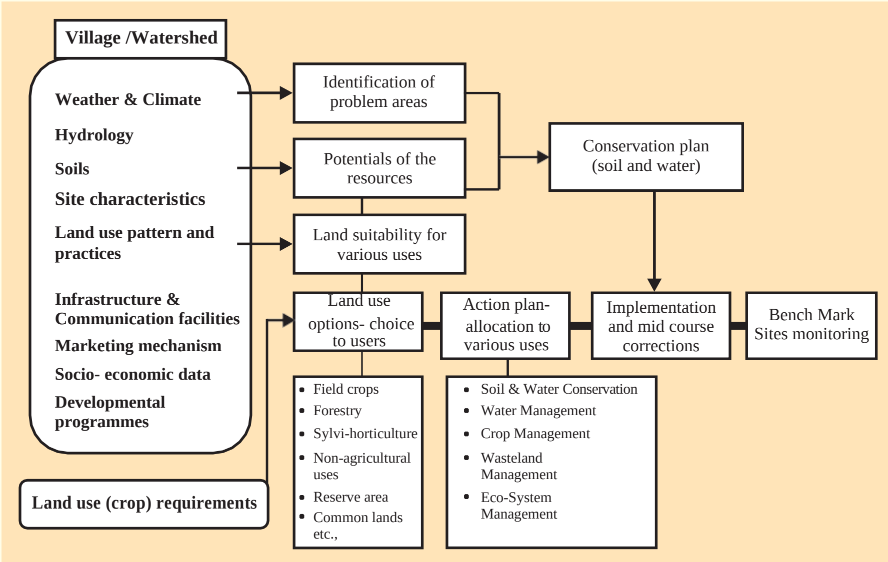


Fig. 2.2 From Land Resource Inventory to Land Use Planning

2.2 Establishment of Digital Library

To be effective, all the spatial and non-spatial database generated and also compiled from different sources needs to be converted into a digital form and made available to the various line departments and developmental agencies on a real time basis through an appropriate delivery mechanism like Portal. To achieve this, under the REWARD project, all spatial and non-spatial datasets generated at watershed/ village level are first converted into digital form, then integrated in a GIS framework and later housed in the Digital Library to be established in each of the five Agricultural/Horticultural Universities to cover the entire state.

This data handling system, its storage, retrieval, analysis and display capability and easy accessibility will be a very valuable tool to the planners, administrators, researchers, extension workers for making land use decisions and for providing proactive advice to the farmers on real time basis.

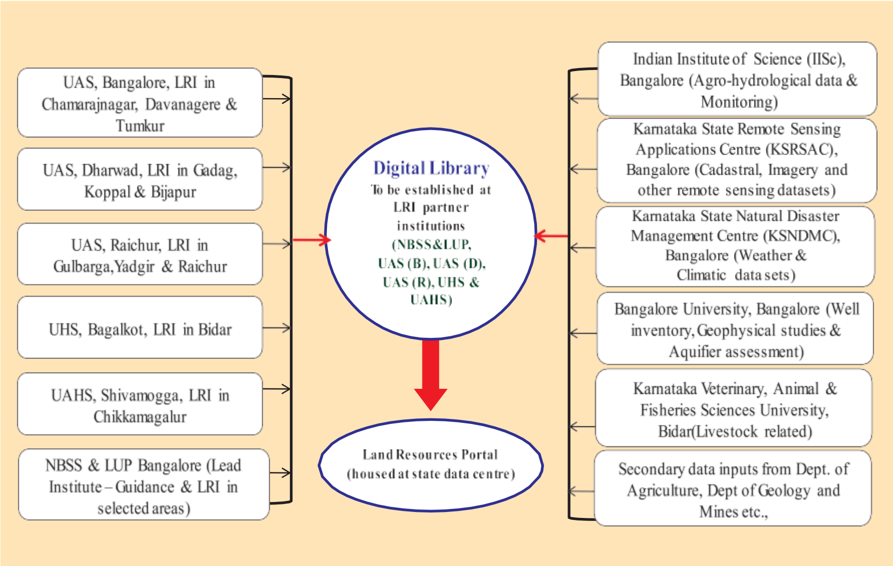


Fig. 2.3 Digital Library showing the flow of datasets from different partners

2.3 Information flow through the Land Resources Portal

Portal helps in the dissemination of information to the line departments, administrators, researchers, NGO's and will also provide the required up-link facilities to the farm families and required day to day information needed to manage their resources at farm level (Fig 2.4). This will be a one stop Portal, which is expected to provide not only the required information to all the stakeholders, but also to enable the users to benefit from the interactive and dynamic mode of operation. Apart from this, all kinds of queries during or before the execution of any land based project can be put on the web-based Decision Support System and needed solutions can be obtained by the developmental agencies as well as farmers in the state on a real time basis.

The establishment of the state- of -the- art Digital Library and their link up with all user agencies at different levels through the commissioning of the Portal, supported by a dynamic DSS is expected to change the entire process of planning, which in most of the cases at present follow a top down approach rather than of grassroots and bring in a paradigm shift by institutionalising/facilitating a two way planning process in addressing the site-specific problems faced by farmers at the grassroots level in the state.

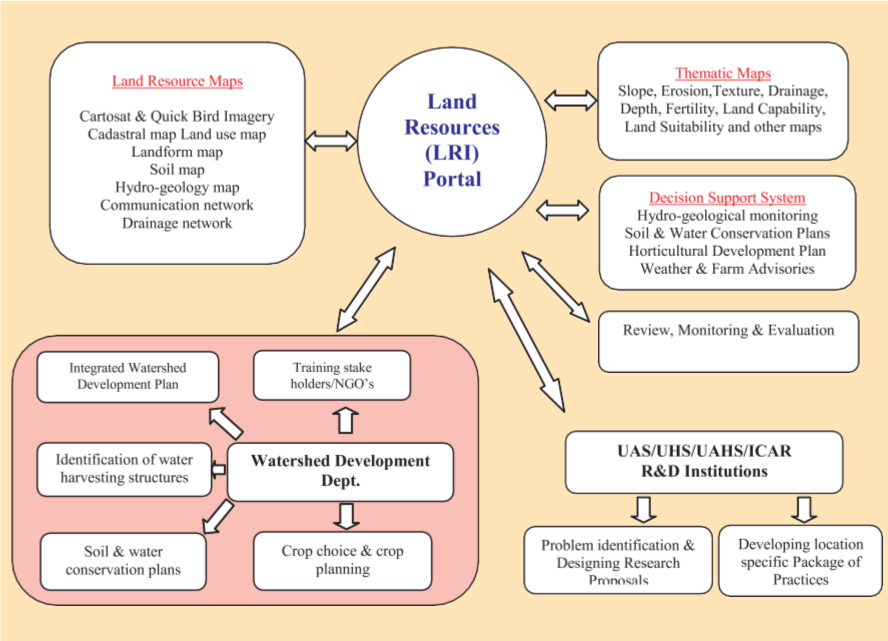


Fig.2.4 Schematic representation of the Land Resources Portal established under SUJALA -III Project and its link to users

Land Resource Inventory (LRI) for Watershed Management

Planning for watershed development or any other programme/schemes pertaining to land resource management requires site-specific datasets and information on all land resources, which encompasses soil, site, land use, weather, climate, surface and ground water, hydrogeology, demographic details, socio-economic particulars, marketing, infrastructural facilities, and details of various schemes etc. Apart from the above remote sensing data, cadastral and topographical maps, geological maps, land use maps, ground water maps and thematic maps are needed to address the demands of various user agencies at different levels. The Land Resource Inventory (LRI) provides the required databases, base maps and thematic outputs needed for planning, implementation and monitoring of watershed and other department schemes in the state (WDD 2016).

The various spatial and non-spatial datasets that are generated through LRI at the farm/watershed/village level and other secondary information compiled from different sources are

1. Physiography/ Geomorphology of the area (landform, elevation, contour)
2. Geology of the area (rock types, composition, extent, lineaments, depth to weathered zone etc)
3. Weather and Climate (precipitation, temperature, relative humidity, evapotranspiration, wind speed and direction, solar radiation)
4. Land use (major crops cultivated and their area, cropping pattern, management practices)
5. Site characteristics (slope, erosion, drainage, salinity and alkalinity, stoniness, rock outcrops etc)
6. Soil characteristics (depth, texture, colour, rock fragments, structure, substratum, pH, CEC, base saturation, nutrient status etc)
7. Hydrology (surface runoff, evapotranspiration, infiltration, soil moisture, base flow, sediment load, groundwater level, depth, and yield, etc)
8. Groundwater status and quality
9. Irrigation (source, type, area under different crops, extent of utilization/deficit etc)
10. Demographic details
11. Livestock details

12 Socio-economic details

12. Marketing and infrastructural facilities
14. Programs and schemes in operation in the area

3.1 Physiography/Geomorphology

Physiography reflects the factors and processes responsible for the evolution of different landforms/landscapes in the state. Accordingly, the state is divided into three major physiographic regions, namely, the Deccan Plateau, Hill Ranges and Coastal Plain (NATMO and SRM-Kar). They are further divided into four regions based on their geographical location namely, South Deccan Plateau, Western Ghats, Eastern Ghats, and West Coast Plains (Fig.3.1). The South Deccan Plateau locally known as Karnataka Plateau is a peneplain in various stages of development and degradation. It is divided into *Malnad* (Hilly area) and *Maidan* (Plains). *Malnad* is an area of rolling to undulating uplands with many valleys and is a transitional zone between Western Ghats and *Maidan*. The highest part is in the southern part and the lowest in the valleys of Tungabhadra and Hagari rivers.

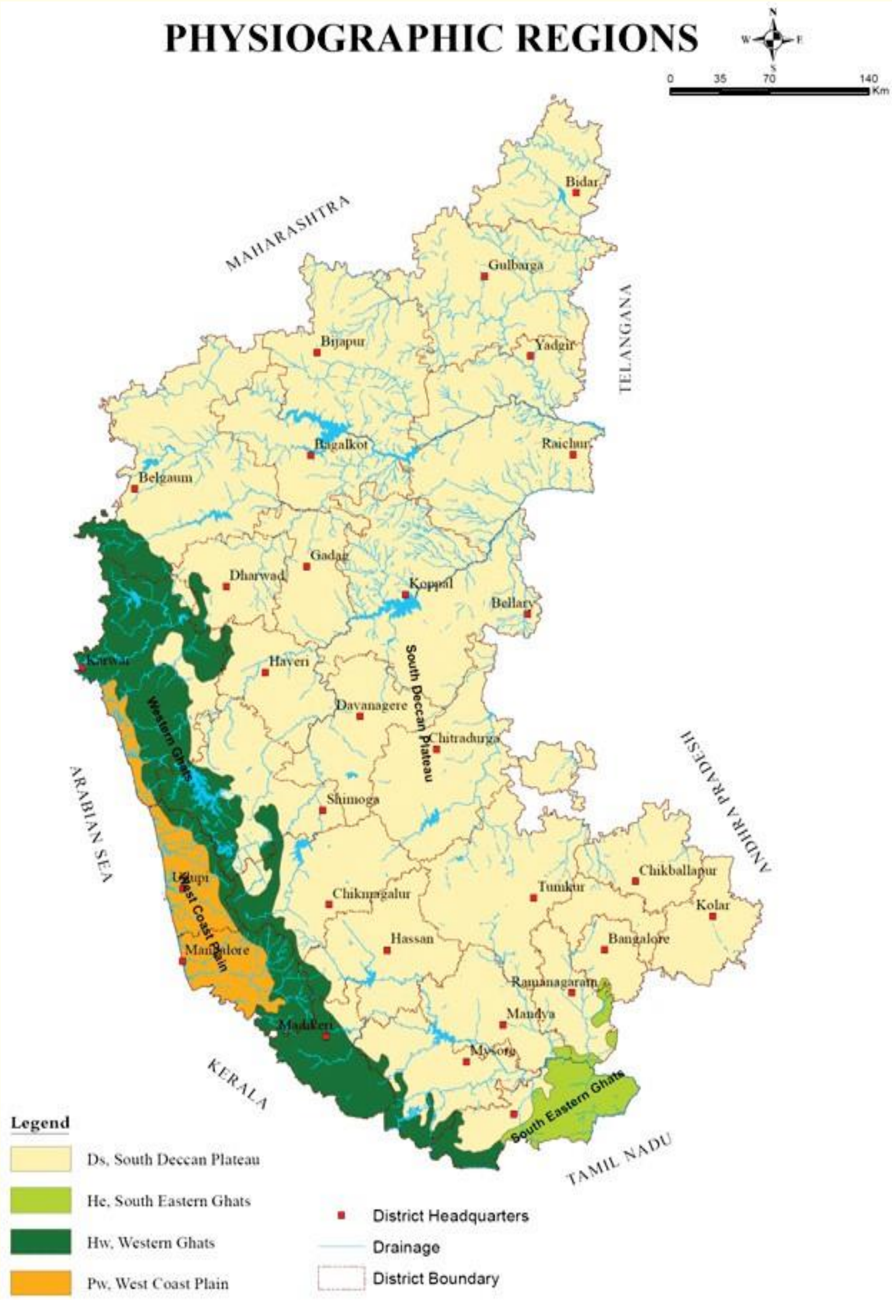


Fig 3.1 Major Physiographic Regions of Karnataka

The northern part of the plateau is drained by the Krishna River and its tributaries Bhima, Malaprabha, Ghataprabha and Tungabhadhadra. The southern part is drained by Cauvery and its tributaries Hemavathi, Kabini and Lakshmanathirtha. Based on geology, the South Deccan Plateau has been divided into granite and granite gneiss, laterite, basalt and schistose landscapes.

Western Ghats is a continuous hill range running parallel to the West Coast of Karnataka. The upper part of the Ghats is made up of a succession of subvertical rocky crags and zones of deep soils. The western escarpment is very steep with numerous V-shaped valleys. Most of the rivers flowing either west or east originate in the Ghats of Karnataka.

Eastern Ghats constitute the hill range and occur along the southeastern border of Karnataka. It covers a small area in Mysore, Chamarajanagar and Bengaluru districts. The Eastern Ghats are drained by the river Cauvery and its tributaries.

West Coast plains lie between the Western Ghats and the Arabian Sea from Karwar in the north to Mangalore in the south for about 350 km. It is divided into high level, largely lateritised, hinterland which is dissected by west flowing rivers and a low-level coastal plain with recent fluvio-littoral formations. The area is drained by the Nethravathi, Swarna, Sita, Haladi, Sharavathi, Gangavali and Kali rivers.

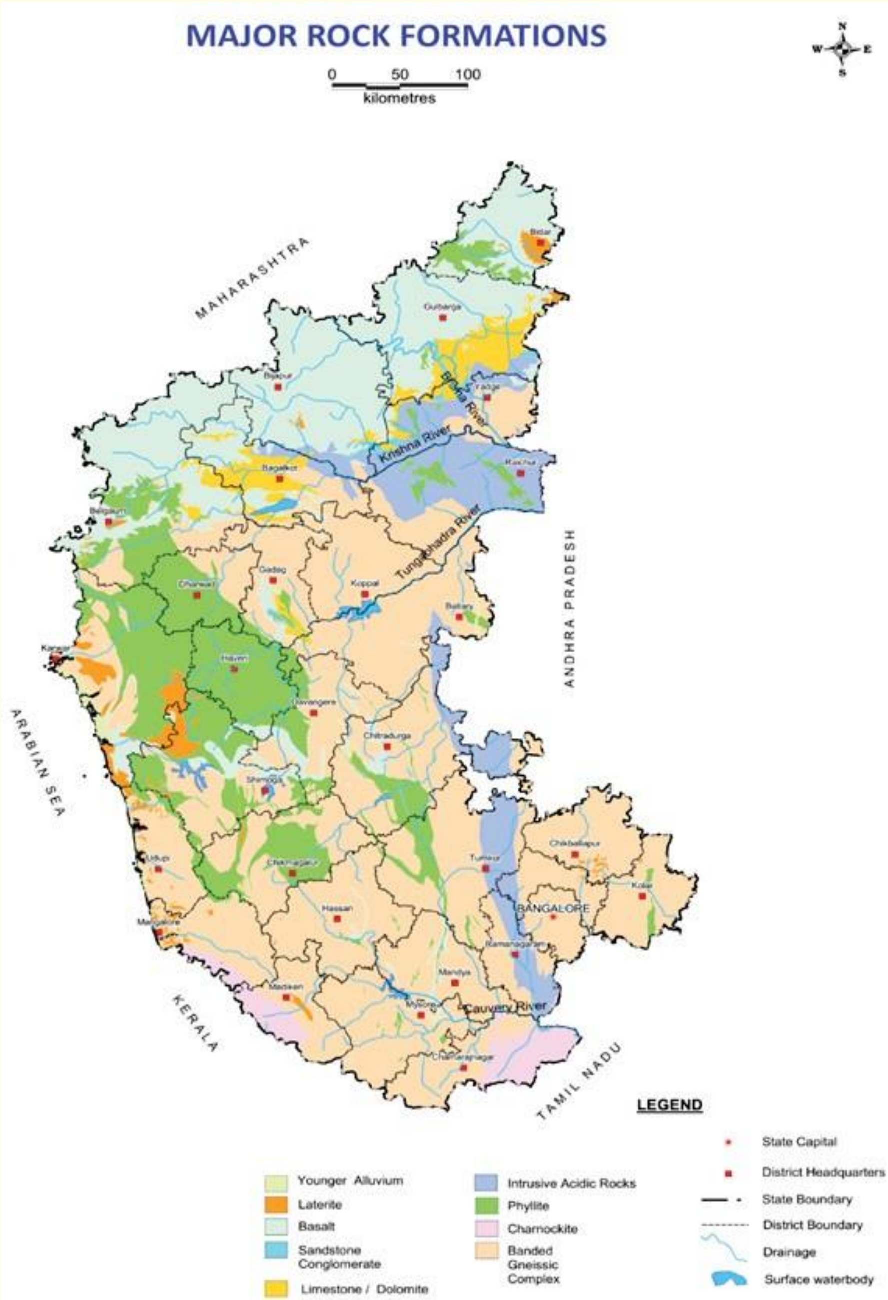
3.2 Geology

The major geological formations found in the state are gniess, granite, charnockite, basalt, schist, limestone, sandstone, laterite, and alluvium (Fig 3.2). These formations are broadly grouped into Archaean, Proterozoic, Mesozoic and Cainozoic rocks. The Archaean or Peninsular Gneiss, which includes granites, gneisses and charnockites are the oldest rock formations covering about 60 per cent area in the state (Table 3.1). They are unfossiliferrous, crystalline, contrasted and faulted rocks. The Dharwar schists of the Proterozoic alternate with Archean crystalline rocks. These rocks show a volcano sedimentary assemblage of rocks comprising ferruginous quartzite, pyroxenite, gabbro, serpentinite, phyllite, chlorite schist, limestone, dolomite, manganese and iron ore and meta basalt.

Sandstone, shale, limestone, and dolomite of the Upper Proterozoic occur in the northern part of Karnataka in Kalaburagi and Vijayapura districts. Basalt or Deccan Traps of Mesozoic is found in the extreme northeastern part of Bidar, Kalaburagi and Belagavi districts. Laterites of Cainozoic occur in the districts of Bengaluru, Bidar, Belagavi, Dakshina Kannada, Uttara Kannada, Hassan, Kodagu, Chikkamagalur and Shivamogga. Recent alluvial deposits are found along river courses and valleys and also in coastal areas (Fig 3.3).

Table 3.1 Extent of various rock formations in Karnataka

Sl.No	**Geological Information**	**Area (Sq. km)**	**% of Total Area**
1	Gniess (Banded Gniess Complex)	97617	50.90
2	Granite	14609	7.61
3	Charnockite	4110	2.14
4	Basalt	35698	18.61
5	Schist	28711	15.00
6	Limestone	6000	3.13
7	Sandstone	623	0.32
8	Laterite	3682	1.92
9	Alluvium	711	0.37
	Total	191761	100.00



Source : CGWB (2012)

Fig. 3.2 Distribution of major rock types in Karnataka


Fine grained granite rock


Coarse grained granite rock


Fine textured basalt rock

Fine textured dense basalt rock


Schist formation, Gadag district


Laterite formation in Bidar district

Fig. 3.3 Major rock types observed in Karnataka

3.3 Weather and Climatic data

The data pertaining to rainfall, temperature, humidity, wind speed and direction, solar radiation etc., are available for the entire state at hobli level for all the 747 hoblies and at gram panchayat level, rainfall data is available for 5625 out of the 6068 total gram panchayats about 5700 rain gauge stations and 750 automatic weather stations are under the control of Karnataka State Natural Disaster Monitoring Centre (KSNDMC). In addition to this, the Indian Meteorological Department (IMD) maintains about 370 weather stations, Water Resources Development Organization, GOI about 170 weather stations and State Agricultural and Horticultural Universities and their Research Stations together about 100 weather stations. Apart from this, about 120 automatic weather stations and 59 telemetric rain gauges are installed, under SUJALA III project. All this adds up to approximately one rain gauge for every 25 sq km and one weather station for about 250 sq km area in the state at present.

The KSNDMC is responsible for the maintenance and collection of all weather-related datasets from all the weather stations/rain gauges and sharing the same with all the project partners/other stakeholders/Portal along with the legacy data in the state.

3.4 Map Inputs Needed Cadastral Map

For farm or watershed or village development, the ideal base to be used for the generation of information is the cadastral map, since only cadastral map provides field boundaries with survey numbers, location of tanks, streams, wells, habitations and other permanent features of an area (Fig 3.4). By referring this map, the planner or any land user/farmer can easily identify any survey number of his/her interest in the watershed area without any problem. Further, this helps in not only identifying the site-specific problems and potentials but also show them exactly on the survey number or on the field in which it occurs. The drawback in the cadastral map is the absence of contour lines or elevation and surface features, which makes it difficult to identify and delineate various landform features (like hills, uplands, valleys, salt affected areas etc) accurately. This can be overcome by the use of high resolution Quick Bird/Worldview imagery, which helps in identifying different landforms, their extent, site and land use details more precisely at the farm level.

Satellite imagery

The Quick Bird/Worldview or other high resolution imagery is to be used for the generation of land resource information in conjunction with the village cadastral map and SOI topographical sheets of 1:50000 scale (Fig 3.5).

Cadastral map overlaid on the imagery

The use of cadastral map alone as a base provides only the cadastral information and not the landform features, but by superimposing the cadastral layer on the imagery we can get both the cadastral information and landform/land use details of the area. For executing the Land Resource Inventory, the cadastral map superimposed over the imagery forms the ideal base at the watershed/village level in the state (Fig 3.6). The development of Digital Elevation Model (DEM) by using 2 or 5 m contour data and its use for mapping along with the above base maps improves the accuracy of the landform delineation and description at the field level.

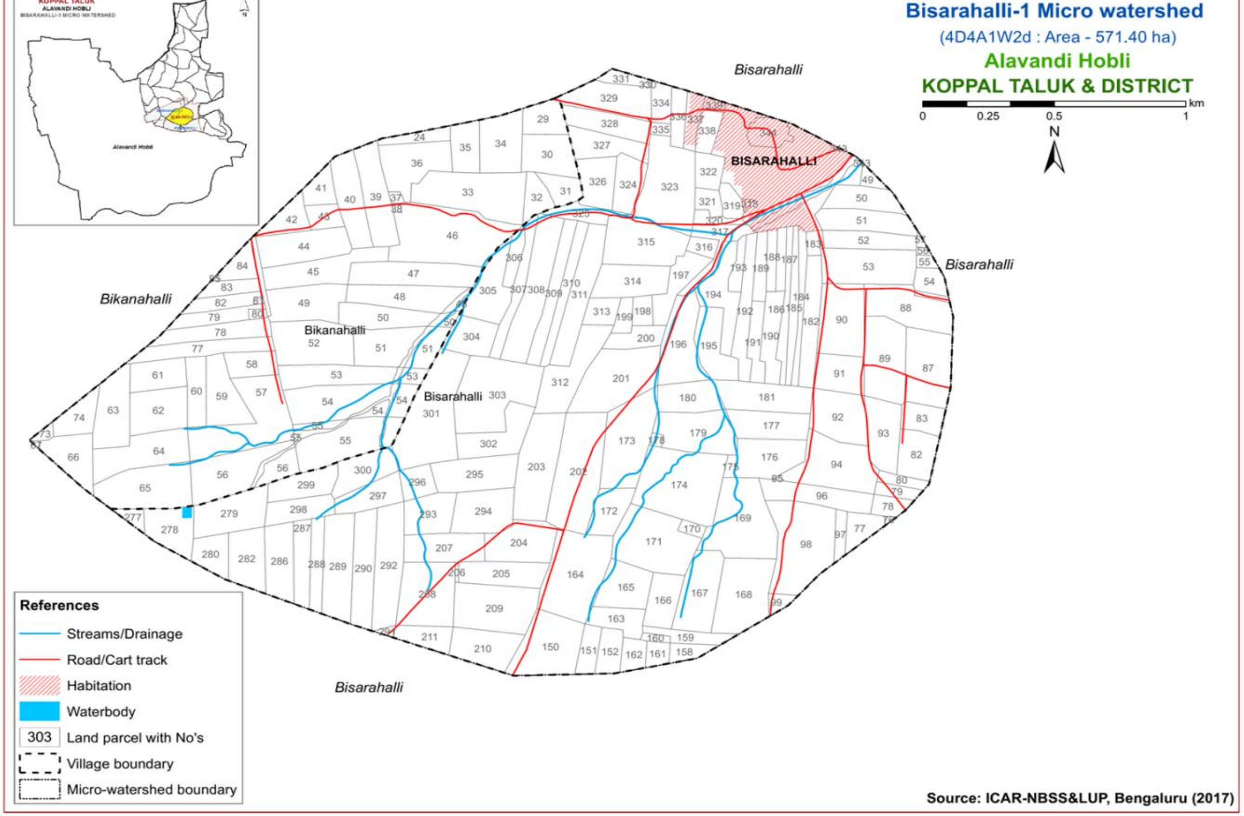


Fig. 3.4 Cadastral map of Bisarahalli-1 microwatershed, Koppal taluk & district

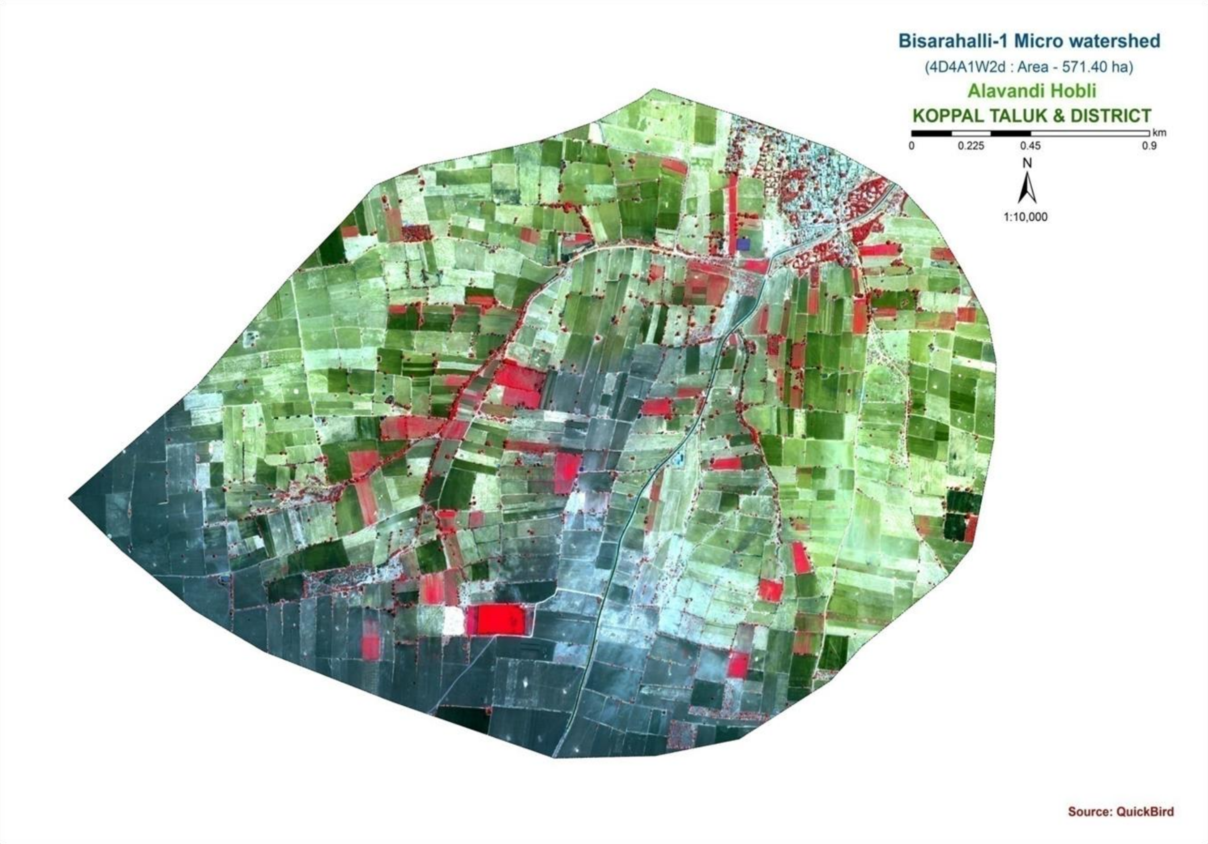


Fig. 3.5 Quick Bird image of Bisarahalli-1 microwatershed, Koppal taluk & district

Bisarahalli Image Overlaid By Interpreted Sheet

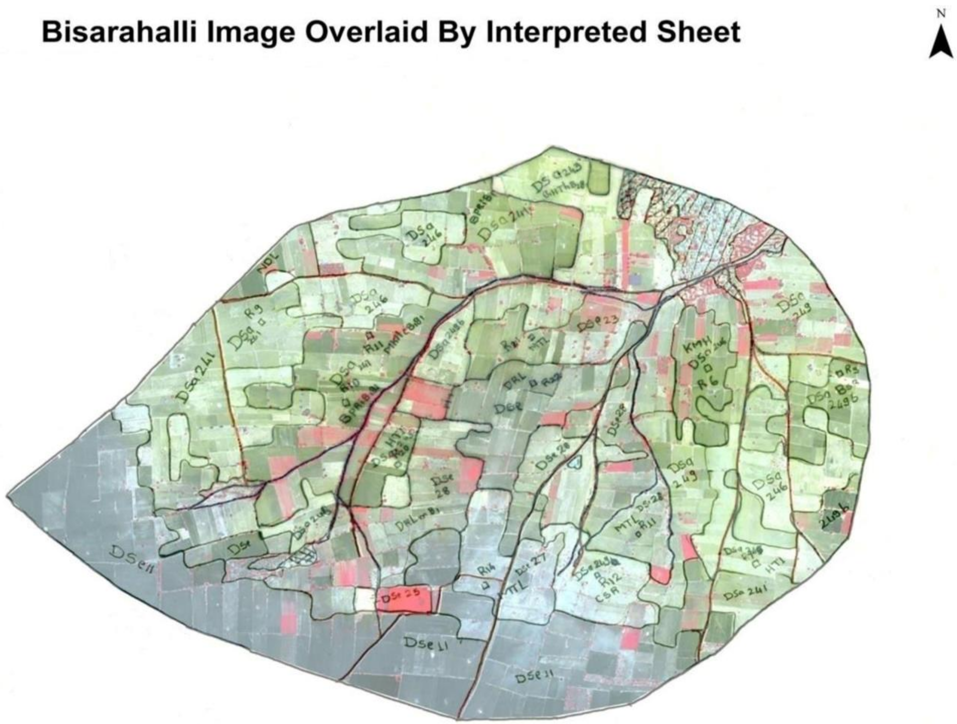


Fig. 3.6 Bisarahalli-1 microwatershed image overlaid by Interpreted Sheet

The geo-referenced cadastral maps (1:7920 scale) and Worldview/Quick Bird /worldview imagery are provided to the project partners by the Karnataka State Remote Sensing Applications Centre (KSRSAC) for all the watersheds/villages in the state. Apart from the above, KSRSAC also provides the required toposheets, imagery at different resolutions and periods, SAR imagery for the selected areas and any other maps and imagery to the project partners as and when required.

The map inputs provided by KSRSAC.

1. Geo referenced Cadastral map at 1:7920 scale for all the micro watersheds/sub watersheds and villages in the state
2. Geo referenced worldview/ Quick Bird or any higher resolution imagery at 1:7920 scale for all the micro watersheds/sub watersheds and villages in the state
3. Worldview/ Quick Bird or any higher resolution imagery superimposed on the geo referenced Cadastral map (1:7920 scale) for all the micro watersheds/sub watersheds and villages in the state
4. Available DEM at 10 and 30 m resolution for the entire state
5. Development of DEM at 2m, 5 m or higher resolution for the entire state
6. Survey of India toposheets at 1:25,000, 1:50,000 and 1:250, 000 scales
7. Georeferenced imagery at 1:25,000, 1:50,000 and 1:250, 000 scales
8. Geology map of the taluk and district at 1:50,000 scale for the entire state
9. Geomorphology, land use/land cover, drainage, water bodies and other maps for the entire state.
10. Any other RS data as per the project need

3.5 Water Resources Database

The data on hydro geomorphology, surface runoff, number of bore wells/open wells, groundwater depth and quality, depth to weathered zone, water table fluctuation, irrigation sources and other hydrological particulars are very critical for planning. The information available on the above are collected from various agencies like Department of Mines and Geology, Central Ground water Board, State Ground water Board, Department of Major and Minor Irrigation and others for the project districts. Apart from this, during Land Resource Inventory, site/location specific data sets pertaining to the above are collected from each micro watershed/village by the project partners and vetted with available information. Wherever location specific datasets are already available they are checked for their accuracy and refined wherever feasible during LRI work.

In addition to the above, the number of wells, both open and bore wells, tube wells in the area are surveyed with their exact locations and well inventory map is prepared for each microwatershed/village in the project districts (Fig 3.7). Also, the water level in selected wells is collected at fixed intervals from the area. This data helps in knowing the water table and its fluctuations in different periods of time. In many watersheds located in the black soil regions of the state, the bore wells in a micro watershed may be few or sometimes there may not be any bore well at all. In such situations, the well inventory can be extended to cover all the micro watersheds in a subwatershed area or village or cluster of villages.

For water quality assessment, samples from all water sources (wells, tanks, canals etc) are collected by the project partners during LRI work and analysed for various parameters.

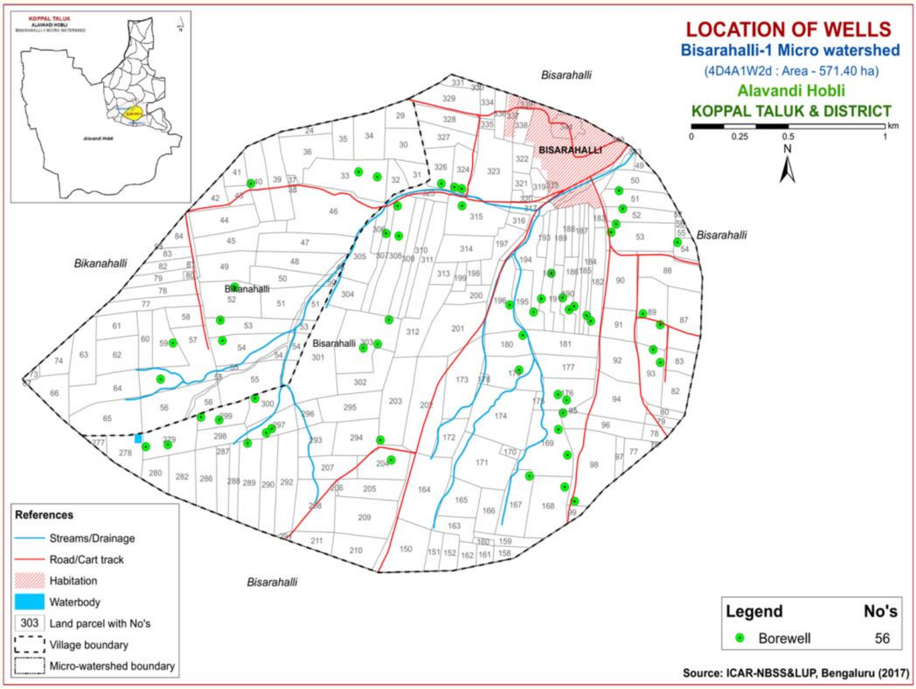


Fig.3.7. Well inventory map of Bisarahalli-1 microwatershed, Koppal taluk & district

3.6 Soil resource database

Unlike other parameters like climate, land use, hydrology, or socio-economic conditions, where the required datasets are either readily available, or they can be collected without much difficulty by allocating the required budget and manpower at the watershed/village level. However, in the case of soil and site characteristics (like slope, erosion, drainage, depth, texture etc), the required data (spatial and point data) is not available at farm/watershed or village level in the state. The data used at present for any farm or watershed development programme is from the generalised information collected earlier at smaller scale or based on point data available and that too only for few locations (Shivaprasad et al, 1998, NBSS&LUP, 2012). It is an established fact that point data on soils cannot be extrapolated even to the neighboring areas or fields due to their inherent variability and hence the generalised information available from small-scale maps is of very limited value for farm/watershed/village level planning in the state.

Soil variations can be very high even within one survey number or farm itself. The variations can range from very shallow to very deep, sandy to clayey texture, gravelly to non gravelly, calcareous to non calcareous at the farm or watershed level (Fig 3.8). Further, they are hidden from view and cannot be observed or viewed like other objects in nature. Due to this, the characterization of soils and mapping their distribution at field level is not that easy like other resources. It needs a multidisciplinary team of professionals with adequate training, experience, and skills. Since no institute or agency in the state is having the required manpower, expertise and infrastructure on their own to take up this task, a consortium of state and national level institutions and agencies is formed to carry out soil resource mapping under REWARD project.

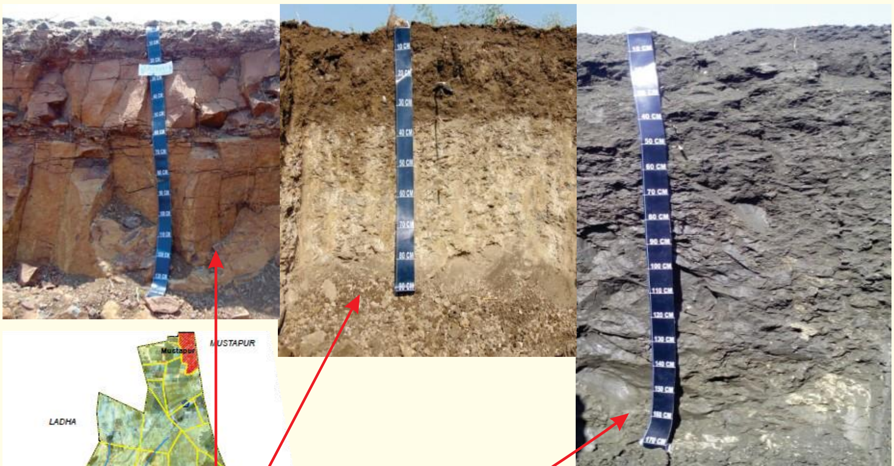
The major activities involved in the generation of soil resource database are

- Image interpretation for physiography and preparation of base map at 1:7920 scale
- Traversing the watershed/village area with the help of cadastral maps, imagery and toposheets to verify and correct the features on the base map
- Identifying rock types, landforms, land use and their description
- Selecting transects representing landform units and subunits
- Opening profiles in selected fields up to 2 m depth
- Studying soil and site characteristics, layer or horizon wise up to the bed rock
- Grouping pedons studied into soil series
- Grouping similar areas based on their soil-site characteristics into management units (soil phases) and mapping their extent
- Mapping land use/land cover, location of wells (well inventory map), existing soil and water conservation structures etc
- Collection of soil samples from representative profiles for analysis
- Collection of surface soil samples at 160/320 m grid interval for fertility analysis
- Collection of water samples for water quality analysis
- Finalisation of soil map (Phase level) of the watershed/village with detailed description of mapping units identified.

The soil map generated by following the above sequence of activities will show the variations observed in the type of soils mapped at the watershed /village level, which may vary from very shallow to very deep, sandy/loamy to clayey, gravelly to non gravelly, calcareous to non calcareous, well drained to poorly drained and varying significantly in other soil properties (Fig 3.10). Apart from this, the variations observed in site characteristics like slope, erosion, salinity/alkalinity etc and depth to weathering zone and hard rock are also captured during the survey and integrated in the map. Since all the variations are assessed at the field level and survey numbers having similar soil and site characteristics are grouped into one management/map unit, management unit as such can be considered as a unit for planning at the watershed/village level for conservation or crop selection or for any other purpose in the state.

For executing the Land Resource Inventory, the project partners are provided with the state-of- the- art field, GIS and lab facilities, required manpower and training and deployed in the project districts. The University of Agricultural Sciences (Bengaluru, Dharwad and Raichur), University of Horticultural Sciences, Bagalkote and University of Agricultural and Horticultural Sciences, Shivamogga are assigned the responsibility of carrying out LRI activities in their jurisdictional districts of the state. The ICAR- National Bureau of Soil Survey and Land Use Planning is the lead partner to provide the required guidance to the LRI partners, apart from carrying out LRI work in selected areas. The detailed methodology to be followed for executing Land Resource Inventory under Sujala-III project is presented in Chapter 4.

Land Resource Inventory (LRI) at Micro watershed level



A micro watershed with 500 ha area in Aurad taluk, Bidar shows wide variability in soil depth and soil texture

This requires

- Site specific soil and water conservation measures
- Selection of best suited crops and tree species
- Farm specific nutrient management

Fig.3.8 Wide soil variability at watershed level, varies from very shallow to very deep and clay loam to very fine clay with or without calcium carbonate substratum or hard rock below the soil

3.7 Socio- economic

The data on various socio-economic parameters, existing infrastructure and marketing facilities for every watershed are needed for integrating with the LRI and hydrology information and for generation of thematic outputs. For this, the available data are collected from Census reports, village records and Directorate of Statistics first and compiled to know the gaps in the existing database at the watershed level, and if the available data is not complete or insufficient, then efforts are made to collect the required additional data for the area through socio-economic survey.

3.8 Land use particulars

The data on land use for each watershed is available with the village officer. This can be collected for all the available years. Also, during the execution of the LRI, the land cover and land use (Fig 3.9) particulars are collected from all the survey numbers and a land use map of the watershed is prepared by the partners as one time exercise. Apart from this, data on cropping patterns practiced in the area, inputs and level of management followed by the farmers, yields obtained for different crops and any other information pertaining to the land use are also collected separately. Any significant shift in the land use over a period is also captured along with the possible reasons for the same. For this, a well-structured questionnaire and personal contact is needed, which is undertaken as a concurrent exercise, during the course of LRI.

Fig. 3.9. Rainfed Ragi as a pure crop with rows of Jowar in Magadi taluk

During the field traverse, first broad land use areas like arable and non arable lands, forest areas, community and wastelands etc are identified, described and delineated on the cadastral map of the area. Then within each land use area, like arable lands, the major crops or combination of crops that are under cultivation are identified and marked for each survey number. Similarly, the tree species, shrubs and other vegetation types observed in non arable, forest, community and wasteland areas are also identified during land use survey. Based on the above observation, land use map of the watershed/village is prepared that will show not only the broad land use classes like the arable and non arable lands, and other land uses, but also the types of crops and species cultivated in the village (Fig 3.10).

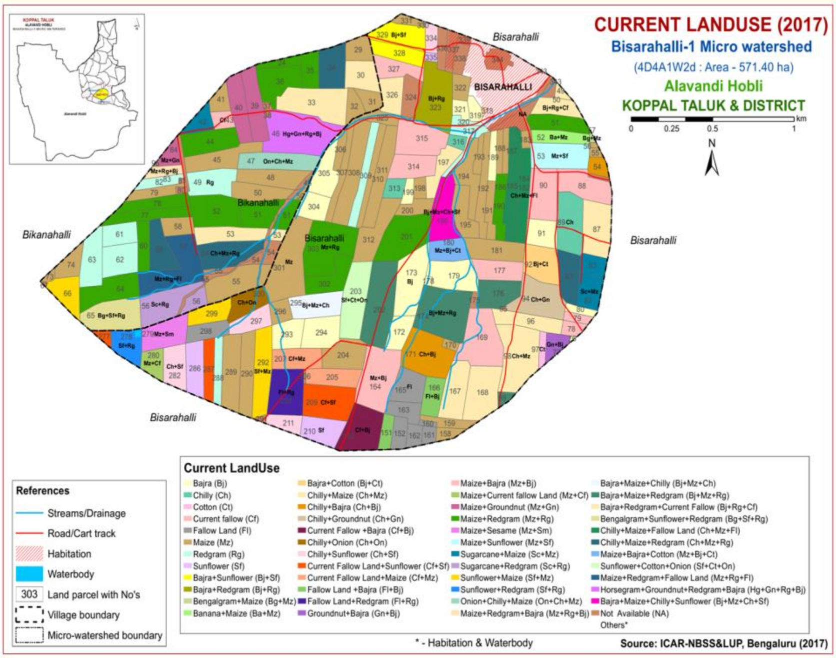


Fig..3.10. Land use map of Bisarahalli-1 microwatershed showing various land uses and combination of crops cultivated

Methodology for Land Resource Inventory (LRI)

The purpose of land resource inventory is to delineate similar areas, which respond or expected to respond similarly to a given level of management. This is achieved in the field by detailed study of all the site (like slope of the land, erosion, drainage, salinity, occurrence of rock fragments etc) and soil characteristics (such as depth, texture, colour, structure, coarse fragments, porosity, soil reaction etc), grouping similar areas (fields or survey numbers) based on soil- site characteristics into management units (phases of series) and showing their extent and geographic distribution on a suitable base map.

For village or farm level planning, cadastral maps showing all the survey numbers with their boundaries forms the ideal base. Hence, village maps at 1: 7920 scale in conjunction with imagery of the same scale are planned to be used for carrying out LRI (Map Inputs-Box). The activities involved in the generation of land resource data and maps can be broadly grouped under pre-field, field, and post-field activities. Pre field activities involve preparation of base map by using cadastral maps, imagery and toposheets and interpretation of the imagery for identifying physiography, rock types, landscapes, landforms, land use and other features (See the box.

Field activities include traverse of the area, checking the features and correcting them wherever necessary, studying soil-site characteristics and grouping similar areas into management/map units and finalizing soil, land use and well inventory maps. Post field activities are generally concerned with finalization of the field maps and handing over the same to GIS section, soil samples to the laboratory, interpretation of LRI data and generation of thematic maps and preparation of LRI report and Atlas for the surveyed area.

Map inputs needed for Land Resource Inventory

- Village cadastral maps at 1:7920 scale
- Seamless mosaic of cadastral maps for micro watersheds, sub watersheds, village (1:7920 scale), Hobli and Taluk on 1:25000 or 50000 scale
- Satellite imagery, Worldview/Quick Bird images at 1:7920 scale
- Seamless image for micro watersheds, sub watersheds and Gram Panchayat on 1:7920 scale
- Seamless image for Hobli on 1:25,000 and Taluk on 1:50,000 scale

- Overlay of seamless cadastral maps on micro watersheds, sub watersheds and Gram Panchayat on 1:7920 scale
- Survey of India Toposheets of 1:50,000 or larger if available and 1:250,000 scale
- Geology map of the Taluk/ District on 1:50, 000 scale
- Overlay of 1:50,000 scale geology map on 1:50,000 scale imagery
- Geomorphology map, wherever available
- Land use/ Land cover map
- Drainage and water bodies map

4.1 Base Map Preparation

Selection of suitable base map and scale is very critical for the study of soil-site characteristics and mapping at field level. As stated in the earlier section, the ideal base map for this purpose is the cadastral layer superimposed over the imagery at 1:7920 scale (Fig 3.7) at village/sub watershed level and Survey of India toposheet and imagery at 1:50, 000 scale at hobli/taluk level. The geo referenced cadastral maps, imagery and cadastral map overlaid on the imagery are generated for each micro watershed/village by KSRSAC and given to the field parties before the start of field work. Similarly, the toposheets, imagery and geology map overlaid on the imagery at 1:50, 000 scale are provided by KSRSAC to LRI partners for executing the survey work at taluk/ district levels. Before taking up any pre field/field activities, the habitations are marked clearly by hatched lines, roads by red and all water bodies (rivers/streams/ nallas/tanks) by using blue colour pencils or markers on the imagery or any other base maps used for taking up LRI work either at taluk or village levels.

4.2 Image interpretation

This is the most important pre-field activity, carried out to identify and delineate different physiographic regions, rock types, landscapes, landforms and their subdivisions at different levels-from district, taluk, watershed and village before the start of the field work in the survey area.

At taluk level: If there are two or more physiographic regions present, then the extent of each of the physiographic region has to be delineated first on the 1:50,000 imagery with the help of topofeatures and image characteristics. Normally, more than one physiographic region occurs if the area falls in the transition zone between two regions or if the difference between two regions is abrupt and occurs in the same taluk or district. For example, in the Chamarajanagar taluk, South Deccan Plateau and Southeastern Ghats or Western Ghats regions occur in the same area (Map 3.1) and they have to be delineated first on the imagery. Except this, all other districts are located in the south deccan plateau region, which is the largest physiographic region of the state.

Within each physiographic region, study carefully the variations in geology or rock types of the area with the help of geology map available and if there is any variation observed in the type of rocks present, then they must be delineated on the imagery based on the image characteristics. For example, in the South Deccan Plateau region of Koppal district, two distinct geological formations viz granite and granite gneiss and alluvial plains are found to occur. The boundary between these two rock formations must be traced on the imagery by referring the geology map of the area and by observing the image characteristics (Fig 4.1).

After identifying and delineating the two distinct geological formations in the taluk, identify and delineate various landforms like hills, mounds, and ridges, side slopes, foot slopes, inselbergs, uplands, and valleys/lowlands etc. that are likely to occur in the granite and gneiss landscape based on contour intervals as observed from the toposheet and matching the same with image characteristics. Similarly, in the alluvial plains landscape, the occurrence of various landforms like plains and valleys/ lowlands are separated based on slope (contours), image characteristics and other converging evidence (Fig 4.2).

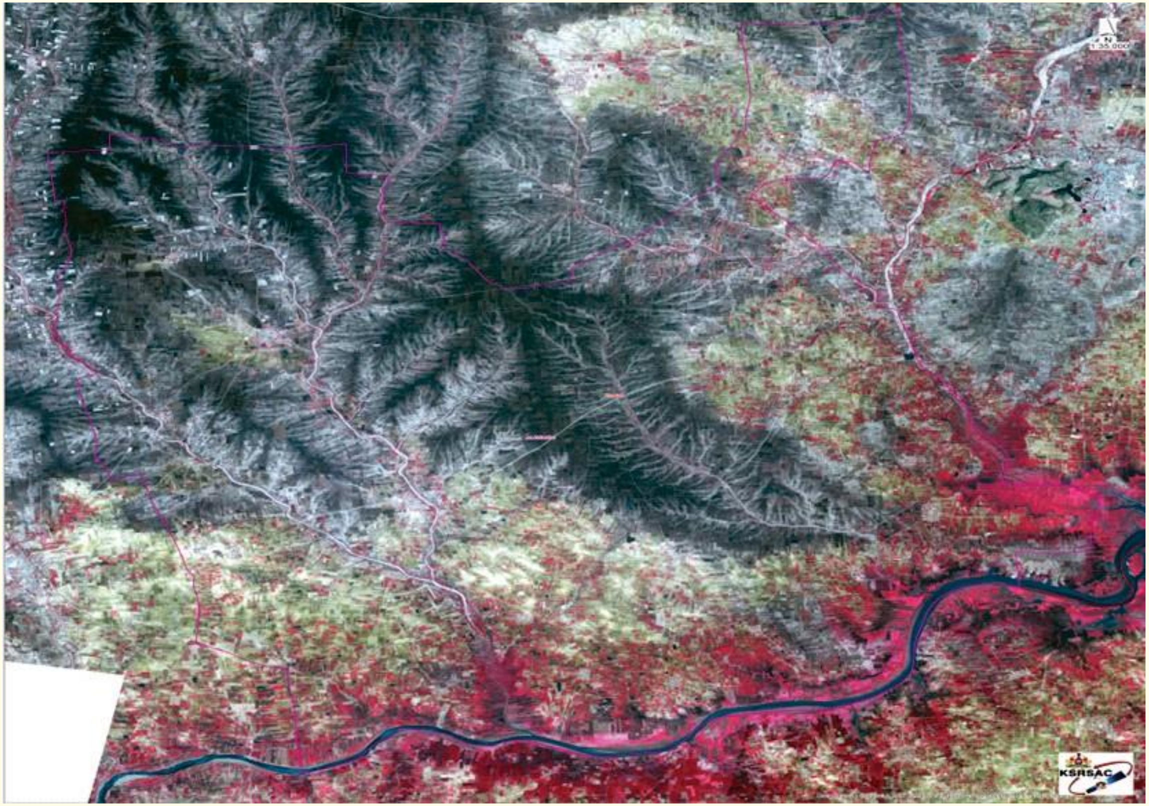


Fig. 4.1 Satellite Image (1:25000 scale) of Alavandi Hobli, Koppal Taluk showing distinct granite/gneiss and Alluvium,

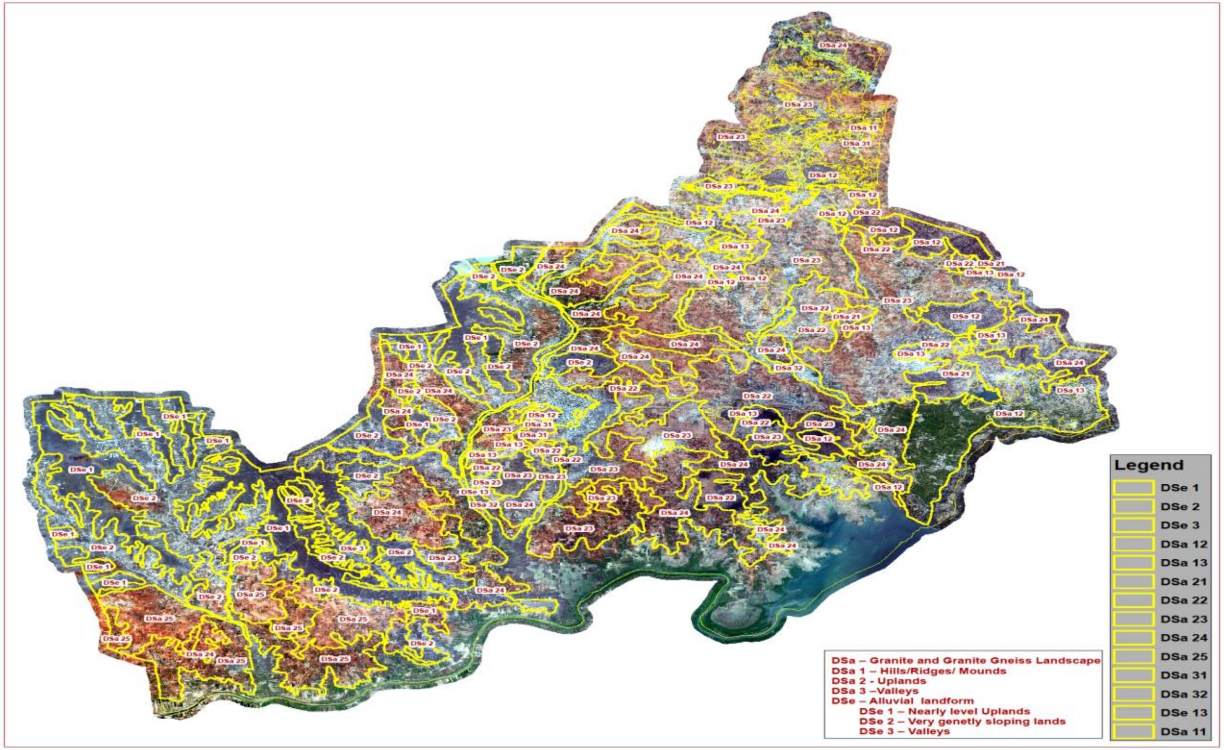


Fig. 4.2 Image Interpretation for Physiography of Koppal Taluk

The landforms occurring in granite/gneiss is unique for that landscape and hence should not be mixed with the landforms of basalt or any other landscape occurring in the area. This three-stage interpretation of the imagery (For physiographic region, geology and landfoms) carried out at taluk level will result in the generation of physiography-landform map of the taluk . An example of image interpretation at taluk level on 1:50000 scale is given below.

D	**Deccan Plateau**		
DS	South Deccan Plateau		
DSa	**Granite and Granite Gneiss Landscape**		
	Dsa 1 Hills/Ridges/ Mounds		
		DSa11	Summits
		DSa12	Hill/Side Slopes
		DSa13	Isolated hillrocks
	DSa 2 Uplands		
		Dsa 21	Rolling Lands
		Dsa 22	Undulating Lands
		DSa23	Gently Sloping Lands
		DSa24	Very gently sloping Lands
		DSa25	Nearly Level Lands
	DSa3 Valleys	Dsa 31	Interhill Valley
		Dsa 32	Valley /Lowlands
DSe	**Alluvial landform**		
	DSe1 Nearly level Uplands		
	DSe2 Very gently sloping lands		
	DSe3 Valleys		

Table 4.1 Image interpretation legend for Phsiography-Koppla Taluk

At Village/watershed level: The landforms occurring in the area are further subdivided into landform units based on slope, land use and other surface features as evidenced through image characteristics and other converging evidence of the area. For example, the hills identified earlier in the area at sub watershed level can be further subdivided into summits, escarpments, side slopes (upper, middle, and lower side slopes) and foot slopes. Similarly, the uplands can be subdivided into summits, upper slopes, middle slopes and lower slopes, plains, narrow/broad valleys, and lowlands.

In the next level, the landform units can be further subdivided based on variations like erosion, presence of gravel/stones/boulders, rock outcrops, drainage, salinity etc., as evidenced further through the image characteristics and other converging evidence of the area. For example, within the summit area of the upland if there are any variations observed in the tonal characteristics of the imagery and such variations are mappable, then such areas are to be delineated on the imagery. The variations at this level could be due to the severity of erosion in some areas of the unit or presence of gravel or stones etc., as elaborated earlier. Many times, the reasons for these variations could not be ascertained clearly on the imagery at this level and in such situations, the delineated unit can be checked in the field later and corrected accordingly.

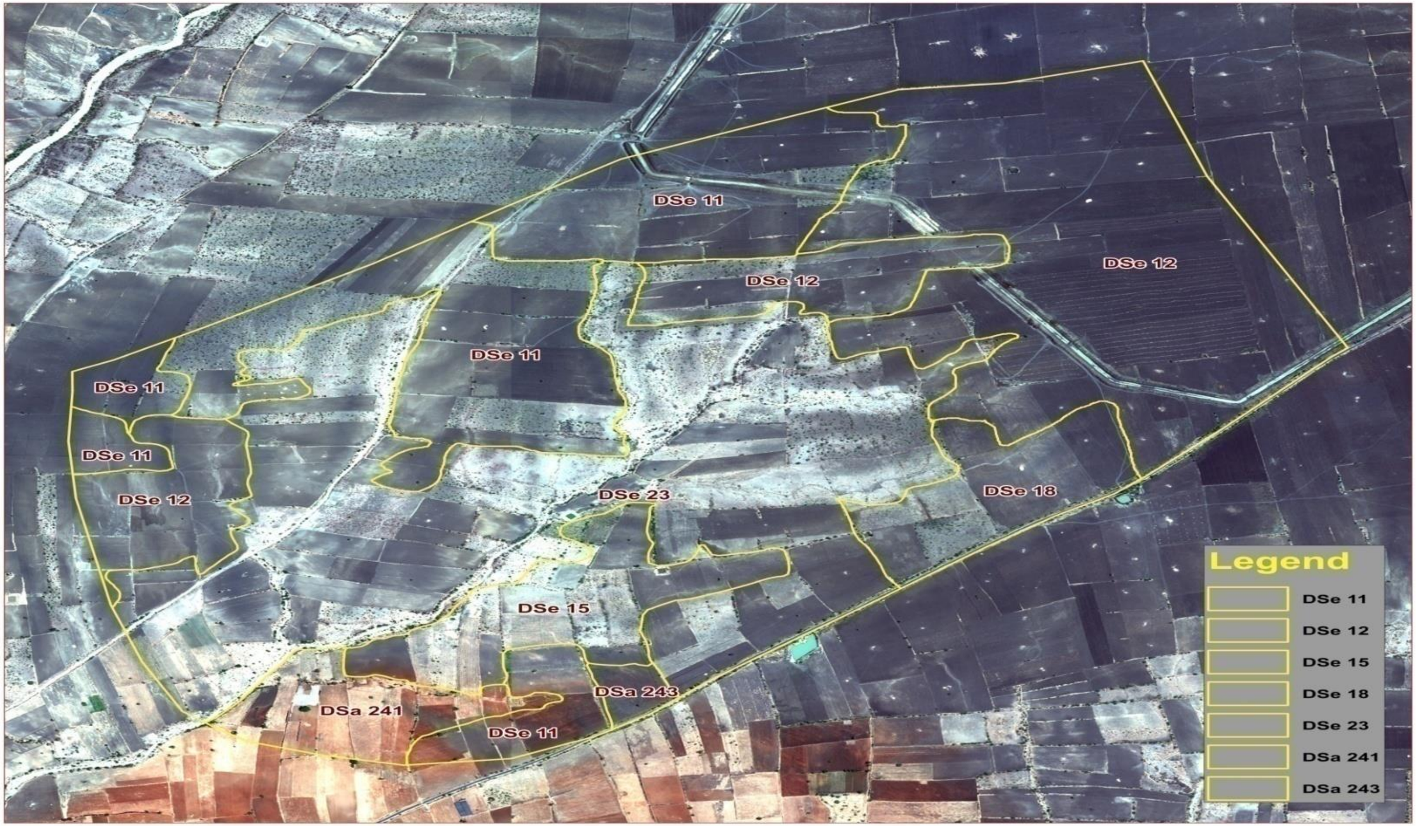


Fig. 4.3 Image Interpretation for Physiography-Adavalli-5(4D4A2P3A) Micro-Watershed of Koppal Taluk

DSe	Alluvial landscape		
	DSe 1 Summit		
		DSe11	Nearly level Uplands with dark grey tone
		DSe12	Nearly level Uplands with medium grey tone
		DSe15	Nearly level Uplands with pinkish grey tone
		DSe18	Nearly level Uplands with greenish grey tone
	DSe 2 Very gently sloping		
		DSe23	Very gently sloping lands, whitish grey tone
DSa2	Uplands	DSa24	Very gently sloping Lands DSa 241- Very gently sloping, medium green tone Dsa 243- Very gently sloping, Whitish green tone

Table 4.2 Image interpretation legend for Phsiography Landform/landform units of Adavalli-5(4D4A2P3A) Micro-Watershed

Similarly, the other landform units can be further subdivided based on the tonal characteristics into subunits wherever necessary. In lowland areas, slope will not be a critical factor, instead soil texture, soil colour, drainage, flooding, salinity and sodicity etc will be critical for management. If there is any significant change in any one of these properties as seen on the imagery, then it needs to be taken care and such changes identified and delineated based on the tonal characteristics in the valley/lowland areas.

An example of the image interpretation carried out for delineating various landforms and their sub uints in Halalli microwatershed is shown in Fig 4.4 and the legend is given in Table 4.3.

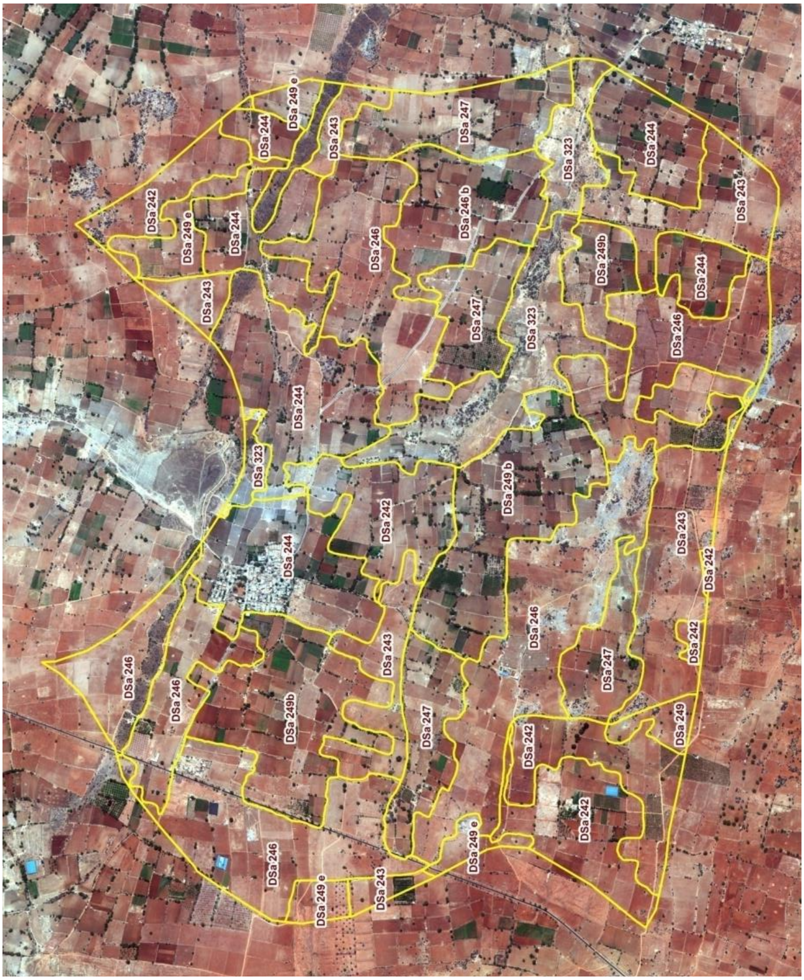


Fig. 4.4 Image Interpretation for Physiography-Halhalli (4D3A9D1b) Micro-Watershed of Koppal Taluk and District

D- Deccan Plateau
DS- South Deccan Plateau
DSa – Granite and Granite Gneiss Landscape

DSa2	Uplands	DSa23	Gently Sloping Lands
		DSa24	Very gently sloping Lands DSa 242- Very gently sloping, greenish grey tone DSa 243- Very gently sloping, whitish green tone DSa 244- Very gently sloping, medium pink tone DSa 245 - Very gently sloping, whitish tone DSa 246- Very gently sloping, light green tone DSa 247- Very gently sloping, medium grey with pink patches DSa 248- Very gently sloping, pinkish grey tone DSa 249- Very gently sloping, Grayish green tone DSa 249a- Very gently sloping, bluish gray tone DSa 249b- Very gently sloping, greenish pink tone DSa 249e- Very gently sloping, light grey
DSa3	Valleys		
		DSa32	Very gently sloping, greyish pink tone DSa 323- Whitish gray (eroded) tone

Table 4.3 Image interpretation legend for Phsiography Halhalli (4D3A9D1b) Micro-Watershed

4.3 LRI Field activities-At Taluk (Sub watershed level)

The physiography-landform map generated for the taluk/sub watershed based on image interpretation needs to be checked for the accuracy of the separation or delineation like the different physiographic regions, rock types and landforms and the description of the separated units in the field. This can be done by taking up rapid traverse of the entire taluk/sub watershed area. During the traverse, the physiography/geology/ landform delineations or boundaries are checked and corrected wherever necessary on the imagery. Apart from this, the description of the units is also checked based on the field observations and corrected wherever necessary.

During the traverse of the taluk/sub watershed itself the available road cuts, fresh excavations for buildings and well cuts are examined, and the variations observed in the soil properties like depth, texture, amount of gravel etc and major site characteristics like slope, erosion, stoniness, etc are recorded on the soil-site description form (Appendix III). Apart from this, few transects are selected to represent major landforms occurring in the area and soil-site characteristics recorded after detailed study of the soils in the profiles. Based on the soil-site characteristics a tentative soil map of the taluk/sub watershed is prepared along with identifying characteristics table for the major soils observed in the area (Table 4.4). This table or preliminary legend forms the basis or framework to take up detailed field investigations at the village level later.

Sl. No	Soil Series	Depth (cm)	Colour	Texture	Gravel (%)	Kind of Horizon & its sequence	Calcar-eousness/ others
Soils of Granite gneiss Landscape							
1	Devihal (Dvh)	<25	2.5YR2.5/4 5YR3/4 ,4/6	cl	<15	Ap-Cr	
2	Harve (Hrv)	25-50	2.5YR3/6 5YR4/4	scl	>35	Ap-Bt-Cr	
Soils of Basalt Landscape							
1	Atharga (Arg)	<25	10YR 2/2,3/3, 3/4, 4/3, 4/4	sc-c	15-35	Ap-Crk	e-es
2	Karjol (Krj)	>150	10YR 2/1,3/1, 3/2,3/3,3/4, 4/1,4/2,4/3	cl-c	<15	Ap-Bss	es-ev

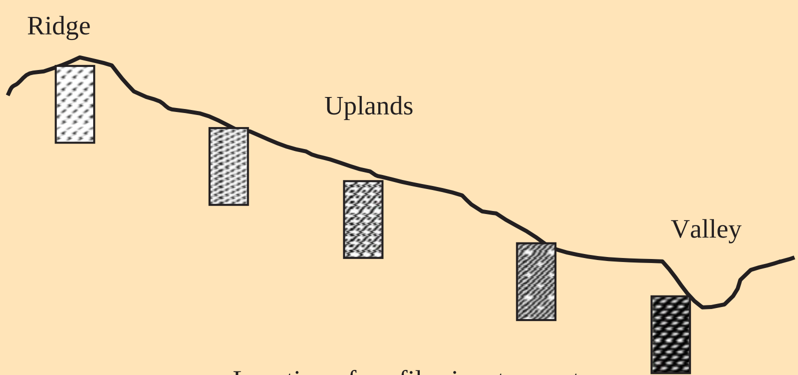
Table 4.4 2Differentiating Characteristics used for identifying Soil Series

At Village/micro watershed level

The detailed interpretation of the imagery at village /microwatershed level, will show, apart from the three broad levels like physiographic regions, rock types and landforms shown at the taluk/sub watershed level, subdivision of the landform units into subunits up to two to three levels further based on image characteristics (Fig 4.2 & 4.3) at the village/MWS level. These units, from physiographic regions, geology, landscapes, landform units and subunits, identified and delineated at the village/MWS level on the imagery needs to be checked thoroughly and corrected by traversing the entire village/MWS area. This is almost like the exercise carried out at the sub watershed/taluk level except that all the boundaries are not checked at the sub watershed/taluk level, whereas they are thoroughly checked at the village/micro watershed level.

After this, starting from a known point, and following permanent features like roads, nallas, tanks etc. the field boundaries and their corresponding survey numbers are to be identified in each cadastral sheet. Wherever new permanent features are seen, they are to be incorporated in the cadastral sheets or imagery by using appropriate colours and symbols. Further, the exact extent of the habitations and new settlements must be marked on the cadastral map/imagery, since the original map will not show the real extent or expansion of the village in the recent times. In addition to this, the occurrence and extent of other features like rock outcrops, gullies and ravines, quarried areas, fish ponds, check dams etc has to be marked on the map or imagery. The result of this exercise will eliminate the areas that are not to be surveyed and indicate only the areas to be surveyed in each village/MWS.

After checking and correcting the delineations and descriptions of the various interpreted units (from physiographic to sub units of landform) on the cadastral map/imagery, updating the cadastral sheets/imagery with new permanent features and familiarisation of the area with survey numbers and field boundaries, intensive traversing of each landform (like ridges, uplands, lowlands/valleys etc.) is undertaken to select representative areas for transect study. Transects are to be located across the slope at right angles to the contours and cover most of the variations or changes observed in a landform. **For example,**



Location of profiles in a transect

In the selected transect, profiles are located at closely spaced intervals to take care of any change in the land features like break in slope, erosion, gravel, stones etc. In the selected sites, profiles (vertical cut showing the soil layers from the surface to the rock or water) are to be opened upto 200 cm or rock or hard substratum, which ever comes earlier, and studied in detail for all their morphological and physical characteristics. Detailed soil and site characteristics are to be recorded on a standard proforma (Appendix III) for all profile sites as per the guidelines given in the Field Guide (Chapters 5 and 6). Apart from the transect study, few additional profiles may be studied at random between transects and in areas not covered by any transect, to bring out all the possible variability in the survey area.

If the area is a plain (like in a delta or alluvial plain) or if the slope gradient is difficult to observe, then location of profiles in transects is not advisable. In such situations, either free style survey or grid type of survey is recommended to locate the profiles. In a free style survey, profiles are located based on the variations observed at the land surface like colour, texture, gravel and stones, erosion status, salinity, wetness, land cover and land use etc. The effectiveness of this method depends on the experience and reference level of the surveyor. In a grid survey, profiles are located at a predetermined distance irrespective of the variations encountered in the field. Though the number of profiles studied will be more in a grid type of survey, it is the easiest one to follow, when one is new to the profession.

Based on the soil-site characteristics recorded from transects study and from random observations, the soils are grouped into different soil series (soil series is the most homogeneous unit having similar horizons and soil properties and behaves uniformly for a given level of management). The important characteristics used to group the pedons into different soil series are soil depth, texture, colour, amount and nature of coarse fragments, kinds of horizon and its sequence, calcareousness, presence of calcium carbonates, mottles, coats, stress features, concentrations, nature of the substratum etc. A significant difference in any one of these characteristics can be the basis for recognising a different series.

For the soil series identified in the village/MWS, the characteristics that differentiate one series from the other are listed in the form of a table (Table 4.5). In any survey area, the differentiating characteristics between one soil to another will be only few in number and this table helps the surveyor to identify and remember them easily. For example, soil depth, the depth of occurrence of calcium carbonate layer in the soil, calcareousness or effervescence in the soil are the major differentiating characteristics of black soils identified in Koppal taluk. This table is used as a key for grouping any new profile, as and when studied in the area.

Detailed soil and site characteristics are to be recorded on a standard proforma (Appendix III) for all profile sites as per the guidelines given in the Field Guide (Chapters 5 and 6). Apart from the transect study, few additional profiles may be studied at random between transects and in areas not covered by any transect, to bring out all the possible variability in the survey area.

Soils of Granite gneiss Landscape

Sl. No	Soil Series	Depth (cm)	Colour	Texture	Gravel (%)	Kind of Horizon and its sequence	Calcar-eousness
1	Devihal (Dvh)	<25	2.5YR2.5/4 5YR3/4 ,4/6	cl	<15	Ap-Cr	-
2	Kanchanahalli (Knh)	25-50	2.5YR3/4	sc	<15	Ap-Bt-Cr	
3	Kaggalipura (Kgp)	25-50	2.5YR2.5/4	scl-sc	15-35	Ap-Bt-Cr	
4	Harve (Hrv)	25-50	2.5YR3/6 5YR4/4	scl	>35	Ap-Bt-Cr-	
5	Muttal (Mtl)	25-50	10YR3/2,3/3,4/2 7.5YR3/2,3/3,6/4	sc-c	15-35	Ap-Bw-Ck	e-ev
6	Chikkasavanur (Csr)	25-50	7.5YR3/2,3/3,3/4	scl	<15	Ap-Bw-Cr	-
7	Lakkur (Lkr)	50-75	2.5YR3/4, 3/6	scl-sc	40-60	Ap-Bt-Bc-Cr	
8	Thammadahalli (Tdh)	50-75	2.5YR2.5/4,3/6	sc-c	-	Ap-Bt-Cr	
9	Kutegoudanahundi (Kgh)	50-75	7.5YR3/2	scl	15-35	Ap-Bt-Cr	
10	Kethanapura (Ktp)	50-75	2.5YR3/4, 3/6	scl	15-35	Ap-Bt-Cr	
11	Mukhadahalli (Mkh)	50-75	5YR3/3,3/4,4/3, 5/4,6/6 2.5YR3/4	scl	>35	Ap-Bt-Cr	
12	Hooradhahalli (Hdh)	75-100	2.5YR2.5/4,3/4, 3/6	scl-sc	>35	Ap-Bt-Cr	
13	Gollarahatti (Ght)	75-100	2.5YR3/4,4/6	scl	15-35	Ap-Bt-Cr	
14	Kanchikere (Kkr)	75-100	10YR3/3,4/2,5/2 7.5YR3/1,3/2,5/2	cl-sc	-	Ap-Bw-BC-Cr	
15	Chikkamegheri (Ckm)	75-100	2.5YR2.5/3,3/4, 3/6	sc	-	Ap-Bt-Cr	
16	Kumchahalli (Kmh)	100-150	2.5YR3/4, 3/6	scl-sc	<15	Ap-Bt-Cr	
17	Balapur (Bpr)	100-150	2.5YR2.5/4,3/4	sc-c	>35	Ap-Bt-Cr	
18	Vaddarahalli (Vdh)	100-150	7.5YR3/2,3/3,3/4	sc-c	-	Ap-Bt-Cr	
19	Lakshmangudda (Lgd)	100-150	10YR3/1,3/2,4/1, 4/2,7.5YR3/1,3/2, 5/1,2.5Y5/2,5/3,6/3	sc-c	<15	Ap-Bss-Ck	e-es
20	Hallikere (Hlk)	>150	5YR3/3,3/4 7.5YR3/3,3/4	c	<15	Ap-Bt	
21	Ranatur (Rtr)	>150	2.5YR2.5/3,2.5/4, 3/3,4/6	c	-	Ap-Bt	
22	Honnenahalli (Hnh)	50-75	7.5YR3/3,4/3 10YR3/3	sc	-	Ap-Bw-Cr	-
23	Chikka Tanda (Ckt)	>150	5YR3/3,3/4	s,sl	-	ApAC-C	-
24	Kengaki (Kgk)	>150	10YR2/12/2,3/1, 3/2,4/1, 4/2,4/3	c	-	Ap-Bw	-

Table 4.5 Differentiating Characteristics used for Identifying Soil Series (characteristics are of series control section)

After grouping the soils into different soil series within each landform, soil mapping is done by intensive traversing on foot covering all plots and survey numbers. During the traverse, starting from one transect area, boundary between two series is established by checking for the differentiating characteristics of one series from the other through a mini pit, auger, road cut or any other information available from the area. This exercise is continued and boundaries established for all the series occurring in the area.

During this exercise itself, within the delineated area of a soil series, based on variations in the surface texture, slope, erosion, presence of gravel, salinity etc, phases of soil series are separated and their boundaries delineated on the cadastral map (phase is a subdivision of a soil series based on features that affect its use and management. The delineated boundaries are checked on both sides by traversing the entire course in the field. After completing the mapping of one cadastral sheet, the adjoining sheets are taken up one after the other for detailed mapping.

The separation of phases based on slope, erosion, surface soil texture, gravel, stones, salinity, wetness etc. can also be attempted at the time of initial traversing of the area itself. If this is done at that stage, then lot of time can be saved and only separation of the series boundary is necessary after the study of the profiles and grouping them into various soil series.

A grouped area based on some similarities and marked on the map is called a delineation. A collection of delineations having similar composition is called a mapping unit. The composition of each mapping unit should be described in detail, including any inclusions present, at the time of mapping itself in a field notebook.

The delineated mapping units occurring in a village are shown on the map in the form of symbols. In arriving at the phase symbols, a combination of letters, both in upper (capital) and lower case and numbers are used. For example the map unit **GHTcB2,** occurring in Hosahalli micro watershed is a phase of Gollarahatti series. In this, the first three letters (GHT) indicate the name of the soil series, the fourth lower case letter c, indicates the texture of the surface soil, the fifth capital letter (B) indicates the slope of the land and the sixth numeral (2) indicates the degree of soil erosion occurring in the map unit. Any other feature observed in the field (like salinity, gravel etc.) can be shown by using appropriate symbols on the map (Fig 4.3).

The soil phase map of Bijjur-1 micro watershed prepared by following the above sequence of pre field and field activities shows the distribution of different manage ment/mapping units in the watershed area (Fig 4.5). The soil map unit description is given in Table 4.6. It is not possible to depict all the variations observed in the field on the map itself. The legend accompanying the map provides detailed description of the properties (like depth, texture, gravel, slope, salinity etc.) and their variations for each mapping unit identified and delineated in the watershed area (Table 4.6).

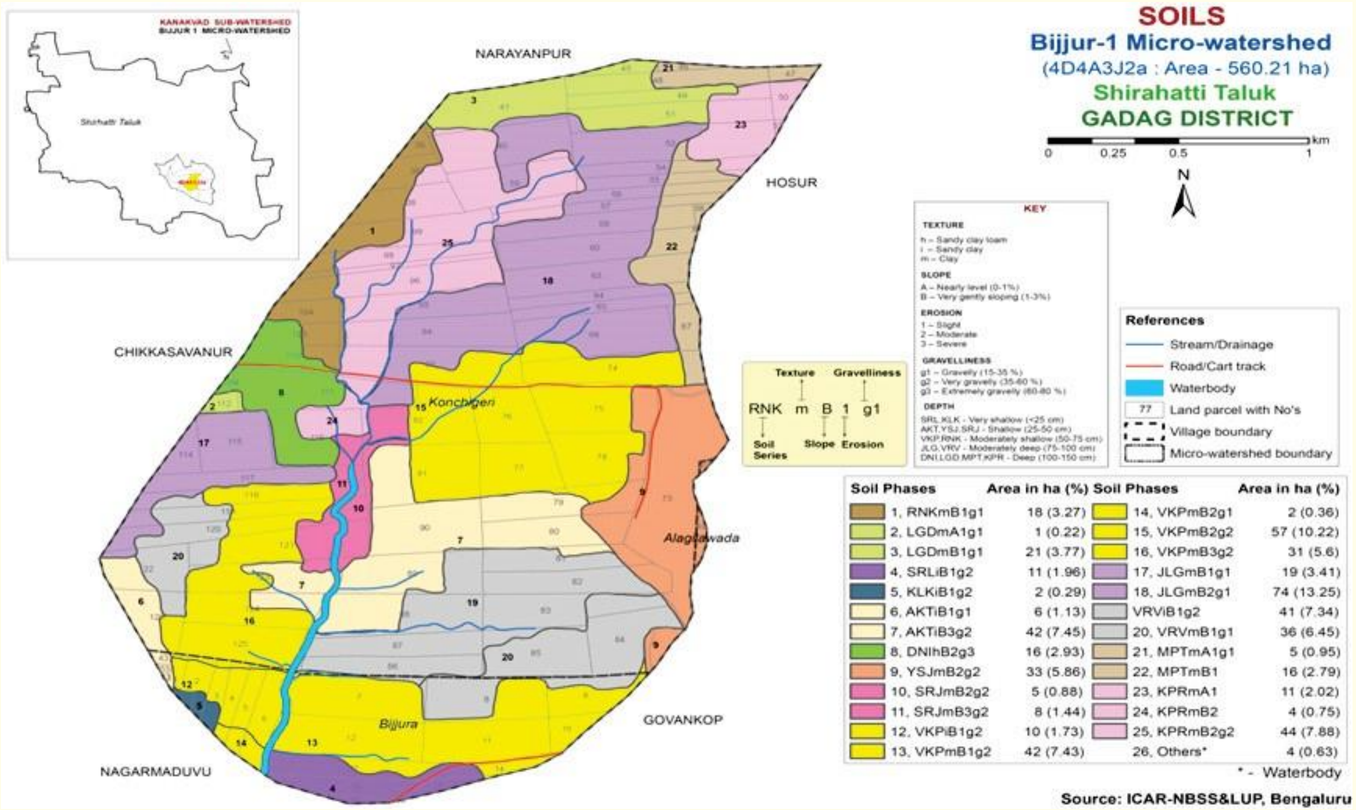


Fig 4.5 Soil Phase map of Bijjur-1 MWS showing the distribution of different soil phases

Table 4.6 Map unit description

Map unit No.	Soil Series	Soil Phase	Mapping Unit Description	Area in ha (%)
SOILS OF GRANITE GNEISS LANDSCAPE				
	RNK	Ravanki soils are moderately shallow (50-75 cm), well drained, black sandy clay to clay calcareous soils occurring on very gently sloping uplands under cultivation		**18.29 (3.26)**
1		RNKmB1g1	Clay surface, slope 1-3 %, slight erosion, gravelly (15-35 %)	18.29 (3.26)
	LGD	Lakshmangudda soils are deep (100 - 150 cm), well drained, have light olive brown to very dark gray clayey calcareous soils occurring on nearly level to very gently sloping uplands under cultivation		**22.36 (3.99)**
2		LGDmA1g1	Clay surface, slope 0-1 %, slight erosion, gravelly (15-35 %)	1.23 (0.22)
3		LGDmB1g1	Clay surface, slope 1-3 %, slight erosion, gravelly (15-35 %)	21.13 (3.77)
SOILS OF BANDED FERRUGENOUS QUARTZITE (BFQ) LANDSCAPE				
	SRL	Shirol soils are very shallow (<25 cm), well drained, have dark reddish brown clayey soils occurring on very gently sloping uplands under cultivation		**11.00 (1.96)**
4		SRLiB1g2	Sandy clay surface, slope 1-3%, slight erosion, very gravelly (35-60 %)	11.00 (1.96)
	KLK	Kabulayathkatti soils are very shallow (<25 cm), well drained, have dark reddish brown gravelly sandy clay loam soils occurring on very gently sloping uplands under rainfed cultivation		**1.62 (0.28)**
5		KLKiB1g2	Sandy clay surface, slope 1-3 %, slight erosion, very gravelly (35-60 %)	1.62 (0.28)
	AKT	Attikatti soils are shallow (25-50 cm), well drained, have dark reddish brown to dusky red clay loam to clay soils occurring on very gently sloping uplands under cultivation		**48.07 (8.57)**
6		AKTiB1g1	Sandy clay surface, slope 1-3%, slight erosion, gravelly (15-35 %)	6.36 (1.13)
7		AKTiB3g2	Sandy clay surface, slope 1-3%, severe erosion, very gravelly (35-60 %)	41.71 (7.44)
	DNI	Dhoni soils are deep (100-150 cm), well drained, have dark reddish brown gravelly clay soils occurring on gently to very gently sloping uplands under rainfed cultivation		16.44 (2.93)
8		DNIhB2g3	Sandy clay loam surface, slope 1-3%, moderate erosion, extremely gravelly (60-80 %)	16.44 (2.93)

SOILS OF SCHIST LANDSCAPE				
	YSJ	Yelisirunj soils are shallow (25 -50 cm), well drained, have very dark		32.83
		brown to very dark grayish brown clay soils occurring on very gently sloping uplands under cultivation		(5.86)
9		YSJmB2g2	Clay surface, slope 1-3 %, moderate erosion, very gravelly (35-60 %)	32.83 (5.86)
	SRJ	Shirunj soils are shallow (25-50 cm), well drained, have very dark greyish brown cracking gravelly clay soils occurring on very gently sloping uplands under cultivation		**12.96 (2.30)**
10		SRJmB2g2	Clay surface, slope 1-3%, moderate erosion, very gravelly (35-60 %)	4.91 (0.87)
11		SRJmB3g2	Clay surface, slope 1-3%, severe erosion, very gravelly (35-60 %)	8.05 (1.43)
	VKP	Venkatapur soils are moderately shallow (50 -75 cm), well drained, have very dark greyish brown cracking clay soils occurring on very gently sloping uplands under cultivation		**141.98 (25.59)**
12		VKPiB1g2	Sandy clay surface, slope 1-3%, slight erosion, very gravelly (35-60%)	9.67 (1.72)
13		VKPmB1g2	Clay surface, slope 1-3%, slight erosion, very gravelly (35-60 %)	41.62 (7.42)
14		VKPmB2g1	Clay surface, slope 1-3%, moderate erosion, gravelly (15-35 %)	2.04 (0.63)
15		VKPmB2g2	Clay surface, slope 1-3%, moderate erosion, very gravelly (35-60 %)	57.28 (10.22)
`16		VKPmB3g2	Clay surface, slope 1-3%, severe erosion, very gravelly (35-60 %)	31.37 (5.60)
	JLG	Jelligeri soils are moderately deep (75-100 cm), moderately well drained, very dark brown to dark brown and black cracking clay soils occurring on very gently sloping uplands under cultivation		**93.32 (16.65)**
17		JLGmB1g1	Clay surface, slope 1-3 %, slight erosion, gravelly (15-35 %)	19.08 (3.40)
18		JLGmB2g1	Clay surface, slope 1-3%, moderate erosion, gravelly (15-35 %)	74.24 (13.25)
	VRV	Varavi soils are moderately deep (75 -100 cm), moderately well drained, have very dark brown cracking clay soils occurring on very gently sloping uplands under cultivation		**77.23 (13.77)**
19		VRViB1g2	Sandy clay surface, slope 1-3 %, slight erosion, very gravelly (35-60 %)	41.12 (7.33)

20		VRVmB1g1	Clay surface, slope 1-3 %, slight erosion, gravelly (15-35 %)	36.11 (6.44)
	MPT	Mahalingapur Tanda soils are deep (100-150 cm), moderately well drained, have very dark brown to very dark grayish brown cracking clay soils occurring on nearly level to very gently sloping uplands under cultivation		**20.92 (3.72)**
21		MPTmA1g1	Clay surface, slope 0-1 %, slight erosion, gravelly (15-35 %)	5.31 (0.94)
22		MPTmB1	Clay surface, slope 1-3 %, slight erosion	15.61 (2.78)
	KPR	Kalasapur soils are deep (100-150 cm), moderately well drained, have very dark gray to very dark grayish brown calcareous cracking clay soils occurring on nearly level to very gently sloping uplands under cultivation		**59.66 (10.64)**
23		KPRmA1	Clay surface, slope 0-1 %, slight erosion	11.32 (2.02)
24		KPRmB2	Clay surface, slope 1-3 %, moderate erosion	4.20 (0.74)
25		KPRmB2g2	Clay surface, slope 1-3 %, moderate erosion, very gravelly (35-60 %)	44.14 (7.88)
26		Waterbody		3.55 (0.63)

4.4 Collection of other particulars from the survey area

There is no need to collect data on climate or weather parameters from the area since the required data are already made available to the field parties by KSNMDC. Only data pertaining to land use pattern, crops grown at present, yield particulars, socio-economic situation, marketing facilities available and other particulars, both at the village and taluk level, are to be collected during the field survey.

4.5 Collection of soil samples

For the soil series identified, soil samples are collected from a representative pedon, and from each pedon, soil samples are collected horizon-wise for laboratory analysis of both physical and chemical characteristics. Based on the number of parameters to be analysed and the amount of gravel present, the quantity of soil sample to be collected from each horizon may be decided accordingly. The samples are placed in polythene bags with appropriate label. Each polythene bag has to be and passed through 2 mm sieve. These processed samples were used for further analysis. In the surveyed village area, some soil series may occur extensively and in such a situation more than one pedon samples are to be collected for analysis.

For labelling the soil samples, the codification given below may be followed:

For example- Gg-Sht-Rtr-Tr1-P1 -P1/1, P1/2, P1/3, P1/n

Gg - indicates the name of the district, Gadag
Sht - indicates the name of the taluk, Shirahatti
Rtr - indicates the name of the village, Ranatur
Tr1 –
Transect No.1 in Ranatur village
P1 – profile No.1 in transect No.1in Ranatur village
P1/1 (0-11 cm) - soil sample No.1 from Profile No.1
P1/2 (11-33 cm) - soil sample No. 2 from profile No.1
- - - - - -
- - - - - -
P1 /n - soil sample No.n from profile No.1
OR
R1 – Random profile No.1 from Ranatur village
R1/1 (0-18 cm) - soil sample No.1 from Random profile No. R1
R1/2 (18-42 cm) - soil sample No. 2 from Random profile No. R1
- - - - - -
- - - - - -
R1/n - soil sample No. n from random profile No.R1

Bulk Density

Bulk density is estimated by core sampler method. The metallic core of known volume is pressed or driven into the soil at the desired depth to collect an undisturbed soil sample from each horizon. Clean the plant debris and big stones on the surface layer and then gently press the core to collect the samples by using wooden hammer. In lower horizons, the core can be used either horizontally or vertically, whichever is more comfortable or easy to drive into the soil at desired depth. Try to avoid samples being made compact and remove the core from inside without disturbing the soil material and trim protruding soil with the knife from both ends of the core. Moist sample weight has to record in the field itself and place in air-tight container for transport to laboratory for estimating bulk density.

Grid soil sampling

Composite soil samples are to be collected for assessing the fertility status of the soils mapped by following grid sampling method. For this, grids are drawn on the village cadastral map overlaid on satellite imagery (Fig 4.6) at every 320 m interval (10.24 ha on square grid) for rainfed and dry land areas and 160 m interval (2.56 ha on a square grid) for irrigated and command areas respectively. For sampling at each grid point, first identify and locate the survey number in which it falls and collect samples within a survey number or land parcel, which covers a large area of major landuse. Collect samples at several points in and around the grid point and mix all the samples and make it one composite sample. Then collect the required quantity from this composite sample to represent that grid for soil fertility status. On an average, about 50 to70 soil samples are collected for an area of about 500 ha.

For labelling the soil samples, the codification as given below may be followed:

For example- Kp/Gn/Kav/F1

Kp- indicates the name of the district, Koppal District
Gn- indicates the name of the taluk, Gangavati Taluk
Kav- indicates the name of the village, Kavalur village
F1- indicates the surface soil sampled at Grid Point No.1

In case, if the District and Taluk name is same, then only District name need be given.

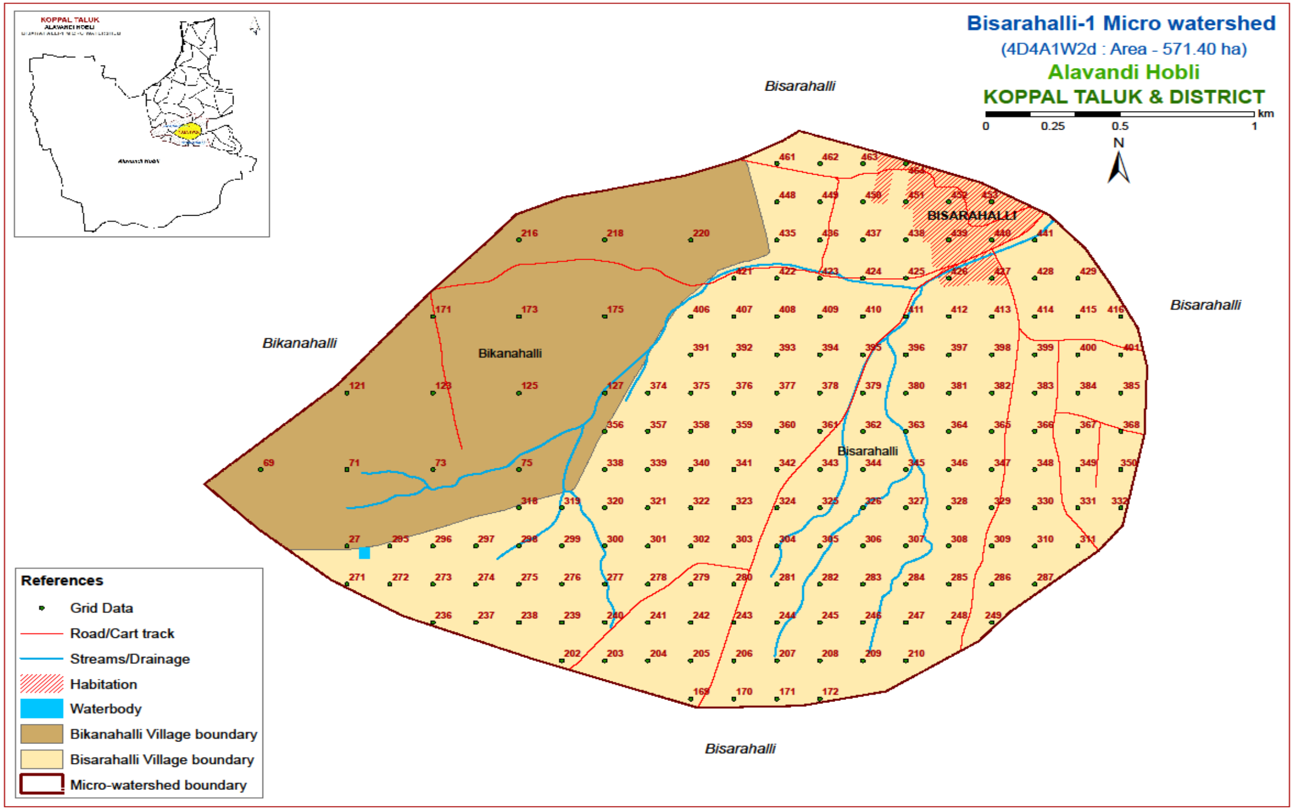


Fig 4.6 Grid map for collecting fertility soil samples, Bisarahalli village (1412 ha) Alavandi Hobli, Koppal Taluk, Koppal District

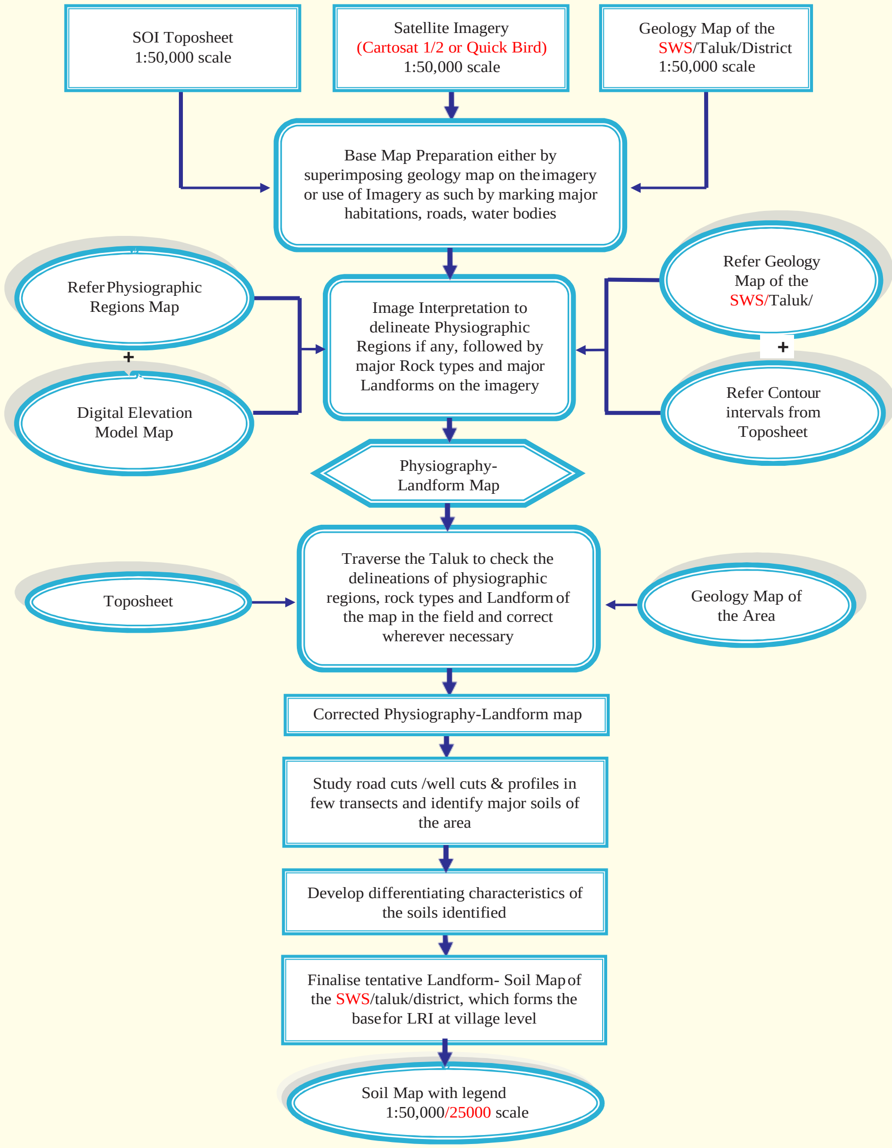


Fig 4.7 Land Resource Inventory activities at sub watershed/Taluk /District Level

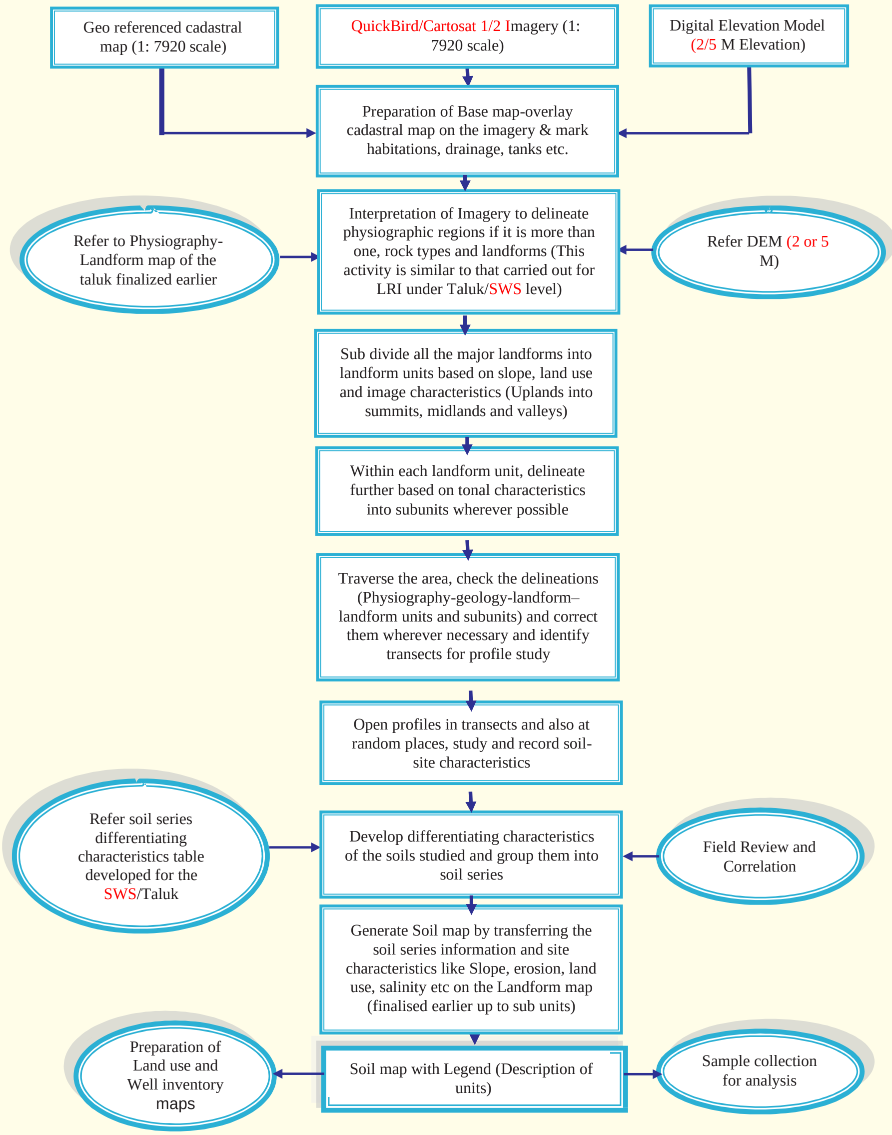


Fig 4.8 LRI activities at Village/micro watershed level

Activities Check list for Land Resource Inventory

I PRE-FIELD ACTIVITIES

1. Preparation of base maps on 1:7920 scale
2.Image interpretation for Geology
   - At Taluk/Hobli/SWS level (1:50000/25000 scale)
   - At Village/Gram panchayat/MWS level (1:7920
scale) 3.Image interpretation for Physiography
   - At Taluk/Hobli/SWS level (Geology, landscapes/physiography/major landforms)
   - At Village/Gram panchayat/MWS level (Landform/physiographic units based on image characteristics)
4.Finalisation of physiography-landform map with legend

II FIELD ACTIVITIES

1. Reconnaissance of the Taluk/SWS by using the required map inputs

- Identification and checking of rock types and their boundaries
- Checking of landscapes, landform/physiography divisions and land use
- Correction of geological/physiographic divisions and other physical and cultural features
- Examination of soils through available cuts (road, well, gully) and with few transects
- Establish broad soil-landform relationships
- Preparation of identifying characteristics table for major soil series identified
- Finalisation of Soil map with preliminary soil legend (Soil series/ association of series)
- Selection of probable transects for study later at village level

2. Field survey and soil mapping at village/microwatershed level

- Rapid traverse of the area (microwatershed/subwatershed/village) with the help of cadastral map, image and physiography map to get an idea of the rock types, landforms/ physiography, crops and cropping systems, soil and site characteristics
- Identification and checking of rock types and physiographic/ image interpretation units
- Corrections if any on rock types and physiographic units
- Selection of transects (cutting across as many physiographic units as possible)
- Digging of soil profile pits up to 2 m depth
- Examination and description of soil profiles in transects
- Study and record of soil-site characteristics
- Photographs of soil profiles, landscapes, land use and any other significant feature like erosion, salinity etc.
- Grouping of soil profiles studied at each transect into soil series

Chapter 5

Study and Description of Site characteristics in the field

The soil continuum seen at the surface of the earth is formed by the influence of at least five soil forming factors like climate, biota, topography, parent material and time and through the interactions of multitudes of processes operating in nature. Since these factors and processes are never static in any given place and time; soil formation is a dynamic and continuous one. They form and change continually at different rates and along different pathways. As a result, they vary spatially in both the horizontal and vertical dimensions.

To understand the complex patterns and spatial distribution of soils on the earth's surface, the role of different soil forming factors and processes that shaped the evolution of landscapes and the distribution of soils on each landscape is essential. To study and map soils, we must understand not only of what they are, but also how they are related to their adjoining counterparts in the field and the sequence there of. For this, we need to know the genesis of soils and the role of rock types, topography, rainfall, vegetation, land use etc in the formation of different soils and their varied patterns observed in an area. Without this, we cannot explain soil patterns or variations encountered in the field satisfactorily.

Further, soils are usually hidden from view, and they do not have identifiable outer boundaries like other objects. Instead, they grade continuously, one into another, in any landform or landscape. Since these gradations are not at random and can be related to the change in the landform features or site characteristics, the spatial variations observed, particularly the horizontal soil variations, can be related to the changes observed in the landform features (like break in slope, rock outcrops, presence of saline patches, wet spots etc.). Deciphering the soil pattern and identification of soil boundary among the soils is possible only when this relationship is established in the field by the surveyor.

So, to identify homogeneous areas in the field, which is the objective of soil survey, we need to have not only a detailed description of the soil characteristics (which is represented by a pedon), but also that of the landform or site characteristics. This chapter provides the necessary guidelines for identifying and describing various site characteristics observed in the field and the next chapter provides guidelines for soil or pedon description.

A standard format to describe the various soil-site characteristics in the field is necessary to avoid missing some of the features and to maintain the sequence of recording by the surveyor. The pedon description form lists the important site characteristics to be recorded in the first page and soil characteristics on the reverse side (Appendix III). The features indicated in the proforma are neither complete nor specific to any area. So always there is scope for observing new features in the area, and if so observed, they have to be recorded in detail, either in the proforma itself or in the field notebook.

The site characteristics to be studied and recorded from the selected site are indicated in the proforma given below, followed by detailed description of each of the items to be filled in the proforma.

Land Resource Inventory-Proforma for Site description

PEDON DESCRIPTION FORM – SITE CHARACTERISTICS

NBSS & LUP	Agricultural University	Dept. of Agriculture	Author: Date :

Series Name:	Map unit Symbol:	Soil Classification:

Observation No.:	Topo sheet No.:	Imagery No.:	Base map: Scale:	Cadastral Sheet No.:

Location:	Latitude: ° ′ ″ Longitude: ° ′ ″	Plot (Survey) No.:	Village: Taluk:	Block: District:

Physiographic division:	Geology:	Parent material:

Topography of the surrounding country: Level / Nearly level / Undulating / Rolling / Hilly / Steep / Very steep	Landform:	Microfeatures:	Profile position:

Soil slope														
Gradient (%)	0-1 A	1-3 B	3-5 C	5-10 D	10-15 E	15-25 F	25-33 G	>33 H	**Erosion**	Very slight	Slight	Mod.	Sev.	V. Sev
Length (m)	0-50	50-150	150-300	300-600	>600				**Runoff**	Ponded	V.Slow	Slow	Med	Rap	V.Rap

Drainage	V. Pr	Pr	Some what Pr.	M. Well	Well	Some what excessive.	Ex.	**G.Water depth (m)**	<1	1-2	2-5	5-10	10-25	25-50	>50
Flooding	No	Occassional	Frequent	Very Frequent				**Salt/Alkali (% sur. coverage)**	No	<20	20-50	>50			
pH	<4.5	4.5-5.5	5.5-6.5	6.5-7.5	7.5-8.5	8.5-9.5	>9.5	**E.C.**	<2	2-4	4-8	8-15	15-25	25-50	>50

Surface fragments	Dia (cm)	<2	2-7.5	7.5-25	25-60	>60	**Rock out-crops**	Dist. Apart (m)	No	35-100	10-35	3.5-10	<3.5	
Coverage of gravels (<25cm)	(%)	<15	15-35	35-60	>60			Coverage(%)	<2	2-10	10-25	25-50	50-90	>90
Coverage of stones&boulders	(%)	0.01-0.1	0.1-3	3-15	15-50	50-90	Elevation above MSL(m):							

LAND USE / VEGETATION

Crop	Season	Yield	Management

Vegetation

Nine fold classification

Forests : evergreen / deciduous / shrub

Area put to non agricultural uses

Barren and uncultivable land

Permanent pastures & other grazing land

Land under misc.tree crops and groves

Culturable wasteland

Fallow lands other than current fallows

Current fallows

LCC

FIELD NOTES

SKETCH

cm

50

100

150

200

Explanation for Site Description Proforma

5.1 Field investigation by NBSS&LUP/UAS/UHS/UAHS – Tick in the appropriate box.

5.2 Author and date - Give the name of the Officer in- charge of the field party and date/time of observation, e.g., Date/Month/Year (10/02/2022); 1030 hrs

5.3 Series Name – This box to be filled at the end of the soil profile study by comparing the pedon description with the series identification table provided for the survey area.

5.4 Map unit symbol - Indicate three letter symbols for the series, followed by the phase symbols.

5.5 Soil classification - This box to be filled at the end of the soil profile study as per Soil Taxonomy.

5.6 Observation No – Follow codification as indicated below (district symbol followed by taluk, village and profile number).

For example: **Gg-Sht-Rtr-1**

Gg - indicates the name of the district, Gadag
Sht - indicates the name of the Taluk, Shirahatti taluk
Rtr - indicates the name of the village Rantur in Shirahatti taluk
No. 1 - indicates the profile number in Rantur village

The list of districts with their symbols in the state, name of taluks and their symbols from each district and list of villages and their symbols in each taluk will be provided to the field parties before the start of LRI. This observation number will be unique for each site and to be followed both on the site description proforma as well as in the collection of soil samples for analysis from the site.

5.7 Toposheet, imagery, base map and cadastral sheet particulars are self-explanatory.

5.8 Location –Indicate the exact location of the profile on the cadastral map within the survey number and describe the location of the profile with reference to some nearby fixed features. Precise GPS reading of the location is to be taken and entered in the box provided for latitude and longitude in the proforma. The other locational details like plot number, village, hobli, taluk etc, are to be entered in their respective spaces.

5.9 Physiographic Regions - Based on geology, relief and land use, the state is divided broadly into four physiographic regions. They are South Deccan Plateau, Western Ghats, Eastern Ghats and West Coast (Map 2.1). Enter the appropriate physiographic region of the LRI area in the box provided. For example, if the profile site is located in South Deccan Plateau, then enter the same in the space provided.

5.10 Geology – Karnataka forms part of the ancient Peninsular Shield, with ancient rocks of diverse origin, forming the geological base of the state. The major geological formations are Gniess (Banded Gniess Complex), Granite, Charnockite, Basalt, Schist, Limestone, Sandstone, Laterite, Alluvium (Map 2.2). Indicate the type of rock or rocks observed in the survey area in the space provided. Geology maps of the area provided to the field parties can be used as a reference and if there is any doubt in the identification of the rock in the field, then a piece of rock may be collected for confirmation in the base camp or office.

5.11 Major Landscape (Landform) areas - Based on geology, elevation, location and other features, the four major physiographic regions of the state are further subdivided broadly into nine landscape areas (Fig 5.1 & 5.2). For example, the South Deccan Plateau region is subdivided broadly into Granite and granite gneiss landscape, basalt landscape, schistose landscape and lateritic landscape. Similarly, the Western Ghats region is divided into northern and southern Ghats, coastal plains into coastal uplands and marine plains. Since there is not much variation in the landscape features of the Eastern Ghats region, it is not subdivided further and retained as such as one landscape area. Enter the appropriate landscape name of the survey area in the proforma.

Fig. 5.1 Basalt landscape with gently sloping (3-5%) uplands in the foreground and ridges in the background, Gonthmar MWS, Belgaum

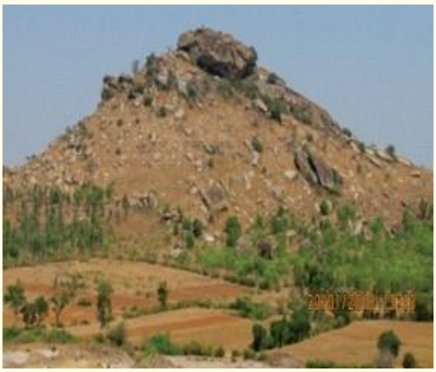
Fig 5.2 Typical granite/gneiss landscape with very gently sloping (1-3 %) uplands in the foreground and low hills in the background, Bengaluru

5.12 Landform - Any physical, recognisable feature of a landscape, having a characteristic shape that is produced by natural processes and mappable at common survey scales in a major landscape area. Examples of some landform features observed within a major landscape area in the state are indicated below (Fig 5.3)

Major landscape areas	Landforms identified
Basalt landscape	Plateau, Mesas, butte, summits, escarpments, side slopes, sloping uplands, plains, valleys
Granite and gneiss landscape	Hills (high hills, low hills), summits, escarpments, hill slopes, ridges, tors, inselbergs, foot slopes, sloping uplands, valleys
Schistose landscape	Hills (high hills, low hills), summits, escarpments, hill slopes, ridges, foot slopes, sloping uplands, valleys
Lateritic landscape	Hills, ridges, mounds, summits, side slopes, sloping uplands, valleys
Western Ghats-northern region	Hills (high hills, low hills), summits, escarpments, hill slopes, ridges, tors, inselbergs, foot slopes, sloping uplands, valleys
Western Ghats-southern region	Hills (high hills, low hills), summits, escarpments, hill slopes, ridges, tors, inselbergs, foot slopes, sloping uplands, valleys
Eastern Ghats landscape	Hills (high hills, low hills), summits, escarpments, hill slopes, ridges, tors, inselbergs, foot slopes, sloping uplands, valleys
Coastal uplands landscape	Mounds, ridges, summits, side slopes, foot slopes, uplands, lowlands, valleys
Coastal plains landscape	Beach, dunes, plains, salt pans, swamps, marshes, islands

Steeply sloping low hills with gently sloping foothills in the foreground

Gently sloping, severely eroded uplands of basalt landform



Conical residual hillock, Chikkarasinakere

Level (< 1 %) lowlands near the stream, Chikkarasinakere hobli

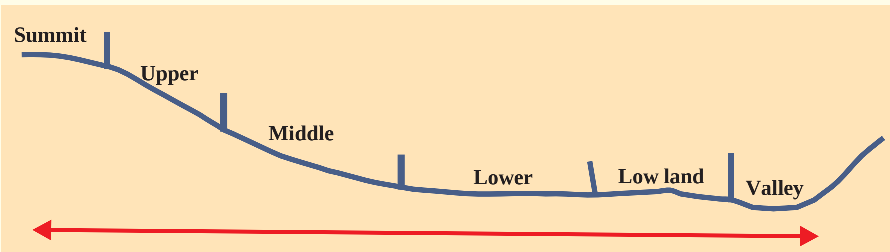
Typical basalt landform-elongated plateau with very gently sloping uplands

Gently sloping (3-5%) uplands in basalt landscape, Gonthmar MWS, Belgaum

Fig. 5.3 Typical landform units of granite gneiss and basalt landscape

5.13 Topography of the landform or surrounding country - The surrounding area of the profile will normally have complex slopes and the terms used to describe the topography of the surrounding country are indicated below. This contrasts with the simple slopes (soil slopes) used to describe the location of the profile in the pedon description form. This indicates the general variation in slope of the landform from its summit to its lowest one. Tick the one which is appropriate for the area in the box after checking the slope in few places with the help of Abney level or Clinometer.

Level	0-1 % slope
Nearly Level	1-3 % slope
Undulating	3-8 % slope
Rolling	8-16 % slope
Hilly	16-30 % slope
Steep	30-60 % slope
Very steep	>60 % slope



5.14 Parent Material - The loose unconsolidated mineral material formed by the weathering of rocks, from which the soils form, is known as the parent material of the soil. The parent material is designated as C horizon in the soil profile. The parent materials can be grouped into those formed in place through the disintegration and decomposition of rocks (Residual, Fig 5.4) and those that have been transported from the place of their origin by various agents like water, wind and gravity etc (Transported).

Parent material formed in place (residual/in-situ)	Weathered rock materials (granite/basalt etc), saprolite
Transported parent material	
By Wind	eolian deposit, eolian sands, loess.
By Mass Movement/gravity	colluvium, talus, landslide (debris fall/flow deposit, rock fall deposit, soil fall deposit), mine spoil or earthy fill deposits.
By Water	alluvium, fluviomarine deposit, marine deposit, swamp deposit, beach sand, estuarine deposit, lacustrine deposit.

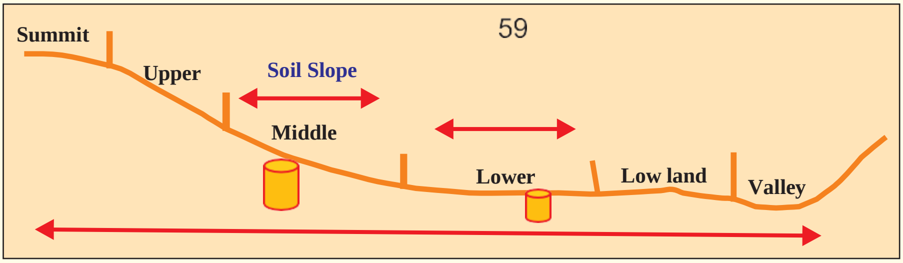
Fig 5.4 In-situ formation of soils from weathered basaltic residual parent material, Gonthmar watershed, Belgaum

5.15 Micro-features - Any discrete, natural or artificial surface feature, occupying very small area on the land surface, which cannot be delineated at the scale of mapping are known as microfeatures. These small features individually cover less than 100m^2 area and the height difference will be within few metres from the ground level. For example, small gullies or sand dunes if they occur in a very small extent in the survey area are described as microfeatures and if the same occupy large areas, then they are delineated and described as a mapping unit.

The other examples of microfeatures are ridge-and-furrow, erosion rills, ant hills, channel, depression, hillock, interdune, intermittent stream, minor scarp, mound, hummocks, dune, gilgai, cracks, pond, pool, ripple mark, shoreline, tank, contour terracing, levees and minor land slip features. Describe the nature and frequency of occurrence of such microfeatures in the survey area and the relationship of the profile site to such features in the proforma.

5.16 Profile position - In a hilly area the profile position can be indicated as summit, shoulder, backslope, footslope or toeslope (Cross-section A), as the case may be. In uplands, the profile position can be indicated as summits, upper, middle and lower part of the upland and lowlands or valleys (Cross-section B).

5.17 Soil Slope - Soil slope refers specifically to the slope of the land immediately surrounding the profile (i.e. within 100 m of the profile pit) or representative section of the landform from which the profile is described. Since soil slope is generally in one direction, it is considered as simple slope. Slope has gradient, complexity, length, form and aspect.



Slope gradient is the inclination of the surface of the soil from the horizontal. It indicates the direction of the surface water flow at the site. The difference in elevation between two points is expressed as a percentage of the distance between those points. If the difference in elevation is 1 meter over a horizontal distance of 100 meters, then slope gradient is 1 per cent. A slope of 45^0 is a slope of 100 per cent, because the difference in elevation between two points 100 meters apart horizontally is 100 meters on a 45^0 slope.

The slope gradient is measured at the profile site by using Abney Level and ranging rods or Clinometer. Obseravtions should be taken facing downslope to avoid any errors associated with the Clinometer. The Abney Level readings, degrees of inclination or declination can be converted into slope percentages and slope classes. The equivalence between percentage gradient, degree of slope angle and class of slope to be used in the field are as follows:

Class of slope	Range of slope %	Abney Level reading
A	0-1	0 to 35 min
B	1-3	35 min to 1 degree 44 min
C	3-5	1 degree 44 min to 2 degrees 52 min
D	5-10	2 degrees 52 min to 5 degrees 43 min
E	10-15	5 degrees 43 min to 8 degrees 32 min
F	15-25	8 degrees 32 mins to 14 degrees 03 mins
G	25-33	14 degrees 03 mins to 18 degrees 16 mins
H	33-50	18 degrees 16 mins to 26 degrees 34 mins

Slope Complexity refers to surface form of the soil delineation or mapping unit delineation. Complex slopes are groups of slopes that have definite breaks in several different directions, which results in different slope gradients within the areas delineated. Complex slopes are used to describe the landform of the surrounding country.

Slope length indicates the distance up to which there is no break in the slope. For example, if the length of B slope is 100 m, then this indicates that the distance between the starting point of the slope and the point where it breaks is about 100 m. Record the gradient and length in the proforma.

5.18 Erosion

The detachment and movement of soil materials from one place to another is known as soil erosion. Depending on the landscape position, vegetation and rainfall, soil erosion may be very slow or very rapid. It is very rapid in the deforested barren hills of the Western Ghats and very slow in the nearly level lands, particularly adjacent to the streams and rivers, and plains. The agents responsible for erosion are water and wind. Sheet, rill and gully erosion is common in the state (Fig 5.5a & 5.5b).

Sheet erosion is responsible for almost uniform removal of soil from an area without leaving any significant marks at the surface. It is difficult to notice in the early stages but is a serious one on many upland soils of the state.

Rill erosion is the removal of soil through many small incipient channels or rills. It is intermediate between sheet and gully erosion.

Gully erosion is the consequence of water that cuts down into the soil along the line of flow. Gullies form in exposed natural drainage ways, in plough furrows, in animal trails in roads, between rows of crop plants and below broken man-made terraces. In contrast to rills, they cannot be obliterated by tillage. **Wind erosion** is likely to become a serious problem in semi-arid and arid dry tracts of the state in future.

Moderately eroded (e2), more than 50 per cent of the surface soil is eroded due to sheet erosion

Very severely eroded (e4), both surface and major part of the subsoil is eroded due to continuous severe sheet erosion

Severely eroded (e3) due to sheet and rill erosion with incipient gullies in black soils

Very severely eroded (e4), complete soil is eroded due to deep and wide gully erosion

Fig 5.5b Types and severity of erosion observed in black and red soils

Soil erosion classes

The erosion classes are estimated in the field based on the proportion of upper horizons/layers that have been removed (Fig 5.6). Since these horizons may range widely in their thickness, estimating the absolute amount of erosion in the field is not possible. The erosion classes indicated below are applicable for both water and wind erosion.

Erosion Class	Criteria: Estimated % loss of the original surface soil (A horizon) or the estimated loss of the upper 20 cm of the soil (if original, surface soil was <20 cm thick)
1	> 0 up to 25%
2	25 up to 75%
3	75 up to 100% >
4	75 % and total removal of surface or even subsoil

Class 1 (slight erosion)

This consists of soils that have lost some, but on the average less than 25 per cent of the original surface soil (A horizon) or the estimated loss of the upper 20 cm of the soil (if original, surface soil was <20 cm thick). Evidence for class 1 erosion includes (1) a few rills, (2) an accumulation of sediment at the base of slopes or in depressions, (3) scattered small areas where the plough layer contains material from below, and (4) evidence of the formation of widely spaced, deep rills or shallow gullies without consistently measurable reduction in thickness or other change in properties between the rills or gullies.

Class 2 (moderate erosion)

This class consists of soils that have lost, on the average, 25 to 75 per cent of the original surface soil (A horizon) or the estimated loss of the upper 20 cm of the soil (if original, surface soil was <20 cm thick). Throughout most cultivated areas of class 2 erosion, the surface layer consists of a mixture of the original A and/or horizons and material from below. Some areas may have intricate patterns, ranging from uneroded small areas to severely eroded small areas. Where the original A horizon was thick, little or no mixing of underlying material may have taken place.

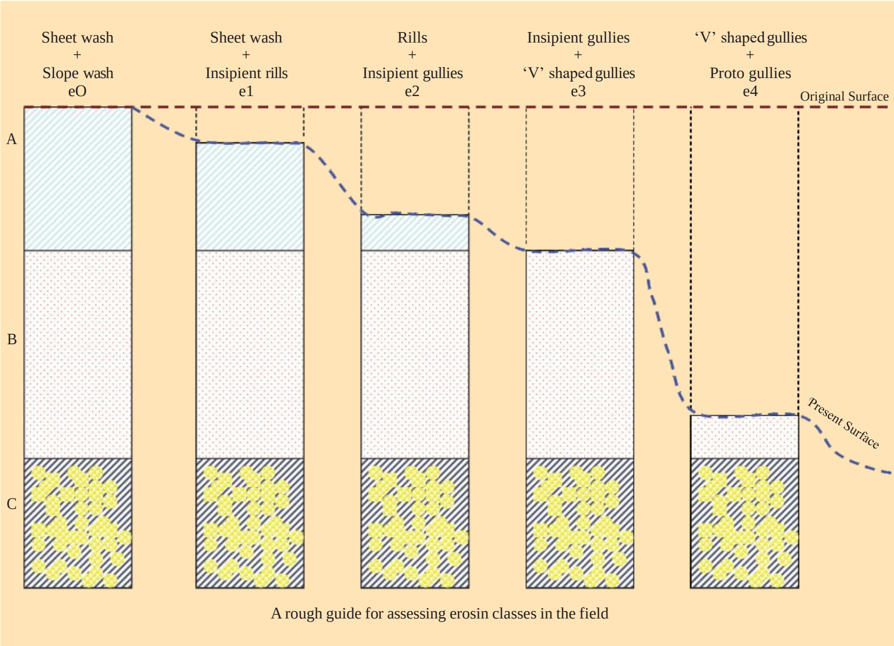


Fig 5.6 A rough guide for assessing erosion classes in the field

Class 3 (severe erosion)

This class consists of soils that have lost, on the average, 75 per cent or more of the original A horizon or of the uppermost 20 cm if the original A horizon was less than 20 cm thick. In most areas of class 3 erosion, material below the original A horizon is exposed at the surface in cultivated areas; the plough layer consists entirely of this material. Even where the original A horizon was very thick, at least some mixing with underlying material is common.

Class 4 (very severe erosion)

This class consists of soils that have lost all of the original A horizon or the uppermost 20 cm if the original A horizon was less than 20 cm thick. In addition, Class 4 includes some or all of the deeper horizons throughout most of the area. The original soil can be identified only in small areas. Some areas may be smooth, but most have an intricate pattern of gullies.

Indicate the kind or degree and class of erosion observed at the profile site in the proforma.

5.19 Surface Runoff

Surface runoff or external soil drainage refers to the loss of water (includes both rainfall and water flowing from other or nearby soils) from an area by flow over the land surface. Six runoff classes are recognized based on the characteristics of the soil profile, soil slope, climate and vegetative cover.

1. **Ponded** - None of the water added to the soil as precipitation or by flow from surrounding areas escapes as runoff. This condition occurs normally in depressed areas.

2. **Very slow** - Surface water flows away **very slowly** that free water lies on the surface for long periods or enters immediately into the soil. In very slow condition, most of the water either passes through the soil or evaporates into the air. This condition is observed normally in level to nearly level areas or in very porous sandy soils (Fig 5.7).

3. **Slow** - Surface water flows away **slowly** that free water lies on the surface for significant periods or enters rapidly into the soil. In very slow condition, large part of the water either passes through the soil or evaporates into the air. This condition is observed normally in nearly level or very gently sloping areas or in sandy soils. Normally there is little or no erosion hazard.

4. **Medium** - Surface water flows away at such a rate that a moderate proportion of the water enters the soil and free water lies on the surface for only short periods. In this condition, large part of the rainfall is absorbed by the soil and used for plant growth. The erosion hazard may be slight to moderate when these soils are brought under cultivation.

5. **Rapid -** A **large part** of the rainfall moves rapidly over the surface of the soil and a **small part** moves through the soil profile. In this condition, water runs off nearly as fast as it is added on the surface. Rapid runoff areas are observed normally in moderately steep to steep areas and in soils with low infiltration capacity. The erosion hazard is normally moderate to high.

6. **Very rapid -** A **very large** part of the rainfall moves rapidly over the surface of the soil and a **very small part** moves through the soil profile. In this condition, water runs off as fast as it is added on the surface. Rapid runoff areas are observed normally in steep to very steep areas and in soils with low infiltration capacity. The erosion hazard is normally high or very high.

Fig. 5.7 Very slow runoff in level to nearly level fields, normally results in the development of salinity in poorly drained soils

5.20 Natural Drainage Classes

Natural drainage class refers to the frequency and duration of wet periods under conditions similar to those under which the soil developed (Table 5.1 and Fig 5.8). Alteration of the water regime, either through drainage or irrigation, is not a consideration unless the alterations have significantly changed the morphology of the soil. After completing the profile study, go through the description provided in above table and compare the soil colour and occurrence of mottles with the chart to find out the drainage class for the soil.

Table 5.1. Description of various drainage classes of soil

Drainage class	Characteristics	Normal water table depth (cm)	Mottles, gleying, & redoximorphic features
Excessively drained	Water is removed from the soil very rapidly. Soil is commonly very coarse textured and have very high hydraulic conductivity or are very shallow or rocky	>100	None in profile
Somewhat excessively drained	Similar to excessively drained soils, but the water table may not be as deep and the soil may be slightly fine textured.	>100	None in profile
Well drained (Fig 5.9)	Water is removed from the soil readily but not rapidly. Internal free water occurrence is very rare or very deep. Water is available to plants throughout most of the growing season. Wetness does not inhibit growth of roots for most or all of the growing season.	at or nearer to 100	Mottles in C or BC horizon
Moderately well drained	Water is removed from the soil somewhat slowly. Soil is wet for only a short time within the rooting zone during the growing season, but long enough that most mesophytic crops are affected. These soils commonly have a slowly pervious layer within the upper one metre, periodically receive high rainfall, or both.	75 - 100	Mottles in lower or middle B horizon and in C horizon
Somewhat poorly drained (imperfectly drained earlier) (Fig.5.10)	The soil is wet at a shallow depth for significant periods during the growing season. Wetness restricts the growth of crops unless artificial drainage is provided. The soils commonly have a pervious layer, a high water table, additional water from seepage and/or nearly continuous rainfall	30 - 75	Mottles in upper B horizon; C and lower B horizons are often gleyed
Poorly drained (Fig.5.11)	The soil is wet at shallow depths periodically during the growing season or remains wet for long periods. Internal free water is shallow or very shallow and common or persistent. Unless the soil is artificially drained, most mesophytic crops cannot be grown. The soil, however, is not continuously wet directly below plow depth. The water table is commonly the result of a low or very low saturated hydraulic conductivity class or persistent rainfall or a combination of these factors.	< 30	Mottles throughout the profile; soil is gleyed in the upper B and lower horizons
Very poorly drained	Similar to poorly drained soils except that the soils occur on level or depressed areas and are frequently ponded.	At surface or < 15	Entire profile has mottles and soil may be gleyed

Source: Soil Survey Division Staff (1993) and R. Schaetzl and S. Anderson (2005)

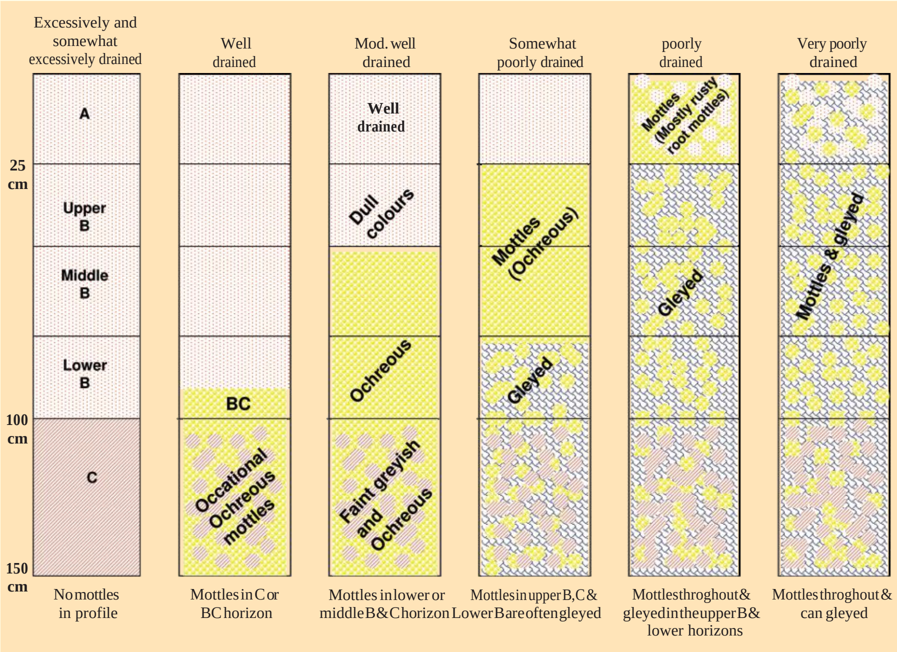


Fig 5.8 Morphological changes observed in soils due to prolonged wetness and poor drainage

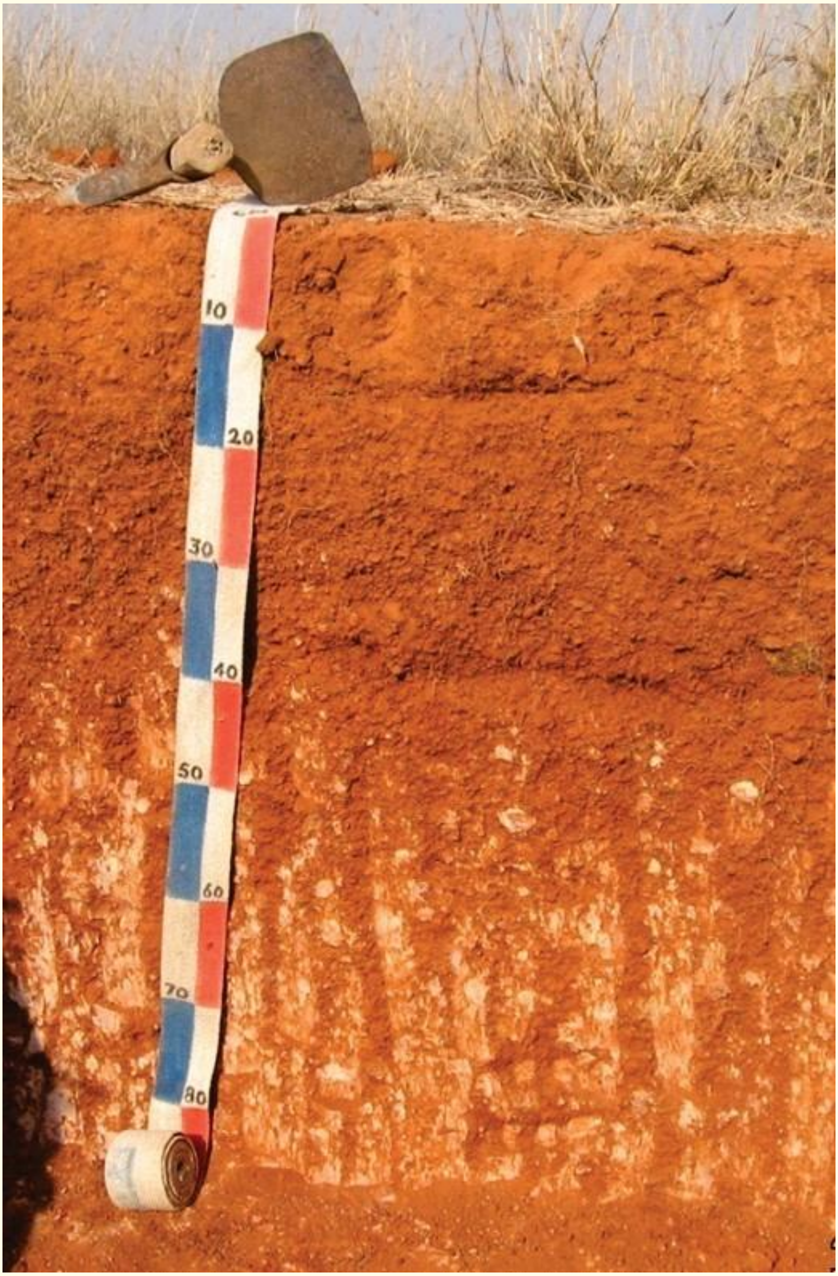


Fig.5.9 Well drained soils in which water is removed from the soil readily without any stagnation and at the same time available to plants throughout most of the growing season (Red soil profile, Kolar district)

Fig.5.10 Somewhat poorly drained soils, mottles in the upper B and gleyed in the lower B horizon, Mandya district

Fig.5.11 Poorly drained soils, gleyed upto the surface layer, Chikkarasinakere series, Mandya district

5.21 Ground water depth

Indicate the depth of the water table and seasonal fluctuations of the profile site area. The water table measurements can be taken from the nearest open or bore wells or by enquiring with the farmers of the area.

5.22 Flooding

Wherever records are available they can be collected, and the frequency can be indicated and in other areas, it can be estimated based on the site characteristics and other converging evidences

Frequency	Classes Criteria
None	No possibility of flooding in the area
Rare	1 to 5 times in 100 years
Occasional	5 to 50 times in 100 years
Frequent	>50 times in 100 years, ie, once in two years
Very frequent	Every month > 15 days in a year, used for tidal flooding.

Estimate the Frequency, Duration and Months that flooding is expected, e.g., rare, brief, July-August

5.23 Salt / alkali (per cent surface coverage)

The presence of salinity or alkalinity can be identified based on the occurrence of barren areas, presence of salt tolerant crops like prosopis (Fig.5.12) and very poor or stunted growth of plants (Fig 5.13). Presence of white encrustation on the surface of the soil is an indication of salinity and smooth or fluffy feel to the feet indicates alkalinity in the field. Observe the extent of the area covered by the saline or alkali areas and indicate the per cent surface cover in the column provided.

Fig. 5.12 Salt encrustation and growth of prosophis due to severe land salinity in Kalgeri village, Koppal district

Fig.5.13 Stunted growth of coconut due to severe salinity, Harve SWS, Chamarajanagar district

5.24 Soil Reaction (pH)

In the field, pH is estimated by using a variety of field test kits like pH indicator papers and portable pH meter. Depending on the availability and convenience, either of the two methods can be used to find out the reaction of the soil. After estimation, tick the appropriate pH values given in the column. Though the soil reaction classes used are normally narrow in their range, for field estimation a combination of classes, as indicated in the proforma is sufficient.

5.25 Electrical Conductivity (EC)

It is a measure of the concentration of water-soluble salts in soils. The occurrence of bare spots, salt tolerant crops like prosopis and uneven crop growth are indicators of salinity and high EC in the field. Portable field EC meters are used to estimate the salt content (extract from saturated soil paste). Wherever field estimation of EC is not possible, try to infer the approximate EC values of the area and indicate it in the respective column.

5.26 Surface fragments

This refers to the presence of coarse fragments (>2 mm in size) on or near the soil surface. The classes used are pebbles, cobbles, stones, and boulders based on their size. Gravel is a collection of pebbles that have diameters ranging from 2 to 75 mm. The size of the cobbles ranges from 75 to 250 mm (3 to 10 inches), stones from 250 to 600 mm (10 to 24 inches) and boulders above 600 mm (>24 inches). Assessment for the surface fragments is done separately for the gravel and for stones and boulders. Indicate the size of the fragments observed in the field. The following classes, based on the areal coverage, are used for gravel (Fig 5.14 & 5.15)

Gravelliness class	% of area covered
Non gravelly	< 15 per cent
Gravelly	15 to 35 per cent
Very gravelly	35 to 60 per cent
Extremely gravelly	60 to 80 per cent
Considered as part of the top soil	> 80 per cent

Fig 5.14 Very gravelly surface with more than 50 % area covered by gravel

Fig 5.15 Gravelly surface with 15 to 35 % area covered by gravel

The approximate amount of stones and boulders present at the surface has to be assessed and reported. The stoniness classes used are indicated below.

The approximate amount of stones and boulders present at the surface has to be assessed and reported. The stoniness classes used are indicated below.

Stoniness class	Percentage of surface covered
Stony (class 1)	0.01 to 0.1 per cent of the surface
Very stony (class 2)	0.1 to 3 per cent of the surface
Extremely stony (class 3)	3 to 15 per cent of the surface
Rubbly (class 4)V	15 to 50 per cent of the surface
ery rubbly (class 5)	>50 per cent of the surface

5.27 Rock outcrops

The distance between the rock outcrops and their percentage coverage in the field is to be recorded as indicated below (Fig 5.16 & 5.17).

Per cent coverage	Description
< 2	No rocks or very few rocks to interfere with tillage
2 to 10	Fairly rocky, sufficient to interfere with tillage but not to make inter-tilled crops impracticable. Exposures are roughly 35 to 100 m apart.
10 to 25	Rocky, sufficient to interfere with tillage of inter-tilled crops impracticable. Exposures are roughly 10 to 35 m apart.
25 to 50	Very rocky, sufficient to make all use of machinery impracticable, except for light machinery. Exposures are roughly 3.5 to 10 m apart.
50 to 90	Extremely rocky, sufficient rock outcrops to make all use of machinery impracticable. Exposures are about 3.5 m apart or less.
Over 90	Rock outcrops


Fig 5.16 Very rocky with about 25 to 50 % area under rock outcrops, Attikatti-5 MWS, Gadag district


Fig.5.17 Rocky with about 20 % of the area under rock outcrops, Nabapur Tanda 1 MWS, Gadag district

5.28 Elevation

Elevation refers to the height of a point on the earth's surface, relative to mean sea level. It can be determined by interpolation from the topographic map contours or by using Global Positioning System (GPS). The elevation of the area is to be noted in the box based on the GPS measurement, e.g., 540 m. The latitude and longitude coordinates can be used to extract an elevation value from a higher resolution Digital Elevation Model, wherever the same is available for the area.

5.29 Land Use

Indicate the name of the crop or combination of crops (common names like bajra, ragi etc. are preferred) cultivated in the current season and wherever possible the crops cultivated in the previous season, if they are different from the present one (Fig 5.18). Also provide the approximate yield/ha and management level (low, medium, or high) followed by the farmer for the major crops cultivated. If the crop is irrigated, indicate the method of irrigation, and indicate the major and minor crops if it is a mixed one.

Fig.5.18 Mosaic of rainfed crops in Nabhapur Tanda-1 MWS, Gadag district

5.30 Vegetation

The type of natural vegetation observed should be described first in simple terms, like evergreen, deciduous or shrub forests, grasslands etc., and then their common names and species names wherever possible (Fig 5.19 & 5.20). Generally, a close relationship exists between native vegetation and kinds of soil. The growth and stand of native vegetation and cultivated crops will be of great help in recognizing soil boundaries in many situations. Even within a field, differences of vigour, stand, or colour of the crop or of weeds commonly mark soil differences and as such are valuable clues to the location of soil boundaries in the field to the surveyor.

Fig.5.19 Natural vegetation consisting of deciduous tree species and shrubs in Gonthmar watershed area, Belgaum district

Fig.5.20 Degraded lands with shrub vegetation in Chamarajanagar district

Chapter 6

Profile study and description of Soil characteristics

Soil is a natural, 3-Dimensional body that has formed at the earth's surface, through the interactions of at least five soil forming factors (climate, biota, relief, parent material and time) and multitudes of soil forming processes. It varies spatially in the horizontal and vertical dimensions. Systematic description of soil characteristics is essential to understand the formation of soils in a study area, grouping similar soils and for mapping their geographic extent. Soil properties are studied in the field by excavating a profile or auguring in a representative area. Normally a pit size of approximately 1 meter across, 2 meters along and 2 meters deep is sufficient for the study of most of the soils in the field (Fig 6.1).

After the excavation, the sides of the pit are cleaned carefully and ped faces are exposed to the sunlight by using a pocketknife or kurpi. The exposed profile face is examined carefully, starting from the top and working downward, to identify any changes in the properties of the soil. Based on the changes observed, boundaries between layers are marked on the face of the pit, and the layers are identified and described. Photographs are to be taken immediately after identifying the layers or horizons and before attempting the study of soil properties. Also, estimation of the volume of stones and features that may be destroyed during the study of the soils should be completed before the layers/horizons are disturbed.

Apart from the excavated profiles, road cuts, quarries, well cuts and any other fresh cuts can also be used to describe the soils of the survey area. However, caution is necessary in studying very old pits or disturbed areas and they must be indicated as such in the proforma.

This chapter provides the necessary guidelines needed for identifying and describing various soil characteristics observed in the excavated profile. The format used to describe the soil profile characteristics is given in the next page, followed by description of the soil properties to be studied and explanatory notes for filling the proforma.

6.1 Soil Depth

Soil depth indicates the depth of the solum, which includes A and B horizons, occurring above the parent material or hard rock. Depth is measured from the soil surface. For soils with a cover of 80 per cent or more rock fragments on the surface, the depth is measured from the surface of the rock fragments. Generally, all the four faces of the pit will not be uniform, and care is necessary to select the typical or representative face of the pit for the study of the profile. Also, the thickness of each horizon or layer may vary within a pedon and this variation can be indicated by recording the average thickness and range in thickness of the horizon; e.g., 12 cm (10- 15 cm).

The limits used to group the soils into various depth classes in the survey area are

Very shallow	< 25 cm
Shallow	25-50 cm
Moderately shallow	50-75 cm
Moderately deep	75-100 cm
Deep	100-150 cm
Very deep	> 150 cm

Land Resource Inventory-Proforma for Soil Description

Observation Method: | Auger p | Minipit | Roadcut

	Depth (cm)	Horizon	Bnd[1] D T	Diag. Hori.	Matrix Color Dry	Matrix Color Moist	Texture[2]	% clay	Rock Frags[3] Sz Knd Vol	Structre [4] Grade Sz Type	Consistence [5] Dry Mst Stk Pls
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

	Mottles/ Redox features [6] Qty Sz Cn Col Sp Loc	Coats/Films/Stress Features[7] Amt Dst Cont Kd Loc Col	Concentrations[8] (Conca, Conir, etc.,) Qty Sz Cn Kd Col	**Roots** [9] Qty Sz Lc	**Pores** [10] Qty Sz Shp	**pH**	Effer[11] (dil Hcl) -1,2,3	**Sample bag No.**

1. **D-Distinctness:** a-abrupt, c-clear, g-gradual, d-diffuse, **T-topography:** s-smooth, w-wavy, i -irregular, b-broken

2. **Texture:** s-sand, ls-loamy sand, sl -sandy loam, l -loam, sil -silt loam, si-silt, scl -sandy clay loam, cl -clay loam, sicl -silty clay loam, sc-sandy clay, sic-silty clay, c-clay.

3. **Size:** fg- fine gravel(<2cm), cg-coarse gravel(2-7.5cm), cb-cobbles(7.5-25cm), st-stones(25-60cm), b-boulders(>60cm).

4. **Grade:** 0-structureless, 1-weak, 2-moderate, 3-strong; **Size:** vf-very fine, f-fine, m-medium, c-coarse, vc-very coarse **Type:** gr-granular, cr-crumb, clr-columnar, pr-prismatic, pl-platy, abk-angular blocky, sbk-subangular blocky, sg-single grain, m-massive, c-cloddy.

5. **Dry:** l-loose, s-soft, sh-slightly hard, h-hard, vh-very hard, eh-extremely hard, **Moist:** l-loose, vfr-very friable, fr-friable, fi-firm, vfi-very firm, efi-extremely firm, **Stickyness:** so-non-sticky, ss-slightly sticky, ms-moderately sticky, vs-very sticky, **Plasticity:** po-non-plastic, sp-slightly plastic, mp-moderately plastic, vp-very plastic.

6. **Quantity(qty):** f-few (<2%), c-common(2-20%), m-many (>20%); **Size(sz):** 1-fine(<2mm), 2-medium(2-<5mm), 3-coarse (5-<20mm), 4-very coarse (>20mm); **Contrast(cn):** f-faint, d-distinct, p-prominent ; **Colour(col); Shape(sp):** c-cylindrical, d-dendritic, i-irregular, p-platy, s-spherical, t-threads, r-reticulate; **Location(Loc)**-matrix/ped/pores/others.

7. **Amount(Amt):** vf-very few(<5%), f-few(5-<25%), c-common(25-<50%), m-many(50-<90%), vm-very many(>90%);**Distinctness(Dst):** f-faint, d-distinct, p-prominent; **Continuity(Cont):** c-continuous, d-discontinuous, p-patchy; **Kind(Kd):** Type of coating/stress features; **Location(Loc)**: on bottom/top or all faces of peds; **Colour(Col)**: Munsell

8. **Concentrations:** Quantity(qty), Size(sz), Contrast (cn) and Colour are to be described similar to that of the mottles; **Kind(Kd)**: Disseminated materials, Masses, Nodules, Concretions, Crystals and Biological concentrations.

9 & 10. **Roots/Pores: Quantity**: f-few (<1 per area), c-common (1-5), m-many (>5); **Size**: vf-very fine, f-fine, m-medium, c-coarse; vc- very coarse; **Location(Loc):** between peds(p), in cracks(c), throughout(t); **Shape(Shp):** tubular/irregular/vesicular/interstitial. 11. **Effervescence:** 1-slight, 2-strong, 3-violent.

6.2 Horizon

Horizon development indicates the extent and degree of soil formation or genesis. It varies widely from soil to soil. In the early stages of soil formation, horizon development may be weak. As the age increases, horizons develop slowly and exhibit distinct characteristics in well-developed soils (Fig 6.1).

Fig.6.1 A well-developed soil profile, normally seen in the upland soils formed from the weathering of granite or gneissic rocks

Designations for horizons

Layers and horizons of different kinds are identified by symbols. Three kinds of symbols are used to designate them. Capital letters (O, A, E, B, C, R and W) are used to designate the master horizons and layers. Lower case letters are used as suffixes to indicate specific characteristics of master horizons and layers. Arabic numerals are used both as suffixes to indicate vertical subdivisions within a horizon or layer and as a prefix to indicate discontinuities (Fig 6.2).

Master Horizons and Layers

O horizons or layers

This layer is dominated by organic material. They consist of undecomposed or partially decomposed litter, deposited on the surface of either mineral or organic soils. The O layer may be present on the surface of a mineral soil or at any depth beneath the surface, if it is buried. A horizon formed by illuviation of organic material into mineral subsoil is not considered as an O horizon.

A horizons

It is a mineral horizon formed at the surface or below O horizon. They exhibit obliteration of all or much of the original rock structure and show an accumulation of humified organic matter intimately mixed with the mineral fraction. This horizon is not dominated by properties of either E or B horizons or properties resulting from cultivation, pasturing, or similar kinds of disturbance.

E horizons

Mineral horizon in which the main feature is loss of silicate clay, iron, aluminium, or some combination of these, leaving a concentration of sand and silt particles. These horizons exhibit obliteration of all or much of the original rock structure. This horizon is usually lighter in colour than B and A horizons. The organic matter is normally less than A horizon and occurs commonly near the surface (below O or A horizon and above B horizon).

B horizons

Horizons that formed below an A, E, or O horizon and are dominated by obliteration of all or much of the original rock structure and show one or more the following:

1. illuvial concentration of silicate clay, iron, aluminium, humus, carbonates, gypsum, or silica, alone / in combination
2. evidence of removal of carbonates

3. residual concentration of sesquioxides
4. coatings of oxides that makes the horizons lower in value, higher in chroma, or redder in hue than overlying and underlying horizons without any illuviation of iron.
5. alteration that forms silicate clay or liberates oxides or both and that forms granular, blocky or prismatic structure
6. brittleness or gleying

C horizons

Horizons or layers, excluding hard bedrock, that are little affected by pedogenic processes and lack properties of O, A, E, or B horizons. The material of C layers may be either like or unlike that from which the solum presumably formed. The C horizon may have been modified even if there is no evidence of pedogenesis.

R layers: Hard Bedrock

The R layer is sufficiently coherent when moist to make hand digging with a spade impractical, although it may be chipped or scrapped. Granite, gniess, quartzite, sandstone, indurated limestone etc are some examples of the bedrock seen in the state and are designated as R.

Transitional horizons

Horizons dominated by properties of one master horizon but having subordinate properties of another. Two capital letter symbols are used to designate the transitional horizons (AB, EB, BE, BC, CB). The master horizon symbol that is given first designates the kind of horizons whose properties dominate the transitional horizon.

Combination horizons

Horizons in which distinct parts have recognisable properties of the two kinds of master horizons indicated by the capital letters. The two capital letters are separated by a slash as A/B, E/B, B/E, B/C.

Harizon	Criteria
0	Organic soil materials
A	Mineral; organic matter (humus) accumulation, loss of Fe, Al, clay
AB (or AE)	Dominantly A horizon characteristics but also contains some characteristics of the B (Or E) horizon
A/B (or A/E) (or A/C)	Discrete, intermingled bodies of A and B (or E, or C) material; majority of horizon is A material
AC	Dominantly A horizon characteristics but also contains some characteristics of C horizon
E	Mineral; loss of Fe, Al, clay, or organic matter
EA (or EB)	Dominantly E horizon characteristics but also contains some attributes of the A (or B) horizon
E/A (or E/B)	Discrete, intermingled bodies of E and A horizon (or E and B) material; majority of horizon is E material
E and Bt (Or B and E)	Thin lamellae (Bt) within a dominantly E horizon (or thin E within dominantly B horizon)
BA (or BE)	Dominantly B characteristics but also contains some attributes of A (or E) horizon
B/A (or B/E)	Discrete, intermingled bodies of B and A (or E) material majority of horizon is B material
B	Subsurface accumulation of clay, Fe, Al, Si, humus, $CaCO_3$, $CaSO_4$; or loss of $CaCO_3$; or accumulation of sesquioxides; or subsurface soil structure
BC	Dominantly B horizon characteristics but also contains some characteristics of the C horizon
B/C	Discrete, intermingled bodies of B and C material; majority of horizon is B material
CB (or CA)	Dominantly C horizon characteristics but also contains some characteristics of the B (or A) horizon
C/B (or C/A)	Discrete, intermingled bodies of C and B (or A) material; majority of horizon is C material
C	Little or no pedogenic alteration, unconsolidated earthy material, soft bedrock
R	Bedrock, Strongly Cemented to Indurated
W	A layer of liquid water (W)

Subordinate Distinctions within Master horizons

They are referred earlier as Horizon Suffixes or Subscripts. Lower case letters are used as suffixes to designate specific kinds of master horizons and layers. The symbols used commonly are indicated in the table below.

Horizon Suffix	Criteria
a	Highly decomposed organic matter. Used with O horizon
b	Buried genetic horizon (not used with C horizons)
c	Concretions or nodules
d	Densic layer (physically root restrictive)
e	Moderately decomposed org. matter
g	Strong gley (Fe reduced and pedogenically removed); chroma 2 or less; may have other redoximorphic (RM F) features.
h	Illuvial organic matter accumulation, seen as coatings on sand and silt particles and filling of the pores
I	Slightly decomposed organic matter, rubbed fiber content is >40% by vol.
j	Jarosite accumulation, e.g., acid sulfate soils.
k	Accumulation of (pedogenic) carbonates
m	Strong cementation (pedogenic, massive)
n	Pedogenic, exchangeable sodium accumulation
o	Residual sesquioxide accumulation (pedogenic)
p	Plow layer or other artificial disturbance
q	Secondary (pedogenic) silica accumulation
r	Weathered or soft bedrock
s	Illuvial accumulation of sesquioxides
ss	Presence of slickensides
t	Illuvial accumulation of silicate clay
v	Presence of plinthite
w	Weak color or structure within B (used only with B)
x	Fragipan characteristics
y	Pedogenic accumulation of gypsum
z	Pedogenic accumulation of salt more soluble than gypsum

Conventions for using letter suffices

- Master horizon symbol (capital letter) should be followed by one or more lower case letters.
- Normally up to two suffices are used and more than three suffices are rarely used. When more than one suffix is used, a, e, h, i, r, t and w are given preference and written first after the capital letter followed by other suffixes.
- B horizon with significant accumulation of clay and also showing evidence of colour or structure, or both, is designated as Bt and not as Btw or Bts or Btws (t has precedence over w, s, and h).

Vertical subdivision

The subdivision of a horizon or layer designated by a single letter, or a combination of letters is indicated at the end by the use of Arabic numerals. For example, the subdivision of B horizon can be shown as Bt1-Bt2-Btk1-Btk2 and not as Bt1-Bt2-Btk3-Btk4.

Discontinuities

Arabic numerals are used as prefixes (preceding A, E, B, C, and R) to indicate discontinuities in mineral soils. Discontinuity is indicated by significant or abrupt change in texture, age or mineralogy between the layers or horizons. Examples: A-Bt-C-2R, Ap-Bt1-2Bt2-2Bt3-2BC-C

Fig. 6.2 Typical horizon designations used to describe the state of profile development in major soils of Karnataka

6.3 Boundaries of Horizons and Layers

A transitional area or layer present between two adjoining horizons or layers is known as the boundary. Boundaries vary in **distinctness** (contrast) and in **topography**.

Distinctness

Distinctness is the distance through which one horizon grades into another. It refers to the thickness of the zone within which the boundary can be located. The distinctness depends on the degree of contrast between the layers and thickness of the transitional zone. Distinctness is defined in terms of thickness of the transitional zone.

Distinctness Class	Criteria: transitional zone thickness
Very Abrupt or sharp	Less than 0.5 cm
Abrubt	0.5 to < 2 cm
Clear	2 to < 5 cm
Gradual	5 to < 15 cm
Diffuse	> 15 cm

Topography

Topography is the lateral undulation and continuity of the boundary between horizons. Topography refers to the irregularities of the surface that divides the horizons (Fig.6.3 & 6.4).

Smooth	The boundary is a plane one with few or no irregularities
Wavy	The boundary has undulations in which the width of undulation is more than the depth
Irregular	Similar to wavy in which the depth of undulation is more than the width
Broken	Discontinuous horizons; discrete but intermingled, or irregular pockets

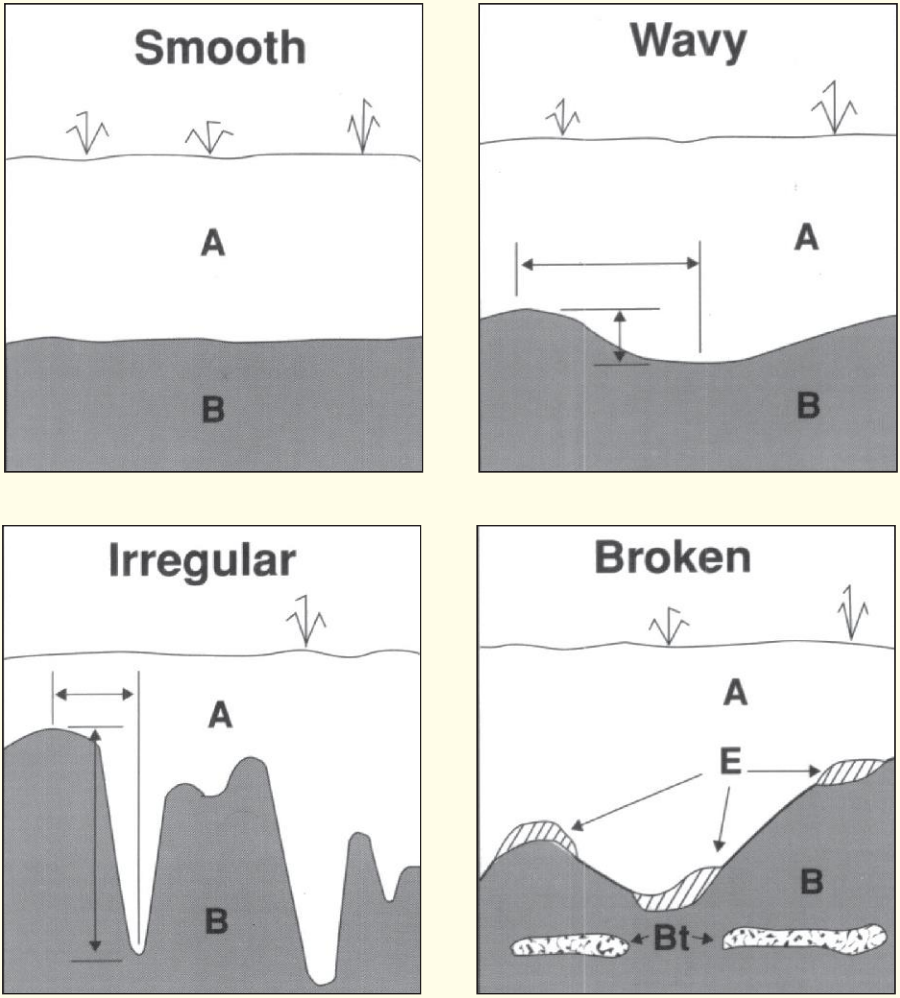


Fig.6.3 Topography of the soil boundaries as seen in the field

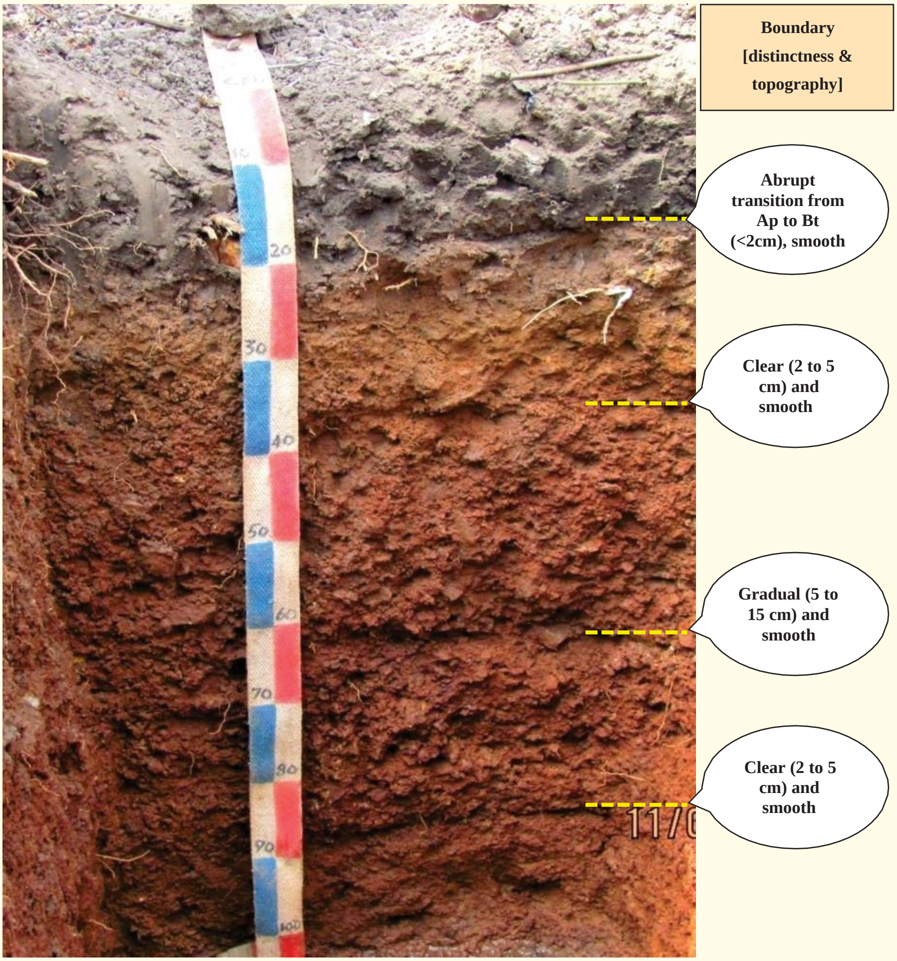


Fig 6.4 Distinctness (contrast between two layers) and topography (undulation) ' of a typical red soil profile under irrigation developed from granite/gneiss, Chikkarasinakere, Mandya district

In the above pedon, the contrast between the surface and subsoil is very sharp and the change is observed well within two cms between these two layers. So the contrast or distinctness in the boundary seen between these two layers can be designated as abrubt and the topography as smooth. Between the second and third layer the change is observed to take place between 2 and 5 cm width, and hence designated as clear, between third and fourth layer the transition is gradual since the change is observed to occur between 5 and 15 cm.

6.4 Diagnostic horizons

This column is to be filled after thorough examination of the soil profile in the field. Identify the type of the diagnostic horizon present in the soil and their upper and lower boundaries. Diagnostic horizons expected to occur in the state are indicated below.

Diagnostic surface horizons (Epipedons)	
Anthropic	This is formed due to the influence of humans
Mollic	Thick, dark coloured, humus rich horizon with good structure and porosity and normally formed from grass vegetation
Umbric	It resembles to that of mollic, but mostly formed under forest vegetation and have low fertility status than the mollic epipedon
	They do not have any specific characteristics to place in a particular diagnostic horizon
Diagnostic subsurface horizons	
Cambic	Altered horizon (of 15 cm or more thick) formed due to the alteration of texture, structure, or change in colour.
Argillic	It has significantly higher amount of illuvial clay, which can be observed by the presence of clay coatings or cutans or bridges.
Duripan	Silica cemented subsurface horizon
Natric	It has all the characteristics of argillic horizon and, in addition, has sodium accumulation (ESP >15 %) with columnar or prismatic structure.
Kandic	Dominated by low activity clays, occurs in highly weathered soils
Calcic	Formed due to the illuvial accumulation of secondary $CaCO3$ (15 per cent calcium carbonate equivalent).
Petrocalcic	Horizon with illuvial secondary calcium carbonate or other carbonates, cemented or indurated by carbonates without silica
Gypsic	Secondary gypsum accumulated horizon ($\geq$15 cm thick, not cemented or indurated, 5 % or more gypsum)
Salic	Horizon of salt accumulation that are more soluble than gypsum, EC of >30 dS/m

6.5 Soil colour

Soil colours are measured in the field by comparing peds with Munsell Colour Chart (Fig.6.5). The notation is recorded in the form of hue, value and chroma - for example, 5YR 5/3. **Hue** is a measure of the chromatic composition of light that reaches the eye. **Value** indicates the degree of lightness or darkness of a colour in relation to a neutral grey scale. The value is a measure of the amount of light that reaches the eye under standard lighting conditions.

Grey is perceived as about halfway between black and white and has a value notation of 5/. **Chroma** is the relative purity or strength of the spectral colour. The scales of chroma for soils extend from /0 for neutral colours to a chroma of /8 as the strongest expression of colour used for soils.

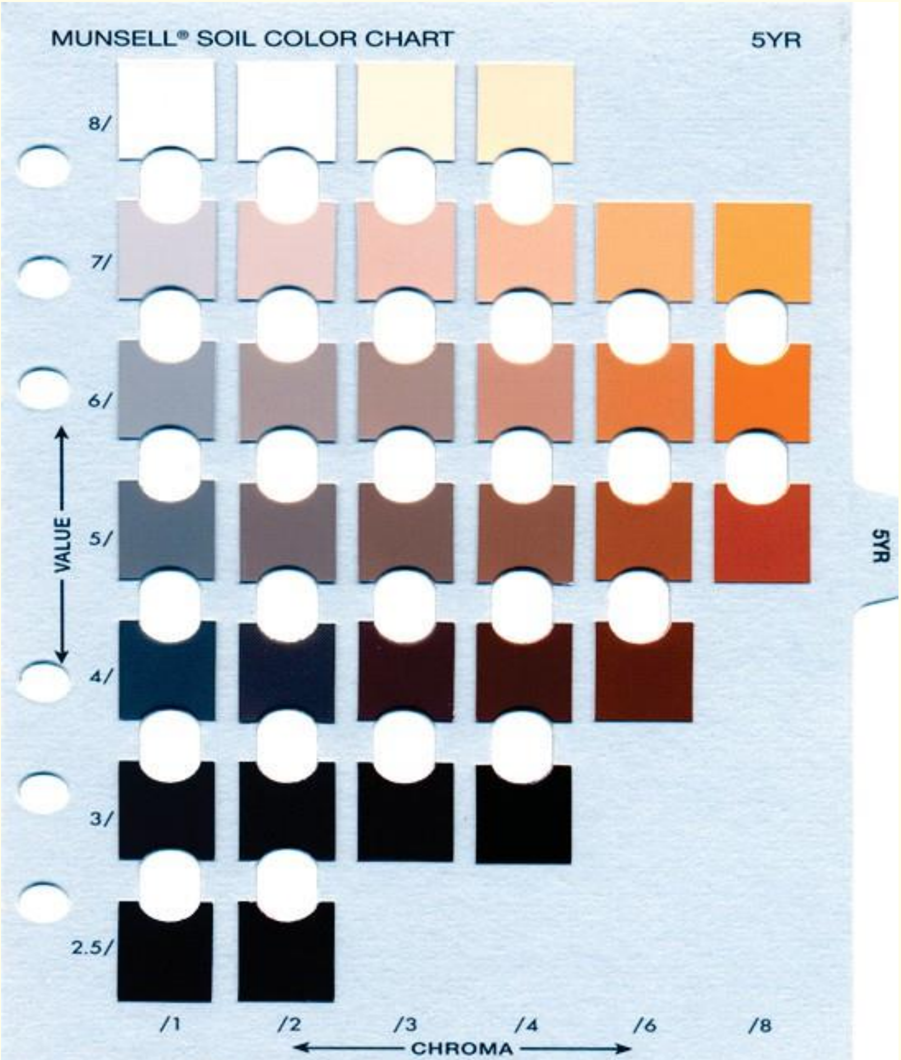


Fig. 6.5 The colour notations as arranged in the colour chip 5YR

Conditions for measuring soil colour

Measurement of soil colour is affected by the quality and intensity of light, moisture content and roughness of the sample selected. Determination done either early in the morning or late in the evening will not be accurate (Fig.6.6). Also, when the sun is low or the atmosphere is smoky, the light reaching the sample and the light reflected will be more towards redder colour. Colours also appear different in the subdued light of a cloudy day than in bright sunlight. Hence, determination of soil colour is undertaken in shade by utilising the shadow of the person holding the colour chart.

Fig.6.6 Typical soil colours as observed in red (5YR 4/6) and black soils (10YR 3/1) of Karnataka

6.6 Mottling

Mottles are spots of different colours which are different from colour variation associated with ped surfaces, worm holes, concretions, nodules, etc. Redoximorphic features are a type of mottling that is associated with wetness. Redoximorphic features and ped and void surface features like clay films are excluded from mottles description. Mottles are described by quantity, size, contrast, colour, and shape in that order.

Quantity indicates the per cent of horizon area covered by mottles.

Few	< 2 % of surface area
Common	2 to 20 % of surface area
Many	> 20 % of surface area

Mottling size refers to dimensions as seen on a plane surface. It is measured along the greatest dimension except in linear forms. The size classes used are

	< 2 mm
Fine	2 to < 5 mm
Medium	5 to < 20 mm
Coarse5 to	> 20 mm
Very Coarse	

Mottling Contrast refers to the degree of visual distinction that is evident between associated colours. Record the colour difference between the mottle and the dominant matrix colour and express the contrast as indicated below

Faint	Evident only on close examination. Faint mottles commonly have the same hue as the colour to which they are compared and differ by no more than 1 unit of chroma or 2 units of value
Distinct	Readily seen but contrast only moderately with the colour to which they are compared
Prominent	Contrast strongly with the colour to which they are compared

6.7 Soil Texture

Soil texture refers to the relative proportion (per cent by weight) of sand, silt and clay present in a soil. Texture is estimated in the field by feel method or quantitatively measured in the lab by hydrometer or pipette method. Soil texture includes only the fine earth fraction (< 2 mm, like sand, silt and clay).

The texture classes range from sand to clay and some of the commonly occurring texture classes are briefly described below (Fig 6.7).

Sand	More than 85 % sand, the percentage of silt plus 1.5 times the % of clay is less than 15
Loamy sand	Between 70 and 91 % sand and the percentage of silt plus 1.5 t imes the percentage of clay is 15 or more, and the percentage of silt plus twice the percentage of clay is < 30
Sandy loam	7 to 20 % clay, > 52 % sand, and the percentage of silt plus twice the percentage of clay is 30 or more; or less than 7 % clay, < 50 % silt, and > 43 % sand
Loam	7 to 27 % clay, 28 to 50 % silt and 52 % or less sand
Silt loam	50 % or more silt and 12 to 27 % clay, or 50 to 80 % silt and less than 12 % clay
Silt	80 % or more silt and less than12 % clay
Sand clay loam	20 to 35 % clay, less than 28 % silt, and more than 45 % sand
Clay loam	27 to 40 % clay and more than 20 to 46 % sand
Silty clay loam	27 to 40 % clay and 20 % or less sand
Sandy clay	35 % or more clay and 45 % or more sand
Silty clay	40 % or more clay and 40 % or more silt
Clay	40 % or more clay, 45 % or more sand, and < 40 % silt

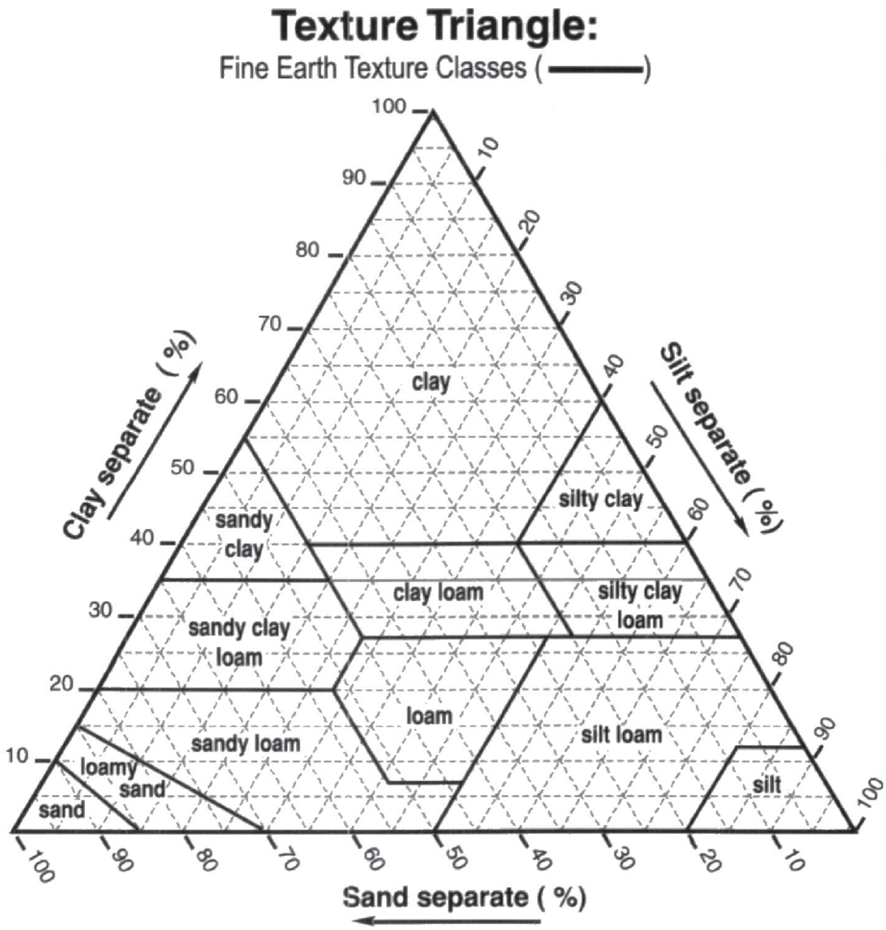


Fig. 6.7 Textural Triangle used for fixation of soil texture

Normally, sand particles feel gritty, and the grains can be seen with the naked eye. Silt cannot be seen with the naked eye, but they have a smooth feel to the fingers both in dry and wet conditions. Clayey soils exhibit sticky and plastic characteristics. Guidelines for the assessment of soil texture in the field are indicated in the table below (Table 6.1, Fig 6.8).

Modifiers used for describing soil texture

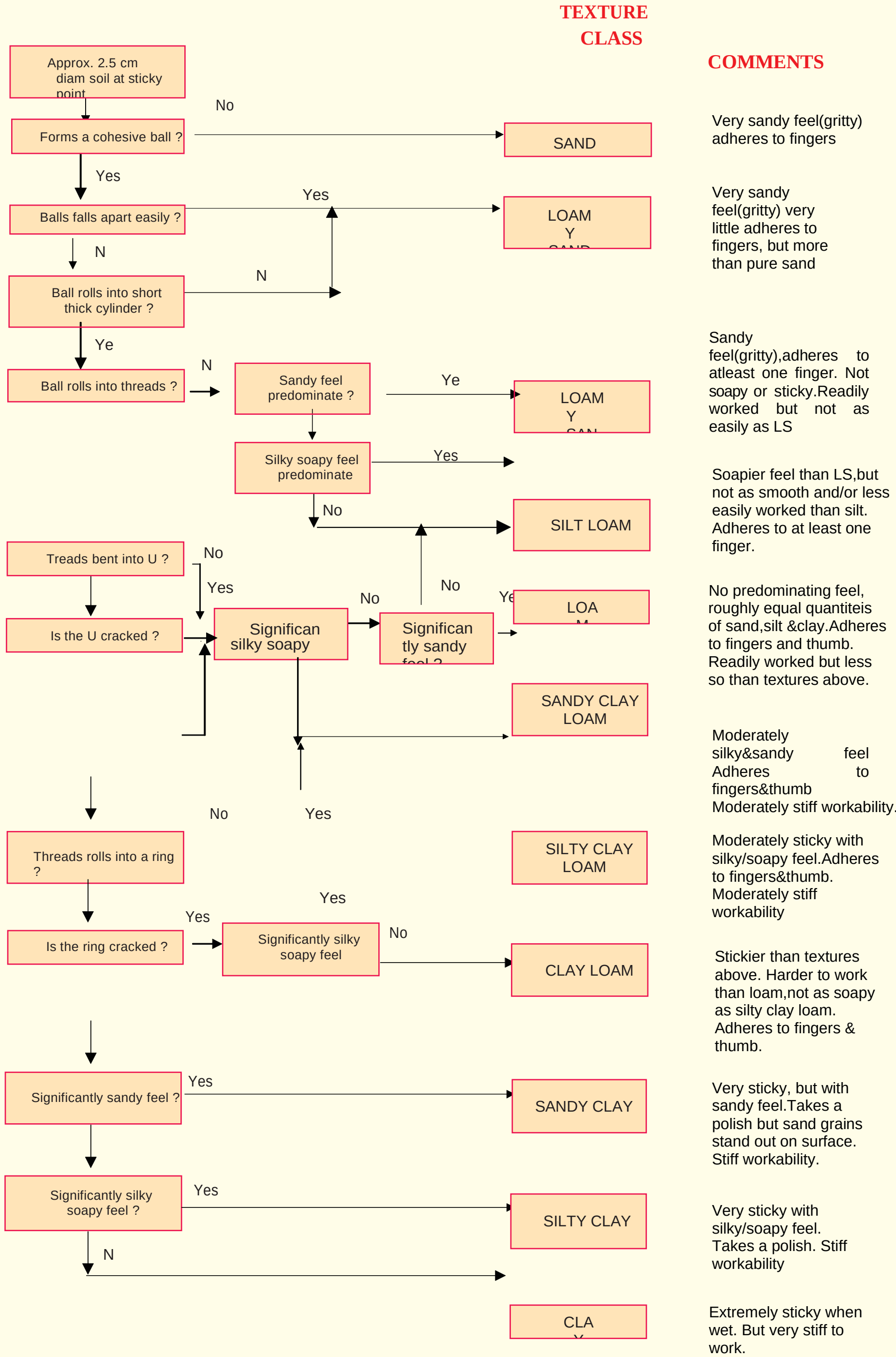
If the soil (fine earth) contains various rock fragments, their quantity and size are recorded and used as a modifier in describing the texture of the soil.

Rock fragments % by volume	Modifier used for texture description
< 15	No texture adjective is used (noun only; e,g., loam)
15 to < 35	Use adjective for appropriate size; e.g., gravelly
35 to < 60	Use “very” with the appropriate size adjective; e.g., very gravelly
60 to < 90	Use “extremely” with the appropriate size adjective; e.g., extremely gravelly
> 90	No adjective or modifier, If the soil contains < 10 % fine earth, use the appropriate noun for the dominant size class; e.g., gravel (used in lieu of texture).

Table 6.1 Guide for assessment of soil texture in the field

SL	No. Texture class	Feel	Coherence of the bolus at sticky point	Ribbon Length [mm]	Other features	Approx clay %
1	Sand [s]	Very gritty	Nil	Nil	Single sand grains adhere to fingers	<5
2	Loamy sand [ls]	Very gritty	Slight	5	Discolors fingers with an organic stain	5-10
3	Sandy loam [sl]	Gritty	Just coherent	15-25	Medium sand readily visible	10-20
4	Loam [l]	Neither very gritty nor very smooth	Coherent	About 25	No obvious sandiness	25
5	Silt loam [sil]	Smooth or buttery	Coherent	About 25	Silky; Very smooth when manipulated	25 (>25 silt)
6	Sandy clay loam [scl]	Moderately gritty	Strong	25-40	Medium sand in fine matrix	20-30
7	Clay loam [cl]	Slightly Gritty	Strong	40-50	No obvious sand grains	30-35
8	Silty clay loam [sicl]	Very smooth	Coherent	40-50	Silky feeling	30-35 (>25 silt)
9	Sandy clay [sc]	Sticky	Coherent	50-75	Fine to medium	35-40
10	Silty clay [sic]	Sticky	Coherent	50-75	Smooth and Silky	35-40 ((>25 silt)
11	Clay [c]	Sticky	Coherent	>75	Smooth with slight to fair resistance to shearing	35-50
12	Heavy Clay [hc]	Very sticky	Coherent	>75	Firm resistance to shearing	>50

A GUIDE TO FILED ASSESSMENT OF SOIL TEXTURE



Source: Encyclopedia of Soil science (2006)

Fig.6.8 Guide to assess soil texture in the field

6.8 Clay per cent in the soil:

Based on the feel method, it is possible to indicate the approximate amount of clay present in the soil.

6.9 Rock fragments (described earlier as coarse fragments)

The discrete unattached pieces of rock, 2 mm in diameter or larger that are strongly cemented or more resistant to rupture are known as rock fragments. Rock fragments are described by their size, shape, and kind of rock. The various size rock fragments and terms used to describe them in the soil are given below.

Shape and size	Noun	Adjective
Spherical, cubelike, or equaxial		
2 - 75 mm diameter -2- 5 mm -5- 20 mm -20- 75 mm	Pebbles -fine pebbles -medium pebbles -coarse pebbles	Gravelly -fine gravelly -medium gravelly -coarse gravelly
75 – 250 mm dia.	Cobbles	Cobbly
250 – 600 mm	Stones	Stony
> 600 mm	Boulders	Bouldery
Flat shape		
2 – 150 mm long	Channers	Channery
150 – 380 mm long	Flagstones	Flaggy
380 – 600 mm long	Stones	Stony
> 600 mm long	Boulders	Bouldery

Based on the volume of the rock fragments present (< 15 %, 15 to 35 %, 35 to 60 %, 60 to 90 % and > 90 %) appropriate adjectives (as indicated in texture section) are used as a modifier to describe the texture of the soil (e.g. loam, gravelly loam, very gravelly loam and extremely gravelly loam).

6.10 Soil Structure

The arrangement of primary soil particles into aggregates is known as structure in soils. The individual structural unit is called as ped. Peds are separated from each other by voids or natural surfaces of weakness. Clods and fragments present in the soil are not considered as structural units, since they are not influenced or formed from any soil forming processes. Soils lacking structure are considered as structureless soils. Structureless soils, when pressed or under stress, will break into soil fragments or single grains, or both. The structure of these soils is described as single grain or massive.

The presence of structure in the soil is described based on the shape (type), size and grade (distinctness) of the units or peds observed (Fig 6.9).

Based on shape (type)	
Platy	The units are flat and plate like and horizontally oriented
Prismatic	Vertically elongated units with flat tops, the individual units are bounded by flat to rounded vertical faces.
Columnar	The units are similar to prisms and are bounded by flat or slightly rounded vertical faces. The tops of columns are very distinct and normally rounded.
Blocky	The units are block like or polyhedral. They are bounded by flat or slightly rounded surfaces that are casts of the faces of the surrounding surfaces. The structure is angular blocky if the faces intersect at relatively sharp angles; subangular blocky if the faces are a mixture of rounded and plane faces and the corners are mostly rounded.
Granular	The units are approximately spherical or polyhedral and are bounded by curved or very irregular faces that are not casts of adjoining peds.

Size

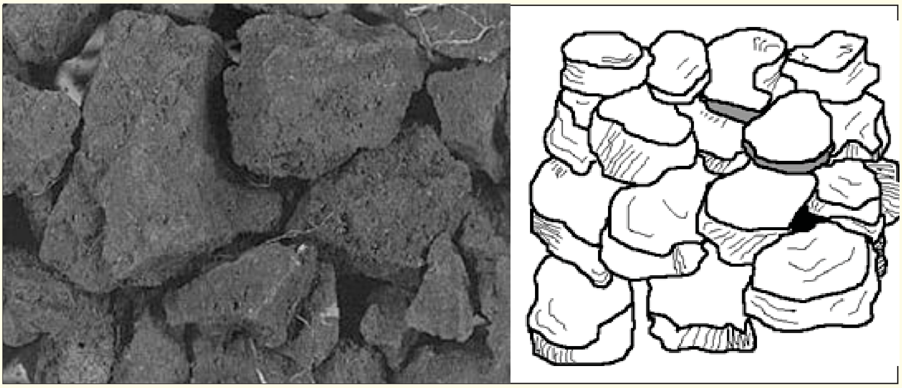
Based on the size, the structural units are described as very fine, fine, medium, coarse and very coarse. The size limits of the classes differ according to the shape of the units. The size limits refer to the smallest dimension of plates, prisms and columns. In describing plates, thin is used instead of fine and thick instead of coarse.

Size classes	Grannular, Platy (mm)	Prismatic & Columnar (mm)	Blocky (mm)
Very fine	< 1	< 10	< 5
Fine	1-2	10-20	5-10
Medium	2-5	20-50	10-20
Coarse	5-10	50-100	20-50
Very coarse	> 10	> 100	> 50

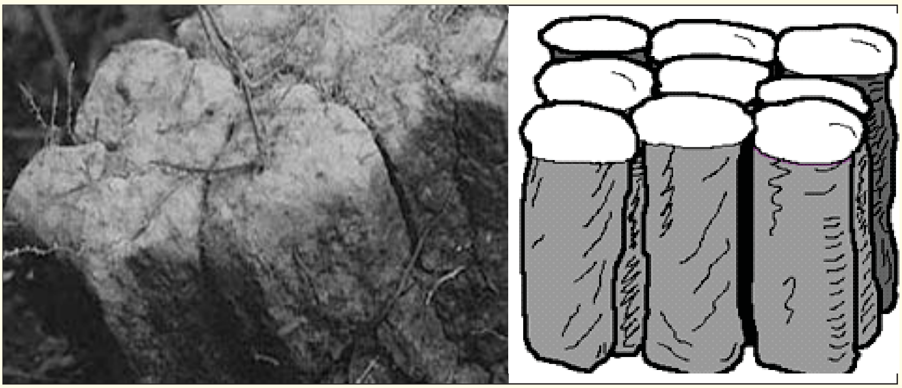
Grade

Grades describe the degree of ped development in the soil. It is distinguished in the field by the portion of the soil appearing as peds and by the frequency and distinctiveness of natural surfaces that persist through wetting and drying cycles. It is assessed by the ease with which the soil separates into peds and their durability. It varies with soil-water state and normally determined at the water state in which it normally occurs in the field. Three classes are used to describe the grade.

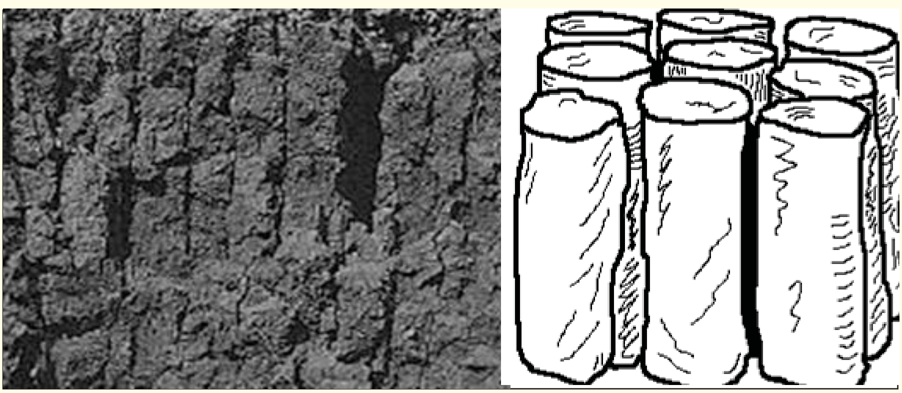
Grade	Code	Criteria
Structure less	0	No discrete units observable in place or in hand sample.
Weak	1	Units are barely observable in place or in a hand sample.
Moderate	2	Units well-formed and evident in place or in a hand sample.
Strong	3	Units are distinct in place (undisturbed soil) and separate cleanly when disturbed



Blocky – Irregular blocks that are usually 1.5 - 5.0 cm in diamter

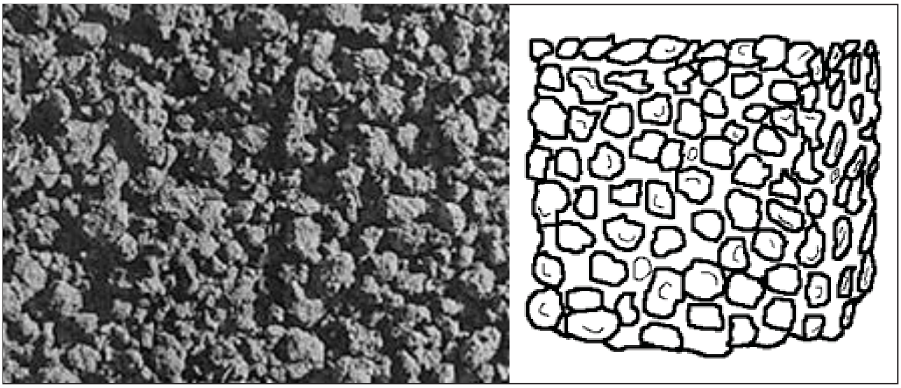


Columnar - Vertical columns of soil that have a salt cap at the top, found in arid climate



Prismatic – Long vertical columns, usually found in lower horizons

Fig 6.9 Different types of structures observed in the soil

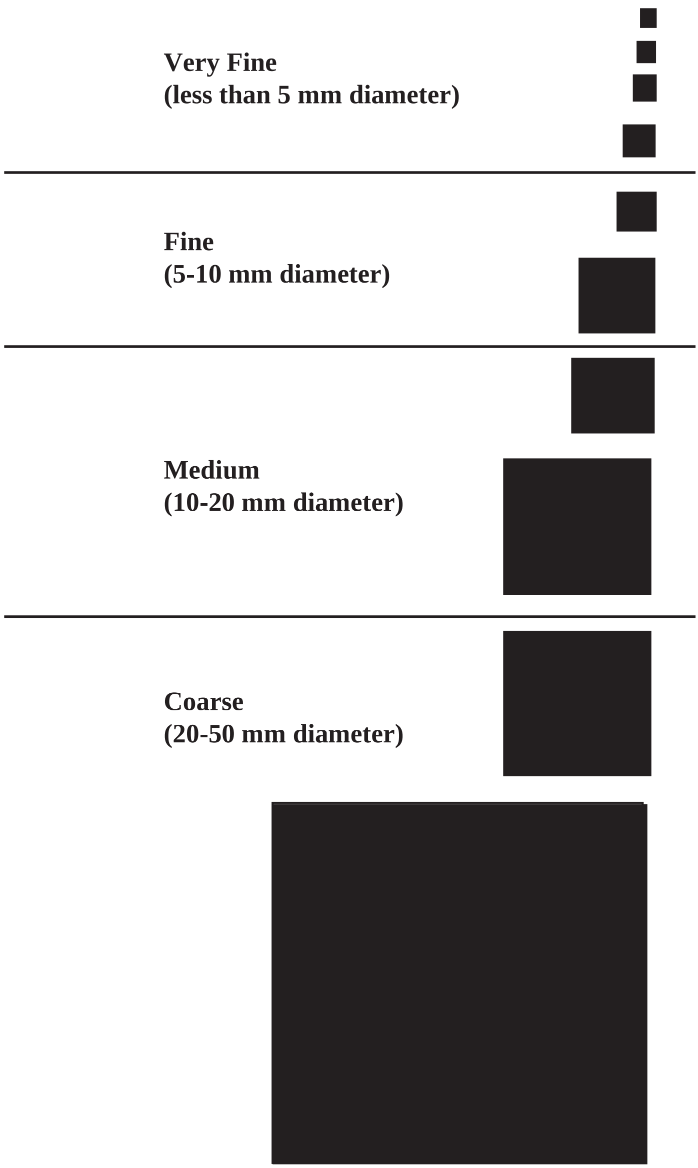


Granular - Resembles cookie crumbs and is usually < 0.5 cm in dia. Commonly found in surface horizons

Platy - Flat plates of soil that lie horizontally. Usually found in compacted soil

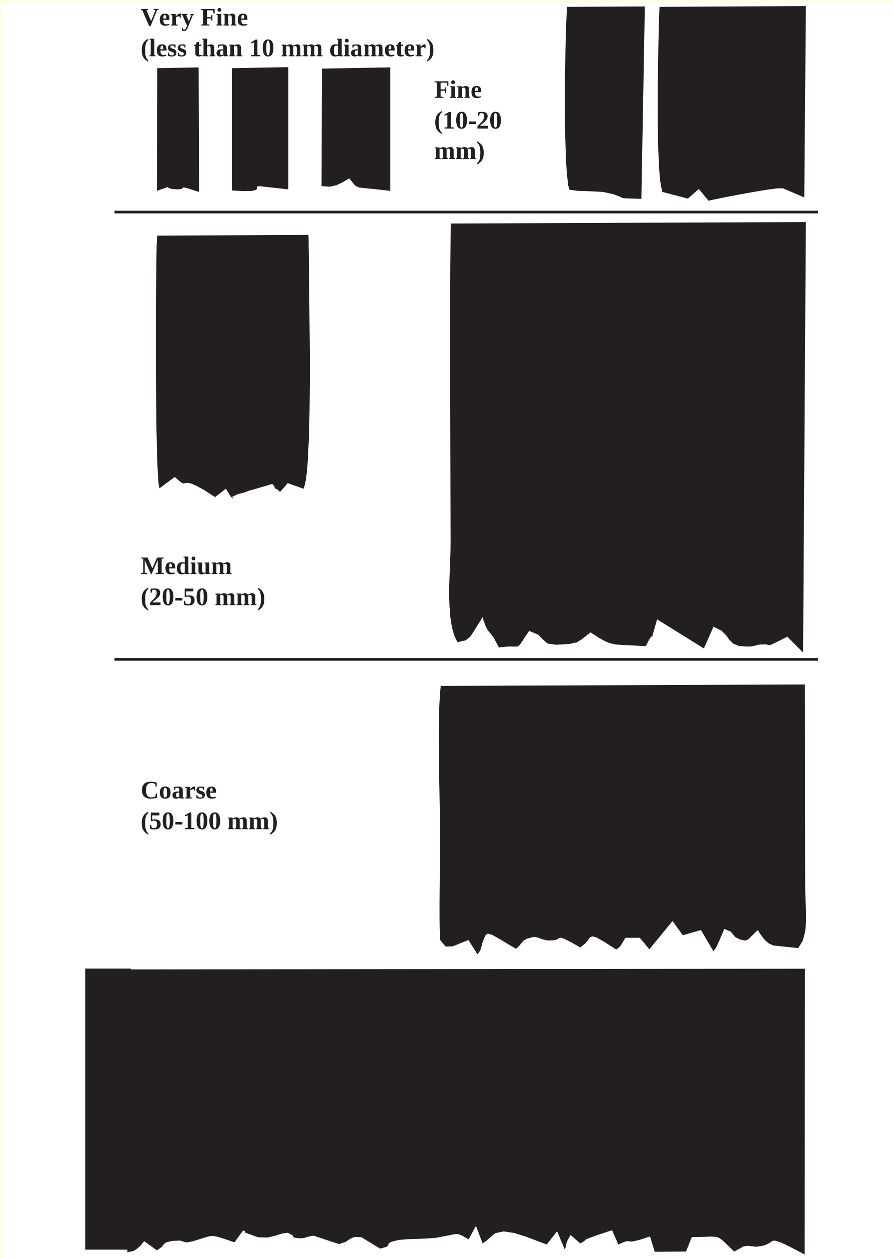
No structure, hard to break, seen in large clods

Angular and Sub-Angular Blocky Structures



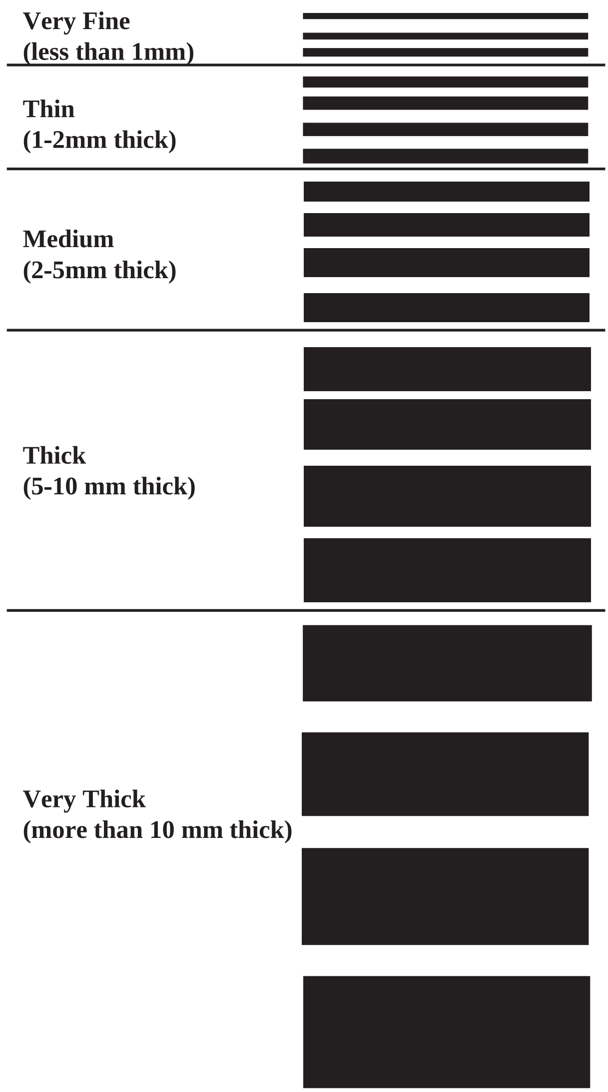
Attention: The pictures are the scale, please do not increase or decrease the size

Prismatic and Columnar Structure



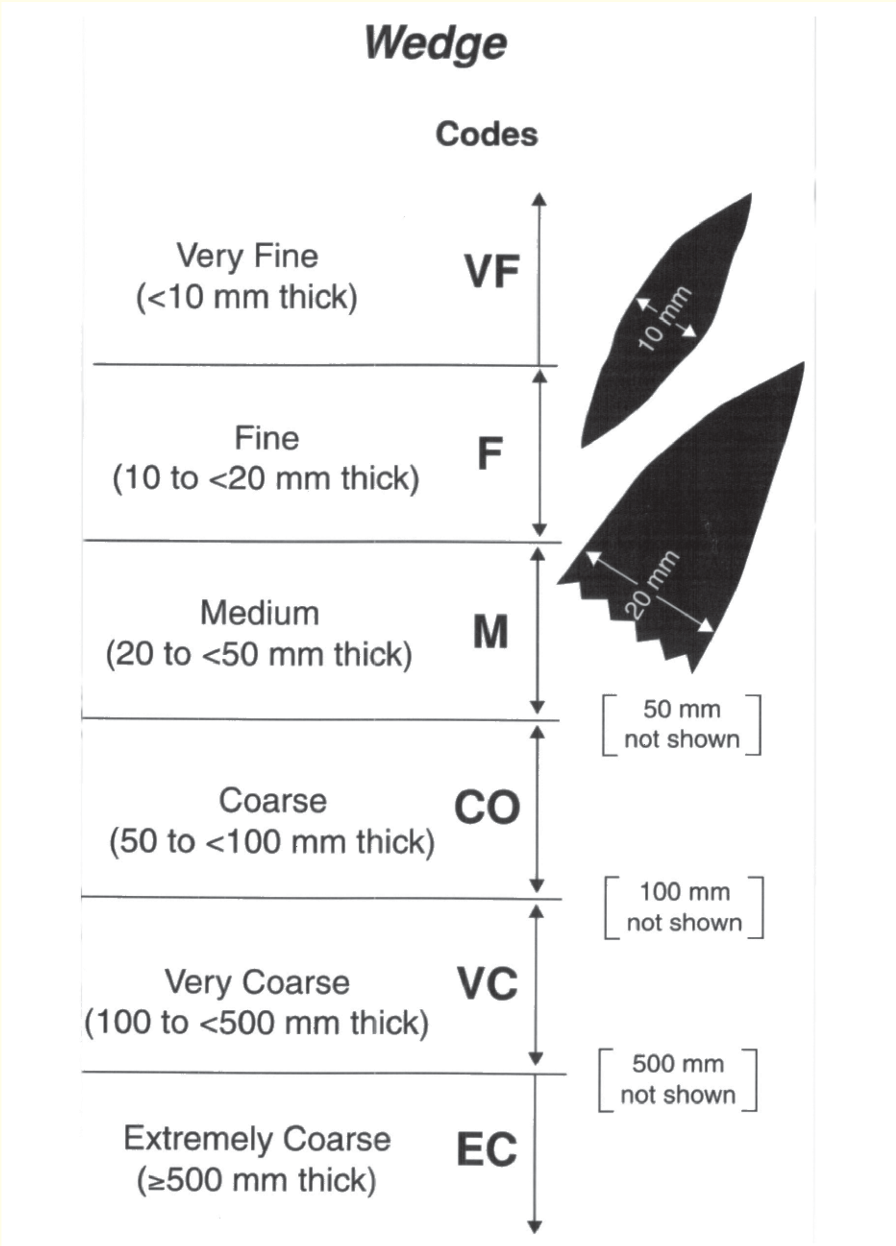
Attention: The pictures are the scale, please do not increase or decrease the size

Platy Structures



Attention: The pictures are the scale, please do not increase or decrease the size

Wedge Shaped Structural Units



Attention: The pictures are the scale, please do not increase or decrease the size

6.11 Consistence

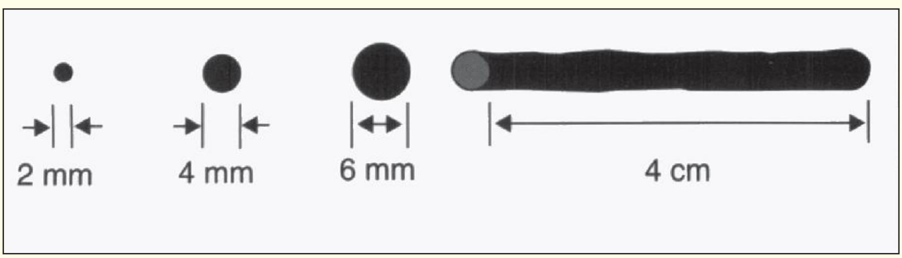
Soil consistence refers to the degree and kind of cohesion and adhesion and/or the resistance of soil to deformation or rupture when stress is applied. Every soil has this property, irrespective of their nature and moisture status. In the field, consistence is evaluated based on the following parameters.

resistance of soil material to rupture,
resistance to penetration,
plasticity, toughness, and stickiness of puddled soil material, and
the manner in which the soil material behaves when subject to compression.

Consistence is highly dependent on the soil-water state and the description should specify the water state observed in the field. Consistence of the soil material is observed for dry and moist soil in the field separately. Stickiness and plasticity are estimated at the appropriate moisture content in the soil.

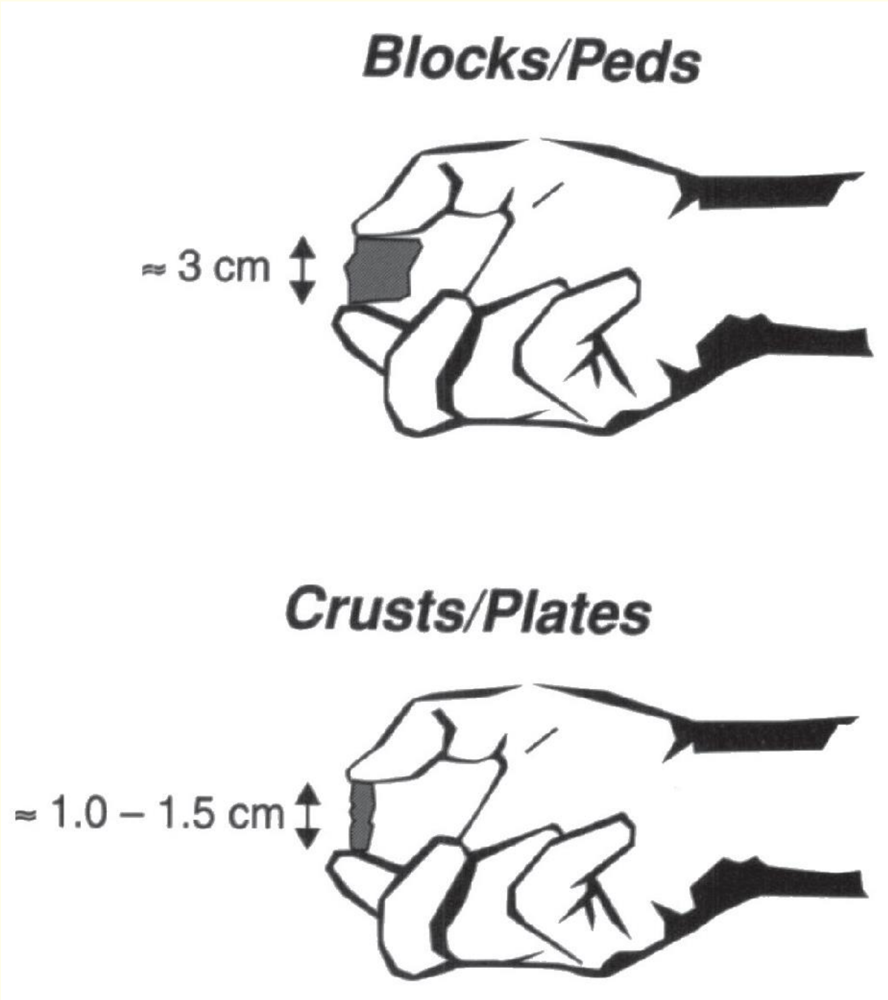
Plasticity-The degree to which puddled or reworked soil can be permanently deformed without rupturing. The evaluation is made by forming a roll (wire) of soil at a water content where the maximum plasticity is expressed.

Plasticity Class	Criteria: make a roll of soil 4 cm long
Non plastic (po)	Will not form a roll 6 mm in diameter, or if a roll is formed, it can't support itself if held on end.
Slightly Plastic (ps)	6 mm diameter roll supports itself; 4 mm diameter roll does not.
Moderately Plastic (p)	4 mm diameter roll supports itself; 2 mm diameter roll does not.
Very Plastic (vp)	2 mm diameter roll supports its weight.



Rupture Resistance

It is the measure of strength of soil to withstand an applied stress. For estimating rupture resistance, select a block shaped specimen of approximately 25-30 mm size (on edge to edge) and compress it (only for a short period) between extended thumb and forefinger, between both hands, or between the foot and a non-resilient flat surface. If the specimen resists rupture by compression, a weight is dropped onto it from increasingly greater heights until it ruptures. Failure is noted at the initial detection of deformation or rupture of the block.



For blocks/peds/clods, about 25 to 30 mm size specimens are used for assessing the rupture resistance.

Rupture Resistance classes for blocks, peds and clods

Dry Class	Moist Class	Specimen fails under
Loose	Loose	Intact specimen not available
Soft	Very friable	Very slight force between fingers
Slightly hard	Friable	Slight force between fingers
Mod. Hard	Firm	Moderate force between fingers
Hard	Very firm	Strong force between fingers
Very hard	Extremely firm	Moderate force between hands
Extremely hard	Slightly rigid	Foot pressure by full body weight
Rigid	Rigid	Cannot be failed underfoot by full body weight
Very rigid	Eery rigid	Cannot be failed underfoot, but by blow of 2 kg weight dropped from 15 cm above

Plasticity is the degree to which puddled soil material is permanently deformed without rupturing by force applied continuously in any direction. The determination is made on thoroughly puddled soil material at a water content where maximum plasticity is expressed. This water content is above the plastic limit, but it is less than the water content at which maximum stickiness is expressed. The water content is adjusted by adding water or removing it during hand manipulation.

Plasticity Class	Code	Description
Non-plastic	so	Will not form a 6 mm diameter roll, or if formed, cannot support itself if held on end
Slightly plastic	sp	6 mm diameter roll supports itself, 4mm diameter roll does not
Moderately plastic	mp	4 mm diameter roll supports itself, 2 mm diameter roll does not
Very plastic	vp	2 mm diameter roll supports itself with its weight

Stickiness - refers to the capacity of a soil to adhere to other objects. The determination is made on puddled < 2 mm soil material at the water content at which the material is most sticky. The sample is crushed in the hand, water is applied while manipulation is continued between thumb and forefinger until maximum stickiness is reached.

Stickiness Class	Code	Criteria-Description
Non-sticky	so	After release of pressure, practically no soil material adheres to fingers
Slightly sticky	ss	Soil adheres to both fingers, after release of pressure. Soil stretches little on separation of fingers.
Moderately Sticky	ms	Soil adheres to both fingers, after release of pressure. Soil stretches some on separation of fingers.
Very Sticky	vs	Soil adheres firmly to both fingers, after release of pressure. Soil stretches greatly on separation of fingers.

6.12 Mottles Redoximorphic Features (RMF)

Mottles are already described under the section soil colour. Redoximorphic Features are a type of mottling that is normally associated with wetness. The colour pattern, associated with RMF, is due to depletion or concentration of pigments compared to the matrix colour and formed by oxidation/reduction of Fe and/or Mn coupled with their removal, translocation, or accrual; or a soil matrix colour controlled by the presence of Fe^{2+}. Due to their significance, RMF are described separately from other mottles, concentrations (e.g. salts); or compositional features (e.g. clay films).

RMF generally occur in one or more of these settings:

- In the soil matrix, not related to the surfaces of peds or pores.
- On or beneath the surfaces of peds.
- As filled pores, linings of pores, or beneath the surfaces of pores.

RMFs include the following:

1. Redox Concentrations - Localized zones of enhanced pigmentation, formed due to the accumulation of Fe-Mn minerals (may be either Ferric or Ferrous forms). Types of redox concentrations observed in the soil are:

- **Masses** – Non cemented bodies of enhanced pigmentation that have a redder or blacker color than the adjacent matrix.
- **Nodules or Concretions** - Cemented bodies of Fe-Mn oxides.

2. Redox Depletions - Localized zones of “decreased" pigmentation that are greyer, lighter, or less red than the adjacent matrix. Redox depletions (chroma $\leq$ 2) are used to define aquic conditions and used extensively in the field to infer occurrence and depth of saturation in soils. Types of redox depletions present in the soil are:

- **Iron Depletions** - Localized zones that have one or more of the following: a yellower, greener; or bluer hue; a higher value; or a lower chroma than the matrix color. Color value is normally $\geq$4. Loss of pigmentation results from the loss of Fe and/or Mn.
- **Clay Depletions -** Localized zones that have either a yellower, greener or bluer hue, a higher value; or a lower chroma than the matrix color. Color value is normally $\geq$ 4. Loss of pigmentation results from a loss of Fe and or Mn and clay. Silt coats or skeletons commonly form as depletions but can be non-redox concentrations, if deposited as flow material in pores or along faces of peds.

3. Reduced Matrix - A soil horizon that has an *in-situ* matrix chroma $\leq$ 2 due to the presence of Fe^{2+}. Color of a sample becomes redder or brighter (oxidizes) when exposed to air. The color change usually occurs within 30 minutes.

RMF are described separately from other color variations, mottles or concentrations after ticking their presence in the column provided. Record **Kind, Quantity** (per cent of area covered), **Size, Contrast, Color, Shape, Location, Hardness, and Boundary** in the proforma.

Kind of redoximorphic features present in the soil are

Reduced matrix - chroma $\leq$ 2 primarily from Fe^{2+}
Redox depletions - clay depletions and iron depletions
Redox concentrations

- Masses (non-cemented) - iron (Fe Fe^{3+}), iron (Fe^{2+}), iron-manganese, manganese
- Nodules (cemented; no layers) – ironstone, iron-manganese, plinthite
- Concretions (cemented; distinct layers)- iron-manganese
  Surtace Coats/Films or Hypocoats
- manganese (mangans: black, very thin, exterior films
- ferriargillans (Fe^{3+}stained clay film)

Note:

- Concentration of reduced iron ($Fe^{2+)}$ can be observed as FeS in acid sulphate soils.
- Concentration of oxidised iron ($Fe^{3+)}$ is normally seen as reddish mottles (e.g. hematite)

- In the field, commonly, Iron and Mn occur in combination and field identification is difficult in many situations. Mn is identified only if the masses in the soil exhibit at least slight effervescence with H_2O_2. Describe nodules and concretions as Iron-Manganese unless colors are distinctly clear to separate them in the field.

- Suggested color guidelines for field distinction of Fe vs. Mn masses are:

  Mn - If both the value and chroma is ≲ 2

  Fe and Mn - If both the value and chroma is > 2 and ≲ 4
  Fe - If both the value and chroma is >4

Quantity (Percent of area covered) of redoximorphic features

Class	Code	Criteria: % of surface area covered
Few	F	< 2
Common	C	2 to < 20
Many	M	≥ 20

Size of redoximorphic features (Refer size class under Mottles or concentrations).

Size Class	Code	Criteria
Fine	1	< 2 mm
Medium	2	2 to < 5 mm
Coarse Very	3	2 to < 5 mm
Coarse	4	20 to < 76 mm
Extremely Coarse	5	≥ 76 mm

Contrast of redoximorphic features – Describe the contrast by mottle - Contrast Table or "Mottle - Contrasts Chart;" e.g., *Prominent* or p.

Colour of the redoximorphic features - use the Color chart to describe them **Moisture state of redoximorphic features- -** describe the moisture condition of the Redoximorphic Feature, e.g., *Moist (M)* or *Dry (D).*

Shape of redoximorphic features - Describe the shape of the redoximorphic feature (use "Concentrations - Shape Table"); e.g., *Spherical (S).*

Location of redoximorphic features - Describe the location of the Redoximorphic Feature within the horizon; e.g. In the matrix around depletions.

Boundary - The gradation between the Redoximorphic Feature and the adjacent matrix (use "Concentrations -Boundary Table"); e.g., *Sharp (S).*

6.13 Concentrations

Concentrations are soil features that form by accumulation of material during pedogenesis. *Dominant* processes involved are chemical dissolution, precipitation, oxidation, and reduction and physical and/or biological removal, transport, and accrual. Types of concentrations include the following (Fig 6.10 & 6.11).

- **Finely Disseminated Materials** are physically small precipitates (e.g. salts, carbonates) dispersed throughout the matrix of a horizon. The materials cannot be readily seen (l0X lens), but can be detected by a chemical reaction (e.g. effervescence of $CaCO_3$ by HCI).

- **Masses** are non-cemented bodies of accumulation of various shapes that cannot be removed from the soil as discrete units, and do not have a crystal structure. Most accumulations consist of calcium carbonate, fine crystals of gypsum or more soluble salts or iron and manganese oxides.

- **Nodules are** cemented bodies of various shapes (commonly spherical or tubular) that can be removed as discrete units from soil. Crystal structure is not discernible with l0X hand lens.

- **Concretions** are cemented bodies similar to nodules, except for the presence of visible concentric layers of material around a point line or plane.

- **Crystals** are macro-crystalline forms of relatively soluble salts (e.g. halite, gypsum, carbonates) that form *in situ* by precipitation from soil solution. The crystalline shape and structure is readily discernible in the field with a l0X hand lens.

- **Biological Concentrations** are discrete bodies accumulated by a biological process (e.g. fecal pellets), or pseudomorphs of biota or biological processes (e.g. insect casts) formed or deposited in soil.

- **Inherited Minerals** are field-observable particles (e.g. mica flakes or aggregates (e.g. glauconite pellets) that impart distinctive soil characteristics and formed by geologic processes in the original parent material and subsequently inherited by the soil rather than formed or concentrated by pedogenic processes.

Plinthite is iron-enriched reddish bodies that are low in organic matter and are coherent enough to be separated readily from the surrounding soil. Plinthite commonly occurs within and above reticulately mottled horizons. It is firm or very firm when moist, hard and very hard when air dry and become moderately cemented on repetitive wetting and drying. They occur as discrete nodules or plates. Horizons containing plinthite are more difficult to penetrate with an auger than adjacent horizons.

Ironstone is an in-place concentration of iron oxides that is at least weakly cemented. Ironstone nodules are commonly found in layers above plinthite. These ironstone nodules are apparently plinthite that has cemented irreversibly as a result of repeated wetting and drying.

Field description of Concentrations

The description of concentrations is similar to that of the mottles or redoximorphic features present in the soil. The important attributes to be described are **Kind, Quantity, Size, Contrast, Color, Moisture State, Shape, Location, Hardness and Boundary**. In the field it may not be possible to describe all the attributes indicated above.

Kind - Identify the composition and the physical state of the concentration in the soil. A rough field guide to identify the physical states of materials is given below.

Finely disseminated (bodies not visible by unaided eye; proposed) ❖ Finely disseminated Carbonates ❖ Finely disseminated Salts
Masses (noncemented; crystals not visible with l0X hand lens) ❖ Carbonates (Ca, Mg. $NaCO_3$) ❖ Gypsum ($CaSO_4$. $2H_2O$) ❖ Salt (Na Cl, Na-Mg sulfates) ❖ Barite ($BaSO_4$), Clay bodies, Silica
Nodules (cemented; non-crystalline at l0X, no layers) ❖ Carbonates ❖ Gibbsite (Al_2O_3)
Concretions (cemented; non-crystalline at l0X, distinct layers) ❖ Carbonates ❖ Gibbsite (Al_2O_3) ❖ Titanium oxide

Crystals (crystals visible with l0X hand lens) ❖ Calcite ($CaCO_3$), Barite ($BaSO_4$) ❖ Gypsum ($CaSO_4$. $2H_2O$) ❖ Salt (NaCl, Na-Mg sulfates)
Biological concentrations (by products or pseudomorphs) ❖ Fecal pellets, insect casts, root sheaths, worm casts, shell fragments
Inherited minerals (geogenic) – mica flakes

Quantity (per cent of area covered): Quantity of concentrations refers to the relative volume of a horizon or other specified unit occupied by the bodies. The classes used are the same as that used for estimating the quantity of mottles and redoximorphic features present in the soil.

Size: Size classes are similar to the classes used for describing mottles and redoximorphic features present in the soil.

Contrast: This is to be described by using the contrast table given earlier for describing Mottle or RMF present in the soil.

Colour: Use the Musell colour chart and describe the colour of the feature observed.

Shape: Size of c oncentrations is variable both among kinds of concentrations and commonly within a concentration. The following terms are suggested:

Shape	Criteria
Cylindrical	Tubular and elongated bodies. e.g., filled wormholes and insect burrows
Dendritic	Tubular, elongated, branched bodies; e.g., pipestems (root pseudomorphs)
Irregular	Bodies of non-repeating spacing or shape, characterised by branching, convoluted or mycelial form
Plate-like	Relatively thin, tabular sheets, lenses e.g., lamellae
Reticulate	Crudely interlocking bodies with similar spacing e.g., plinthite
Spherical	Well-rounded to crudely spherical bodies e.g., Fe / Mn spots
Threads	Thin elongated filaments; generally, not dentritic e.g., very fine $CaCO_3$ filaments

Location - The location (s) of the concentration within the horizon is described by using the terms as indicated below.

Matrix (in soil matrix; not associated with ped faces or pores) ❖ In the matrix not associated with peds/pores ❖ In matrix around depletions and concentrations ❖ Throughout (e.g. finely disseminated carbonates)
Peds (on or associated with faces of peds) ❖ Between peds ❖ Infused into the matrix along faces of peds (hypocoats) ❖ On faces of peds (all orientations) ❖ On horizontal faces of peds ❖ On vertical faces of peds
Pores (in pores, or associated with surfaces along pores) ❖ On surfaces along pores ❖ On surfaces along root channels ❖ Infused into the matrix adjacent to pores (hypocoats) ❖ Lining pores
Other locations ❖ In cracks ❖ At top of horizon ❖ Around rock fragments ❖ On bottom of rock fragments (e.g., pendants) ❖ On slickensides

Hardness: The relative force required to crush the concentration body (use the same criteria and classes as the "Rupture Resistance for Blocks, Peds, and Clods - Cementation" column) is to be described wherever possible.

Boundary: This is the gradation observed between the feature and the matrix in the soil. The boundary is described as indicated below.

Boundary	Criteria
Sharp	Color changes in < 0.1 mm; change is abrupt even under a l0X hand lens.
Clear	Color changes within 0.1 to < 2 mm; gradation is visible without l0X lens.
Diffuse	Color changes in ≥ 2 mm; gradation is easily visible without l0X hand lens.

Composition of bodies is described if known. Carbonates and iron are common substances that dominate or impregnate nodular or concretionary bodies. Discrete nodules of clay are found in some soils. Materials dominated by manganese are rare, but manganese is conspicuous in some nodules that are high in iron and mistakenly called manganese nodules.

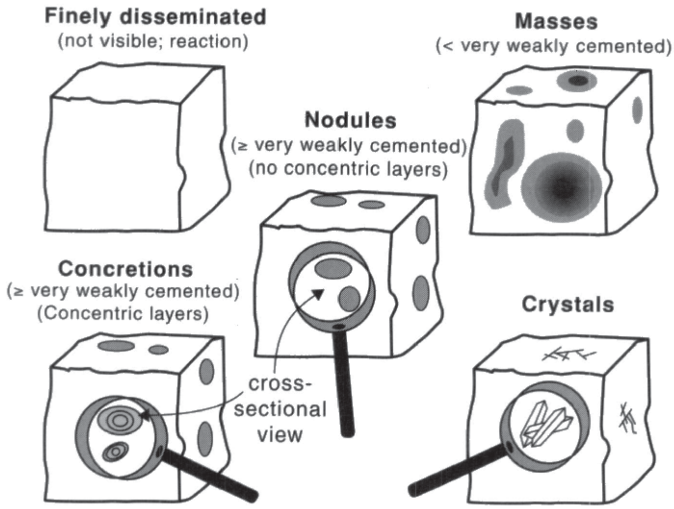


Fig 6.10 Types of Concentrations present in the soil

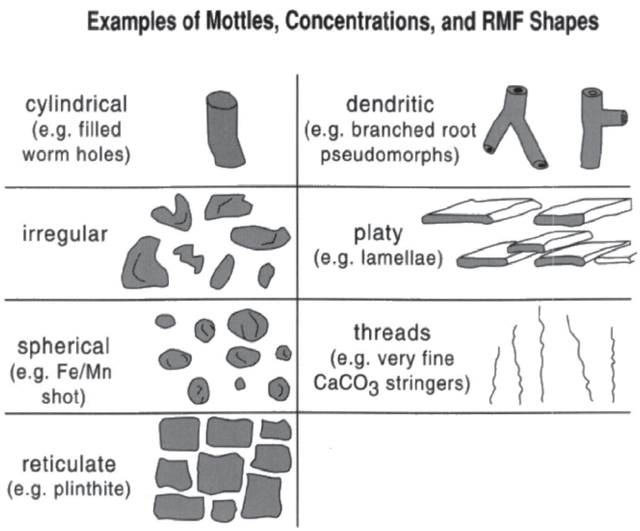


Fig 6.11 Different shapes of Mottles, Concentrations and RMF seen in the soils

6.14 Coats/Films/ Stress Features (Internal Surface Features)

These features include coats/films, hypocoats, or stress features and formed by translocation and deposition, or shrink-swell processes on or along surfaces. Description of surface features may include kind, amount, continuity, distinctness, location, and thickness of the feature. In addition, colour, texture and other characteristics may be described, especially if they contrast with the characteristics of the adjacent material (Fig 6.12 & 6.13).

Kind of ped and void surface features (non-redoximorphic)

Kind	Field Criteria
Coats, Films (exterior, carbonate coats adhered to surface)	
Carbonate coats	Off-white, effervescent with HCI
Silica (silans, opal)	Off-white, non-effervescent with
Clay films (argillans)	HCI Waxy exterior coats
Clay bridging	"wax" between sand grains
Ferriargillans	Fe^{3+} stained clay film
Gibbsite coats (sesquan)	$AIOH_3$, off-white, non-effervescent with HCI
Manganese (mangans)	black, thin films effervescent with H_2O_2
Organic stains	dark organic films
Organoargillans	dark, organic stained clay films
Sand coats	separate grains visible with lOX
Silt coats	separate grains not visible at lOX
Skeletans 2 (sand or silt)	clean sand or silt grains as coats
Skeletans on argillans	clean sand or silt over clay coats
Hypocoats (A stain infused beneath a surface)	
Stress Features (exterior face)	
Pressure faces (i.e. stress cutans)	look like clay films; sand grains uncoated
Slickensides (pedogenic) (Fig 6.13)	shrink-swell shear features (e.g. grooves, striations and glossy surface) on pedo-structure surfaces; (e.g. wedges and bowls)
Slickensides (geogenic)	vertical / oblique, roughly planar shear face from external stress (e.g. faults; mass movement): striations, grooves

Amount of ped and void surface features - Estimate the relative per cent of the visible surface area that a ped surtace feature occupies in a horizon (use of the graph will make the estimation easier and consistent).

Amount classVery Few	Codevf	Criteria: percent of surface area<5 per cent
Few	f	5 to<25 per cent
Many	c	25 to < 50 per cent
Common	m	50 to < 90 per cent
Very Many	vm	$\geq$ 90 per cent

Continuity: It is described as continuous if the feature covers the entire surface, discontinuous if only partially covered and patchy if only isolated patches are covered.

Distinctness: The relative extent to which a ped surface feature visually stands out from the adjacent material is known as its distinctness. The classes used are

Distinctness Class	**Code**	**Criteria**
Faint	f	Visible with magnification only (10X hand lens); little contrast between materials.
Distinct	d	Visible without magnification; significant contrast between materials.
Prominent	p	Markedly visible without magnification; sharp visual contrast between materials.

Location of ped and void surface features: Specify where ped surface features occur within a horizon, e.g., Between *sand grains.*

Location –Peds

- ❖ On bottom faces of peds, On top faces of peds
- ❖ On verfical faces of peds, On all faces of peds (vertical & horizontal)
- ❖ On top of soil columns

Location –Other (Non-Ped)

- ❖ Between sand grains *(bridging)*
- ❖ On surfaces along pores, On surfaces along root channels
- ❖ On concretions, On nodules, On rock fragments, On slickensides
- ❖ On top surfaces of rock fragments, On bottom surfaces of rock fragments

Colour of the ped and void surface features: Colour is noted by using colour chart

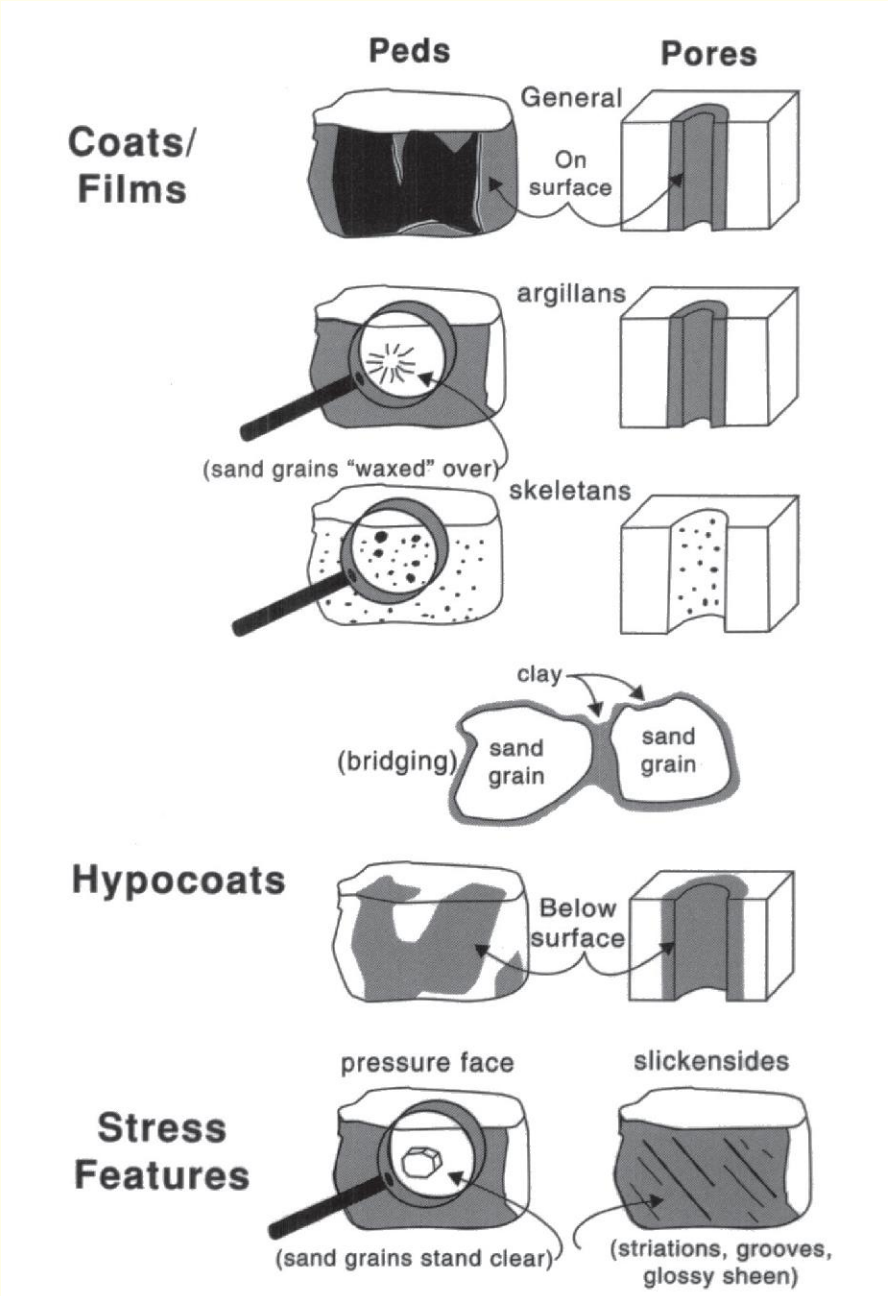


Fig 6.12 Coats/Films, Hypocoats and Stress Features observed in the soil

Fig.6.13 Prominent slickensides due to the shrink and swell properties of black soils formed from basalt

6.15 Roots

Quantity, size, and location of roots in each layer are to be recorded in the proforma. Any other features like root length, nodulation, and the relationships to special soil attributes or to structure may be recorded as notes in the field notebook. Describe the quantity (number) of roots for each size class in a horizontal plane. But in the field, normally, this is done across a vertical plane, such as a profile face. Record the average quantity from 3 to 5 representative unit areas. The unit area that is evaluated varies with the size class of the roots being considered. The unit area for different root size classes are: 1 sq cm for very fine and fine roots, 1 sq dm (10 x 10 cm) for medium and coarse roots, and 1 m^2 for very coarse roots (Fig 6.13).

Quantity

Quantity Class	Code	Average Count (per assessed area)
Few Very Few Moderately Few	f	<1 per area <0.2 per area 0.2 to < 1 per area)
Common	c	1 to<5 per area
Many	m	≥ 5 per area

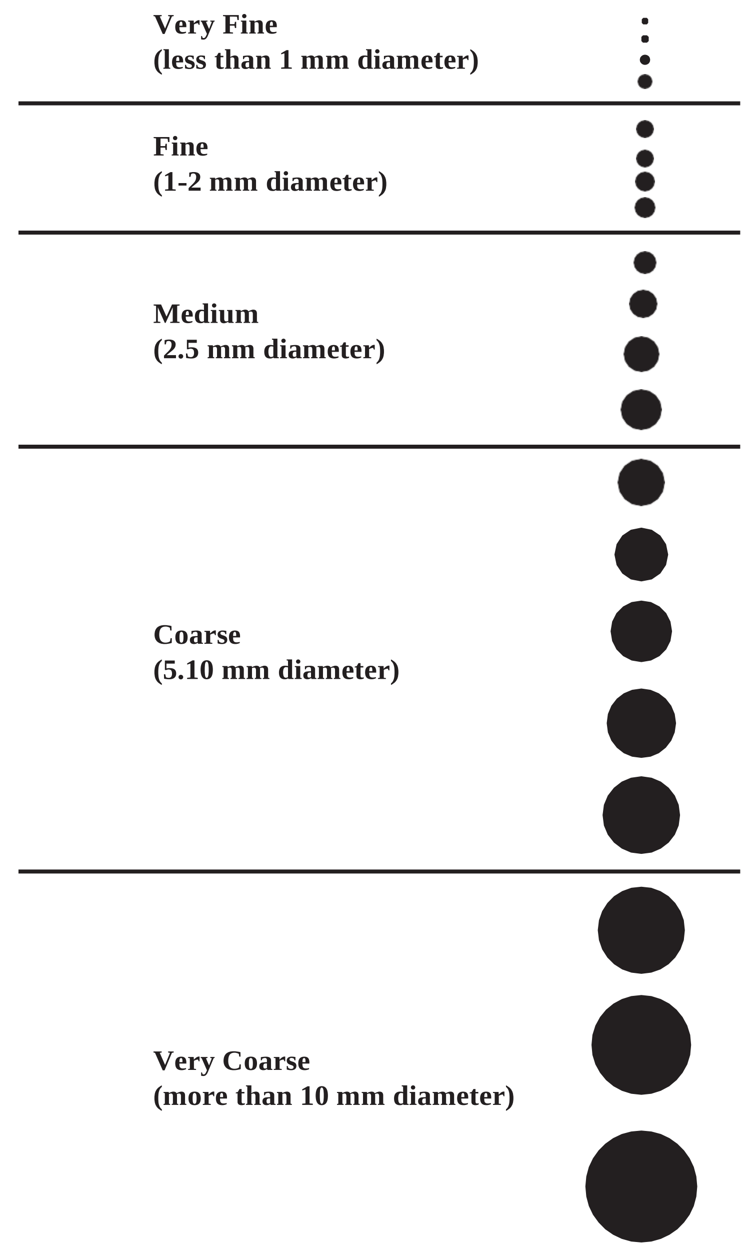
Very few and moderately few sub-classes are optional and used only for roots and not applied to pores.

Size of Roots (and Pores)

Size Class	Code	Diameter	Soil Area Assessed
Very Fine	vf	<1 mm	1 cm^2
Fine	f	l to<2 mm	1 cm^2
Medium	m	2 to<5 mm	1 dm^2
Coarse	c	5 to< 10 mm	1 dm^2
Very Coarse	vc	≥ 10 mm	1 m^2

Location of roots: Identify where the roots occur, whether it is between peds, in cracks, throughout, in mat at top of horizon, matted around rock fragments, etc. The location of roots within a layer may be described in relation to other features. In some soils, the pattern or root growth may not correspond to soil horizons or layers; therefore, a summary statement of root development by increments of 15 cm or 30 cm or some other convenient thickness is often helpful. In other soils, root distribution may be summarized by grouping layers. For annual plants, the time of the root observation may be indicated.

Fig 6.13 Root, Pore Size, Granular and Crumb Structure Classes



6.16 Pores

Pores are the air or water filled voids present in the soil. Pore space includes matrix, non matrix, and inter structural pore spaces. It is difficult to assess very small size pores (e.g. < 0.05 mm) in the field. So, field observations are limited to those pores that can be seen through a 10X hands lens or larger.

Pores are described by **Quantity, Size, Shape, and Vertical Continuity** (Fig 6.14). Description of soil pore Shape and Vertical Continuity is optional. Quantity classes pertain to number of pores per unit area^{-1} cm^{2} for very fine and fine pores, 1 dm^{2} (10 x 10 cm) for medium and coarse pores, and 1 m 2 for very coarse. The quantity and size classes are similar to the classes used for pores. (Quantity: Few - < 1 per unit area, Common-1 to 5 per unit area, Many - > 5 per unit area; Size: Very fine - < 0.5 mm, Fine -1 to < 2 mm, Medium -2 to < 5 mm, Coarse -5 to < 10mm and Very coarse ≥ 10 mm).

Shape of pores (or Type): Record the dominant form (or type) of pores discernible with a 10X hand lens and by the unaided eye. Most non matrix pores are either vesicular (approximately spherical or elliptical) or tubular (approximately cylindrical and elongated) in form and some are irregularly shaped.

Type	Criteria
Dendritic Tubular	Cylindrical, elongated, branching voids; e.g., *empty* root *channels.*
Irregular	Non-connected cavities, chambers; e.g., various shapes.
Tubular	Cylindrical and elongated voids; e.g., *worm tunnels.*
Vesicular	Ovoid to spherical voids; e.g., solidified pseudomorphs *of entrapped, gas bubbles* concentrated below a *crust,* most common in arid and semi-arid areas.
Interstitial	Voids between sand grains or rock fragments.

Continuity of pores: The average vertical distance through which the minimum pore diameter exceeds 0.5 mm is taken into consideration and described. Continuity is described as low if the vertical distance is < 1 cm, moderate if it is between 1to <10 cm and high if it is ≥ 10 cm.

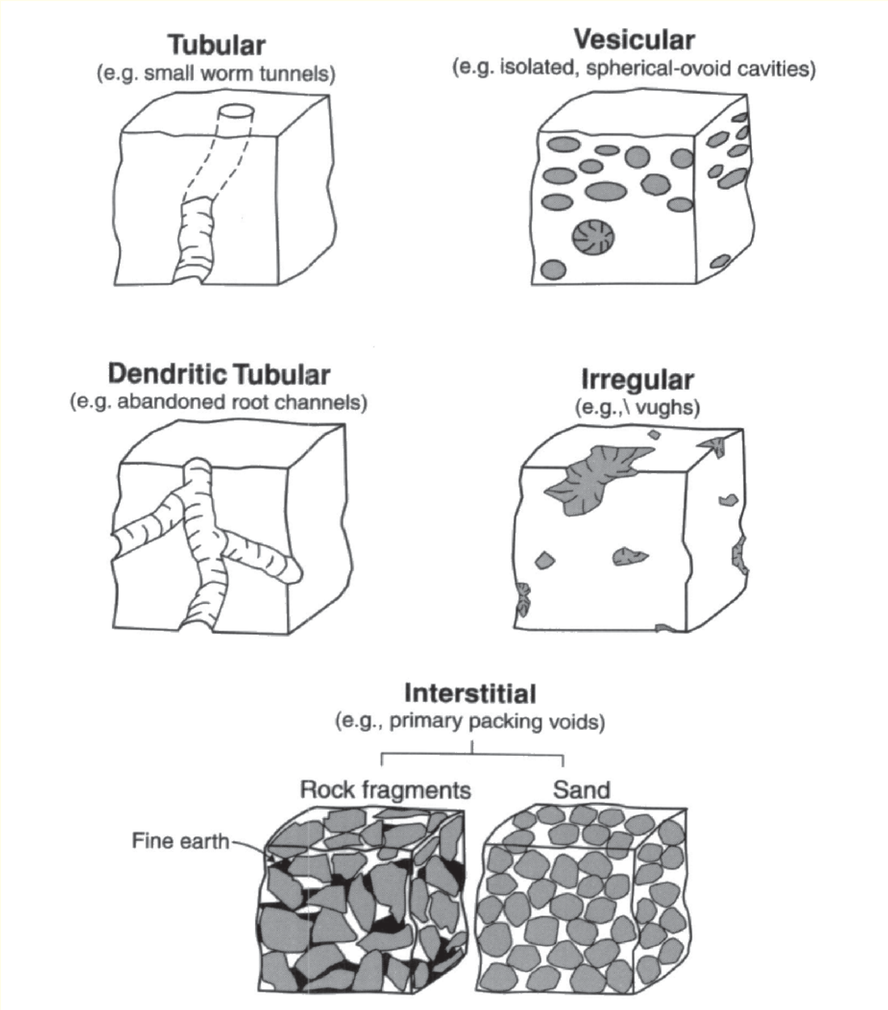


Fig 6.14 Types of pores observed in soils

6.17 Cracks

Cracks are fissures other than those attributed to soil structure (also known as extra-structural cracks). Cracks are commonly vertical, sub-planar, polygonal and are the result of desiccation, dewatering or consolidation of earthy material (Fig 6.15). Cracks are primarily associated with clayey soils and are most pronounced in high shrink-swell soils. Record the **Relative Frequency (**estimated average number per m^2), **Depth** (average) and **Kind.**

Kind of Cracks - Identify the dominant types of fissures

Kind	General Description
Crust-related cracks (shallow vertical cracks related to crusts; derived from raindrop-splash and soil puddling followed by dewatering/consolidation and desiccation)	
Reversible	Very shallow (e.g., 0.7 - 0.5 cm); very transient (generally persist less than a few weeks); formed by drying from surface down; minimal, seasonal influence on ponded infiltration (e.g., rain drop crust cracks).
Irreversible	Shallow (e.g., 0.5 – 2 cm): seasonally transient (not present year-round nor every year); minor influence on ponded infiltration (e.g., freeze-thaw crust and associated cracks).
Trans-horizon cracks (deep, vertical cracks that commonly extend across more than one horizon and may extend to the surface; derived from wetting and drying or original dewatering and consolidation of parent material)	
Reversible	Transient (commonly seasonal; close when rewetted); large influence on ponded infiltration formed by wetting and drying of soil; (e.g.Vertisols, vertic subgroups).
Irreversible	Permanent (persist year-round), large influence on ponded infiltration (e.g., extremely coarse subsurface fissures within glacial till; drained polder cracks).

Depth of Cracks - Record the average apparent depth measured from the surface, as determined by the wire-insertion method (about 2 mm dia wire). Depth of subsurface cracks can be inferred from the *Horizon Depth* column of layers exhibiting subsurface cracks (Fig 6.16).

Relative frequency of cracks - Record **the Average number of cracks,** per meter, across the surface.

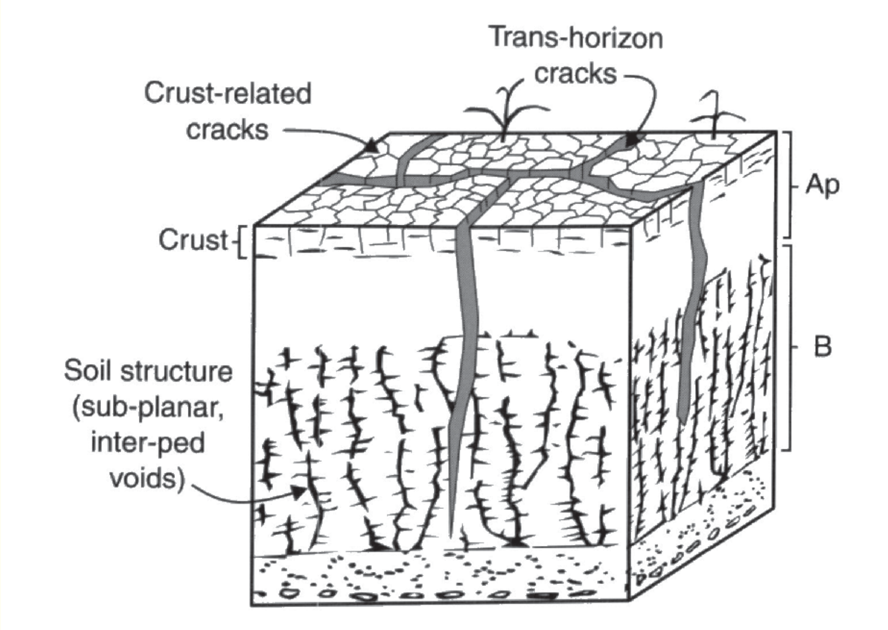


Fig.6.15 Type of cracks observed in the soil

Fig 6.16 Deep and wide cracks on very gently sloping (1-2 % slope) uplands in S. No 52, Ladha 2 MWS, Kaudgaon village, Aurad Taluk, Bidar District

Soil Crusts

A soil crust is a thin (e.g. <1 cm up to 10 cm thick) surface layer of soil particles bound together by living organisms and / or by minerals into a horizontal mat or small polygonal plates. Soil crusts form at the soil surface and have different physical and /or chemical characteristics than the underlying soil material. Typically soil crusts change the infiltration rate of the mineral soil and stabilize loose soil particles and aggregates. There are two general categories of soil crusts: Biological crusts, and Mineral crusts.

Biological Crusts: a thin, biotically dominated surface layer or mat formed most commonly by cyanobacteria (blue green algae), green and brown algae, mosses, and/or lichens that form in or on the soil surface.

Mineral Crusts: a thin surface layer composed of reversibly bonded soil particles or secondary mineral crystals, sometimes laminated, that is not physically dominated by a microbiotic mat.

i). Chemical Crusts (e.g. salt incrustations): a thin surface layer that is dominated by macro- or microcrystalline evaporites of halite (NaCI), $MgSO_4$, mirabilite (Na_2SO_4. $10H_2O$), epsomite ($MgSO_4$ $7H_2O$), gypsum ($CaSO_4$).

ii). Physical Crusts: a physically reconstituted, reaggregated or reorganized surface layer composed predominantly of primary mineral particles.

a). Raindrop Impact Crust: a thin layer that forms due to raindrop impact, which causes the clay in the soil to disperse, and subsequently hardens into a massive structureless or platy surface layer when it dries.

b). Depositional Crust is a surface layer, commonly laminated and of variable thickness, consisting of small aggregates of primary mineral grains deposited by short range runoff and subsequently dried.

Description of Soil Crusts - Record the type of (kind) surface crust present in the soil.

6.18 Chemical Response of the soil

It is the response of a soil sample to an applied solution or a measured value. Responses are used to identify the presence or absence of some materials; to obtain a rough assessment of the amount present; to measure the intensity of a chemical parameter (e.g., pH.); or to identify the presence of some compounds (e.g. Fe^{2+}) in the soil.

6.19 Soil Reaction (pH)

Both colorimetric and electrometric methods are used for measuring pH. Colorimetric methods are simple and inexpensive. Reliable portable pH meters are available for measurements. The pH ranges to be followed are < 4.5, 4.5 to 5.5, 5.5 to 6.5, 6.5 to 7.5, 7.5 to 8.5, 8.5 to 9.5 and >9.5. Record the pH and method of observation. Estimation of pH by using a pH meter in 1:1 soil:water is the preferred one.

6.20 Effervescence

The gaseous response (seen as bubbles) of soil to applied HCl (carbonate test), H_2O_2 (MnO_2 test), or other chemicals. Normally, cold dilute (about 1:10 dilution) hydrochloric acid is used to test the presence of carbonates in the field. The amount and expression of effervescence is affected by size distribution and mineralogy as well as the amount of carbonates present in the soil. Apply the chemical to the soil matrix (Effervescence class refers only to the matrix, do not include carbonate masses) and record the observed response.

Four classes of effervescence are used:

Very slightly effervescent	—	few bubbles seen
Slightly effervescent	—	bubbles readily seen
Strongly effervescent	—	bubbles form low foam
Violently effervescent	—	thick foam forms quickly

Salinity and Sodicity

Reasonable estimates of salinity and sodicity can be made in the field quickly by relating the observations made in the field with laboratory measurements. If the electrical conductivity is measured, then record the actual value and method used. If the concentration of dissolved salts is estimated in a saturated paste extract, then the salinity classes to be used are as follows.

Salinity Class	Code	Criteria:(Electrical Conductivity) dS/m (mmhos/cm)
Non-Saline	0	< 2
Very slightly Saline	1	2 to < 4
Slightly Saline	2	4 to < 8
Moderately Saline	3	8 to < 16
Strongly Saline	4	≥ 16

Sodium Adsorption Ratio (SAR): It is an estimation of the equilibrium between sodium (Na) in solution and exchangeable Na adsorbed on the soil. It is applied to soil solution extracts and irrigation waters. The SAR is expressed as a ratio. As a field method, it is commonly determined with soil paste and an electronic wand.

Odour: The presence of any strong smell is to be recorded in each horizon. Strongly reduced soil containing sulfur compounds gives rotten eggs smell.

6.21 Other/Special features

Presence of Animals

Mixing, changing, and moving of soil material by animals affect some properties of soils. The features seen on the land surface may be described, like the presence of Termite mounds, ant hills, heaps of excavated earth beside burrows, the openings of burrows, paths, feeding grounds, earthworm or other castings and other traces on the surface as special notes or in the proforma. The features produced by animals in the soil are described by using common words.

Fig. 6.17 Large number of Termite mounds in current fallow lands, Kolar district

Krotovinas - They are irregular tubular streaks within one layer of material transported from another layer. They are caused by the filling of tunnels made by burrowing animals in one layer with material from outside the layer. In a profile, they appear as rounded or elliptical volumes of various sizes.

Stone line - A natural concentration of rock fragments caused by fluvial action or other transport agents, if present in the soil is to identified and described. **Tongues of argillic material,** seen in some soils needs to described

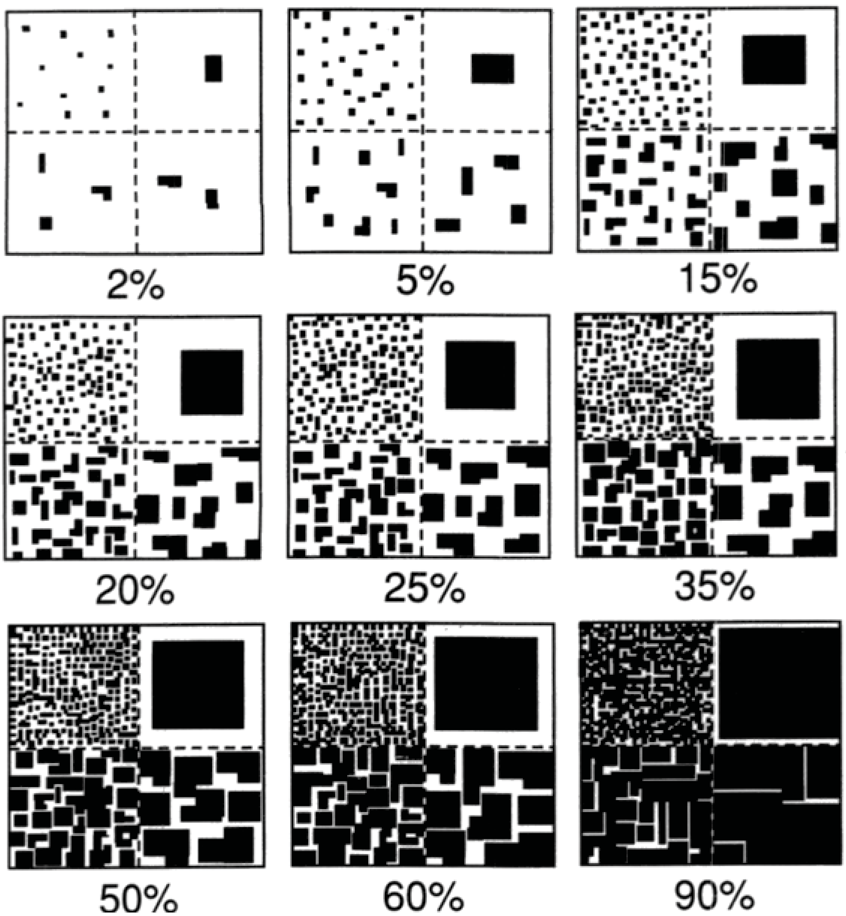
6.22 Miscellaneous Field Notes

Use additional adjectives, descriptors, and sketches to capture and convey pertinent information and any features for which there is no pre-existing data element or symbol. Record such additional information as free hand notes under Field Notes in the proforma or if additional space is needed, in the field notebook.

REFERENCES

- CGWB (2012) Aquifer Systems of Karnataka, Central Ground Water Board, Ministry of Water Resources, GOI, Bengaluru Region.
- IARI (1971) Soil Survey Manual, All India Soil and Land Use Survey Organisation, IARI, New Delhi, 121 Pp.
- Natarajan, A. and Dipak Sarkar (2009) Field Guide for Soil Survey, National Bureau of Soil Survey and Land Use Planning (ICAR), Nagpur.
- NBSS&LUP (2012) Land Resource Inventory for Farm Planning in Chikkarasinakere Hobli, Maddur Taluk, Mandya District, Karnataka, NBSS&LUP, Regional Centre, Bengaluru.
- Rattan Lal. (editor), 2006 Encyclopedia of Soil Science, Vol.2, Taylor and Francis Group, New York.
- Schaetzl, R. and S. Anderson (2005) Soils: Genesis and Geomorphology. Cambridge University Press, New York.
- Schoeneberger, P.J., Wysocki, D.A., Benham, E.C. and Broderson, W.D.(editors), 2002. Field book for describing and sampling soils, Version 2.0. National Resources Conservation Service, National Soil Survey Centre, Lincoln, NE.
- Schoeneberger, P.J., Wysocki, D.A., Benham, E.C., and Soil Survey Staff (2012). Field book for describing and sampling soils, Version 3.0. National Resources Conservation Service, National Soil Survey Centre, Lincoln, NE.
- Shivaprasad, C.R, R.S. Reddy, J.Sehgal and M.Velayutham (1998) Soils of Karnataka for Optimising Land Use, NBSS Publ. 47b, NBSS and LUP, Nagapur, India. 111pp.
- Soil Survey Staff (1951) Soil Survey Manual, Agriculture Handbook No. 18, Washington DC, 503 Pp.
- Soil Survey Staff (1993) Soil Survey Manual, Agriculture Handbook No. 18, US Department of Agriculture, Washington DC, USA, 437 Pp.
- Soil Survey Staff (1996) National Resources Conservation Service, National Soil Survey Handbook, Title 430 – VI, US Department of Agriculture, Washington DC, USA.
- Soil Survey Staff (2003) Soil Taxonomy, Agricultural Handbook, Title 436, Third Edition, US Department of Agriculture, Washington DC, USA, 869 Pp.
- Watershed Development Department (2016) Implementation Manual for SUJALA III Project (Guidelines for Integrating Land Resources Information for Watershed Planning and Development), KWDP II (SUJALA III), Watershed Development Department, Bengaluru.

For Estimation of per cent of area covered in Soil



Examples of per cent of area covered. The above graphic can be used to assess the amount or quantity of mottles, concentrations, redoximorphic features and ped and void surface features present in the soil. Within any given box above, each quadrant contains the same total area covered, but with by different sized objects.

Appendix-II

Check List for Field Work

Digging Tools Crowbar Pick axe Spade Shovel Khurpi Plastic tray Field kit bag Auger (Hand) or Probe Light tables (portable) Map board Sieves Soil test kit bag Knife	**Soil Description** Hand lens (10X) Acid Bottle (1N – HCl) Water Bottle Colour Charts (Munsell) Picture Tapes for Photographs Tape Measure (metric) Fine Point Permanent Marker Pens Pocket pH (pocket size) Pocket Soil Thermometer Camera Sample Bags (both polythene and cloth) Pedon Description Forms Polythene sheet for spreading EC meter (pocket size)
Site Description Field Notebook GPS Unit (Handheld) Abney Level Clinometer Compass, Magnetic Altimeter (pocket sized) Thermometer Altimeter	**Field and Camp use** Toposheets Cadastral Maps Imagery of the area Geology Maps Soil Survey Maps and Reports of the area Field Notebook for any additional notes Soil Survey Manual Field Guidebook for soil-site description
Others Laptops Mobile Phone Hats (Broad one) First Aid Box Towels	Sunscreen Umbrella Pens/Pencils Drinking water Iron Box

Land Resource Inventory-Proforma for Soil-Site description

NBSS & LUP	University of Agricultural Sciences			UHS	UAHS	Author:
Bangalore	Bangalore	Dharwad	Raichur	Bagalkote	Shivamogga	Date :

Series Name:	Map unit Symbol:	Soil Classification:

Observation No.:	Topo sheet No.:	Imagery .:	Base map: Scale:	Cadastral Sheet No.:

Location:	Latitude: ° ′ ″ Longitude: ° ′ ″	Plot (Survey) No.:	Village: Hobli: Taluk: District:

Physiographic Region:	Landscape:	Geology:	Landform:

Topography of the surrounding country: Level / Nearly level / Undulating / Rolling / Hilly / Steep / Very steep	Parent material:	Microfeatures:	Profile position:

Soil slope	Gradient (%)	0-1 A	1-3 B	3-5 C	5-10 D	10-15 E	15-25 F	25-33 G	>33 H	**Erosion**	Very slight	Slight	Mod.	Sev.	V. Sev
	Length (m)	0-50	50-150	150-300	300-600	>600				**Runoff**	Ponded	V.Slow	Slow	Med	Rap	V.Rap

Drainage	V. Pr	Pr	Some what Pr.	M. Well	Well	Some what excessive.	Ex.	**G. Water depth (m)**	<1	1-2	2-5	5-10	10-25	25-50	>50
Flooding	No	Occassional	Frequent	Very Frequent				**Salt/Alkali (% sur. coverage)**	No	<20	20-50	>50			
pH	<4.5	4.5-5.5	5.5-6.5	6.5-7.5	7.5-8.5	8.5-9.5	>9.5	**E.C.**	<2	2-4	4-8	8-15	15-25	25-50	>50

Surface fragments	Dia (cm)	<2	2-7.5	7.5-25	25-60	>60	**Rock out-crops**	Dist. Apart (m)	No	35-100	10-35	3.5-10	<3.5	
Coverage of gravels (<25cm)	(%)	<15	15-35	35-60	>60			Coverage(%)	<2	2-10	10-25	25-50	50-90	>90
Coverage of stones & boulders	(%)	0.01-0.1	0.1-3	3-15	15-50	50-90	Elevation above MSL(m):							

LAND USE / VEGETATION			
Crop	Season	Yield	Management
Vegetation			
Nine fold classification			
Forests : evergreen / deciduous / shrub			
Area put to non agricultural uses			
Barren and uncultivable land			
Permanent pastures & other grazing land			
Land under misc.tree crops and groves			
Culturable wasteland			
Fallow lands other than current fallows			
Current fallows			
LCC			

FIELD NOTES	SKETCH
	cm
	50
	100
	150
	200

Notes :

Observation Method:		Auger p	Minipit	Roadcut

	Depth (cm)	Horizon	Bnd[1] D T	Diag. Hori.	Matrix Color		Texture[2]	% clay	Rock Frags[3] Sz Knd Vol	Structre[4] Grade Sz Type	Consistence[5] Dry Mst Stk Pls
					Dry	Moist					
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

	Mottles/ Redox features[6] Qty Sz Cn Col Sp Loc	Coats/Films/Stress Features[7] Amt Dst Cont Kd Loc Col	Concentrations[8] (Conca, Conir, etc.,) Qty Sz Cn Kd Col	**Roots[9]** Qty Sz Lc	**Pores[10]** Qty Sz Shp	**pH**	Effer[11] (dil Hcl) -1,2,3	**Sample bag No.**

1. **D-Distinctness:** a-abrupt, c-clear, g-gradual, d-diffuse, **T-topography:** s-smooth, w-wavy, i -irregular, b-broken
2. **Texture:** s-sand, ls-loamy sand, sl -sandy loam, l -loam, sil -silt loam, si-silt, scl -sandy clay loam, cl -clay loam, sicl -silty clay loam, sc-sandy clay, sic-silty clay, c-clay.
3. **Size:** fg- fine gravel(<2cm), cg-coarse gravel(2-7.5cm), cb-cobbles(7.5-25cm), st-stones(25-60cm), b-boulders (>60cm).
4. **Grade:** 0-structureless, 1-weak, 2-moderate, 3-strong; **Size:** vf-very fine, f-fine, m-medium, c-coarse, vc-very coarse **Type:** gr-granular, cr-crumb, clr-columnar, pr-prismatic, pl-platy, abk-angular blocky, sbk-subangular blocky, sg-single grain, m-massive, c-cloddy.
5. **Dry:** l-loose, s-soft, sh-slightly hard, h-hard, vh-very hard, eh-extremely hard, **Moist:** l-loose, vfr-very friable, fr-friable, fi-firm, vfi-very firm, efi-extremely firm, **Stickyness:** so-non-sticky, ss-slightly sticky, ms-moderately sticky, vs-very sticky, **Plasticity:** po-non-plastic, sp-slightly plastic, mp-moderately plastic, vp-very plastic.
6. **Quantity(qty):** f-few(<2%), c-common(2-20%), m-many(>20%); **Size(sz):** 1-fine(<2mm), 2-medium(2-<5mm), 3-coarse (5-<20mm), 4-very coarse(>20mm); **Contrast(cn):** f-faint, d-distinct, p-prominent ; **Colour(col); Shape(sp):** c-cylindrical, d-dendritic, i-irregular, p-platy, s-spherical, t-threads, r-reticulate; **Location(Loc)**-matrix/ped/pores/others.
7. **Amount(Amt):** vf-very few(<5%), f-few(5-<25%), c-common(25-<50%), m-many(50-<90%), vm-very many (>90%);**Distinctness(Dst):** f-faint, d-distinct, p-prominent; **Continuity(Cont):** c-continuous, d-discontinuous, p-patchy; **Kind(Kd):** Type of coating/stress features; **Location(Loc)**: on bottom/top or all faces of peds; **Colour(Col)**: Munsell
8. **Concentrations:** Quantity(qty), Size(sz), Contrast(cn) and Colour are to be described similar to that of the mottles; **Kind(Kd)**: Disseminated materials, Masses, Nodules, Concretions, Crystals and Biological concentrations.

9 & 10 **Roots/Pores: Quantity**: f-few(<1 per area), c-common(1-5), m-many(>5); **Size**: vf-very fine, f-fine, m-medium, c-coarse; vc- very coarse; **Location(Loc):** between peds(p), in cracks(c), throughout(t); **Shape(Shp):** tubular/irregular/vesicular/interstitial. 11. **Effervescence:** 1-slight, 2-strong, 3-violent.

SYMBOLS USED FOR SOIL-SITE CHARACTERISTICS

Surface Soil Texture	Soil Gravelliness	Soil Slope
a - Sand b - Loamy sand c - Sandy loam d - Loam e - Silt loam f - Clay loam g - Silty clay loam h - Sandy clay loam i - Sandy clay k - Silty clay m - Clay	g0 - Non gravelly (<15 %) g1 - Gravelly (15-35 %) g2 - Very gravelly (35-60 %) g3 - Extremely gravelly (60-80 %) g4 - Considered as part of the top soil (>80 %)	A - Nearly level (0-1%) B - Very gently sloping (1-3%) C - Gently sloping (3-5%) D - Moderately sloping (5-10%) E - Strongly sloping (10-15%) F - Very Strongly sloping (15-25%) G - Moderately Steeply Sloping (25-33%) H - Steeply Sloping (33 - 50%) I - Very Steeply Sloping (>50%)

Erosion

- e0 - Nil
- e1 - Slight
- e2 - Moderate
- e3 - Severe
- e4 - Very severe

Stoniness

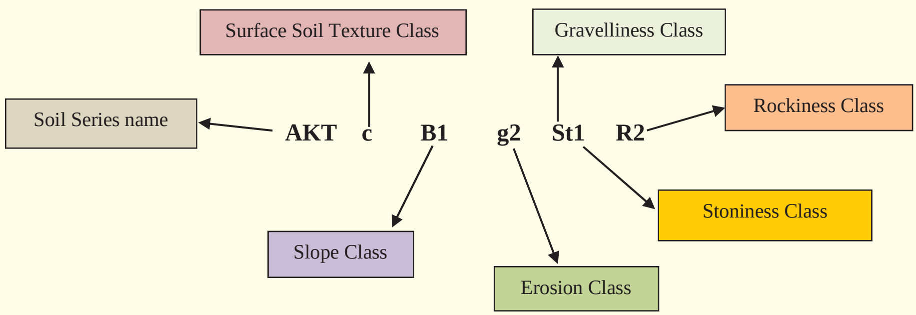
Code	Area covered	Class
St1	0.01 to 0.1%	Strong
St2	0.1 to 3%	Very strong
St3	3 to 15%	Extremely strong
St4	15 to 50%	Rubbly
St5	50 to 90%	Very rubbly
St	>90%	Stony

Rocks

- No to very few rocks (<2%)
- Fairly rocky (2-10%)
- Rocky (10-25%)
- Very rocky (25-50 %)
- Extremely rocky (50-90 %)
- Rock outcrops (>90%)

Soil Map Unit (Soil Phase) Symbol

For Example: AKTcB1g2St1R2



AKT	**Soil Series name**	**Attikatti soils**
c	Texture class	Sandy loam
B	Slope class	3% slope-1
1	Erosion class	Slight erosion
g2	Gravelliness class	Very gravelly (35-60%)
St1	Stoniness class	0.01 to 0.1% surface area covered
R2	Rockiness class	10 to 25% surface area covered

About ICAR-NBSS & LUP

The ICAR-National Bureau of Soil Survey and Land Use Planning (NBSS & LUP), Nagpur, a premier Institute of the Indian Council of Agricultural Research (ICAR), was set up in the year 1976 with the objective to prepare soil resource maps at state and district level and to provide research inputs in soil resource mapping, and its applications, land evaluation, land use planning, land resource management and database management using GIS for optimizing land use on different kinds of soils in the country. The Bureau has been engaged in carrying out agro-ecological, soil degradation mapping and large-scale land resource inventory for farm level planning at village/watershed, taluk, district and state level for assessment and monitoring the soil health towards viable land use planning.

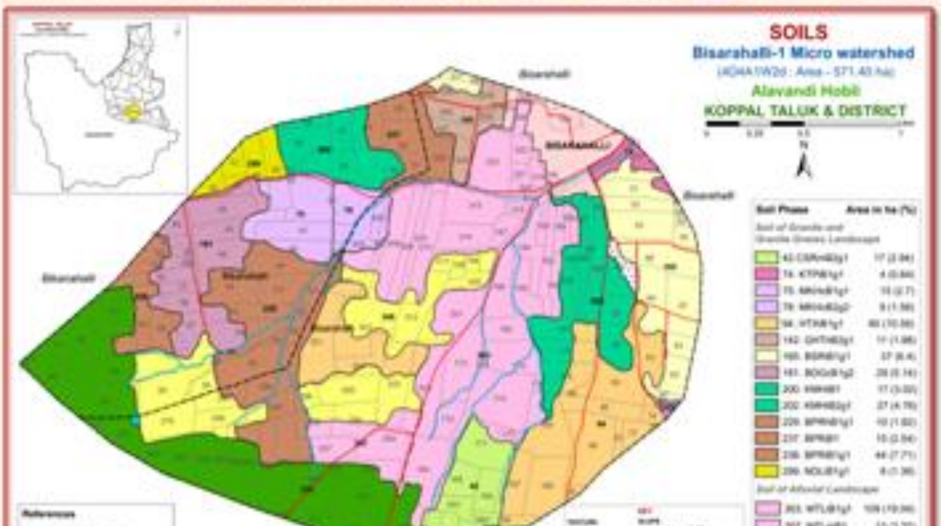
The research activities of the Bureau have resulted in identifying the soil potentials and problems and the various applications of the soil survey with the ultimate objective of sustainable agricultural development. The Bureau has the mandate to correlate and classify soils of the country and maintain a National Register of all the established soil series.

The Institute is also imparting in-service training to staff of the soil survey agencies in the area of soil survey and land evaluation, soil survey interpretations for land use planning. The Bureau in collaboration with state agricultural universities (SAUS) is running post-graduate teaching and research programme in resource management leading to M.Sc. and Ph.D. degrees.

FOR FURTHER INFORMATION, OR TO OBTAIN COPIES OF THIS BULLETIN,

Please write to:

Director, **:** ICAR-National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), Amravati Road, Nagpur – 440 033.
Phone **:** (0712) 2500386, 1500545, 2500664
Telefax **:** +91-0712-2500534
Telex **:** 0715-7262 NBSL IN
E-mail **:** director@nbsslup.ernet.in
ISBN **:** 81-85460-66-3 **OR**
Head, **:** Regional Centre, NBSS&LUP (ICAR), UAS campus, Hebbal, Bengaluru-560024
Phone **:** (080) 23412242, 23410993, 23415683
E-mail **:** nbssrcb@gmail.com


SOILS
Bisarshalli-1 Micro watershed
Alavandi Hobli
KOPPAL TALUK & DISTRICT
Source: ICAR-NBSS&LUP, Bengaluru (2017)