

**LAND RESOURCE INVENTORY IN THE DAMBAL-II MICRO-
WATERSHED OF GADAG DISTRICT USING REMOTE
SENSING AND GIS TECHNIQUES**

SURESH BIRANI

**DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL
CHEMISTRY
COLLEGE OF AGRICULTURE, DHARWAD
UNIVERSITY OF AGRICULTURAL SCIENCES,
DHARWAD – 580 005**

JULY, 2016

LAND RESOURCE INVENTORY IN THE DAMBAL-II MICRO- WATERSHED OF GADAG DISTRICT USING REMOTE SENSING AND GIS TECHNIQUES

*Thesis submitted to the
University of Agricultural Sciences, Dharwad
in partial fulfillment of the requirements for the
Degree of*

**MASTER OF SCIENCE (AGRICULTURE)
IN
SOIL SCIENCE**

**BY
SURESH BIRANI**

**DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL
CHEMISTRY
COLLEGE OF AGRICULTURE, DHARWAD
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CERTIFICATE

This is to certify that the thesis entitled "LAND RESOURCE INVENTORY IN THE DAMBAL-II MICRO-WATERSHED OF GADAG DISTRICT USING REMOTE SENSING AND GIS TECHNIQUES" submitted by Mr. SURESH BIRANI for the degree of MASTER OF SCIENCE (AGRICULTURE) in SOIL SCIENCE to the University of Agricultural Sciences, Dharwad is a record of research work done by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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Acknowledgement

Here comes the most awaited moment to go back at the traversed path, that leads to this endeavor and express my gratitude to all the minds, hearts and hands that played a role for this thesis.

I take an opportunity to express my deep senses of gratitude to excellence pursuing and very helpful unique personality and on sincere regard to Dr. S. S. GUNDLUR, Soil Physicist, IWMRC, Belavatagi, University of Agricultural Sciences, Dharwad, the Chairman of my Advisory Committee for his valuable and systematic guidance, constructive criticism, kind support, critical examinations of manuscript and keen interest in bringing out this thesis in to reality.

I am also grateful to Dr. V. B. KULIGOD, Professor, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Dharwad, Dr. RAJKUMARA S, Associate Professor, Department of Agronomy, College of Agriculture, Dharwad, the members of my advisory committee for providing all the needful help, moral support and for their valuable suggestions during the critical stages of research.

With grate profound, I wish to express my deep sense of reverence and sincere thanks to Dr. B. I. Bidari, Professor and Head, Dr.P. L. Patil, Professor Dr. K. K. Math, Professor, Dr. N. S. Hebsur, Professor, Dr. Manjunatha Hebbar, Professor, Dept. Soil Science and Agricultural Chemistry, College of Agriculture, Dharwad, Dr. Niranjana, NBSS and LUP, Bangalore, for their sustained guidance, kind treatment, unfailing courtesy extended at all the time an his efforts for providing me with the atmosphere and facilitates that I need for completing this investigation successful all more fully appreciated can be expressed here.

I acknowledge the sacrifice, my reverential gratitude to my beloved parents Shri. LAXMAN, Smt. GANGAVVA and my brothers MAHESH and NINGESH, who fed me love affection and encourage than any thing else which is alive and agile in my every cell.

Friends are ever lasting source of love, inspiration, energy and courage. No less share of credit goes to brilliant galaxy of friends. I am also thankful to my seniors Manjunath Chari, Nagendra B. R, Pramod Tumbal, Mallikarjun Rodagi, Veerabhadra, Mallikarjun, Nagaral, Anjali, Manasa, Sankalpa, Dhanalaxmi Ashwini, Jahnavi, Jyoti, Deepa, Asha, Ramachandra, friends, Mahantesh, Ravi (Jersy), Nikhil, Dharshan, Manu, Prabhakar, Bharathkumar, Shushma, Guru, Shivanand, Laxman, Shashi Jayashri, Chijina, Babu, Utpal, Naganagouda, Ajmir, Basanagouda, Beerappa, Pinku, Goutam, Vijay, Vittal, Shivaputra, Leheru, Prathibha K.S, Usha G.K, Chendregouda, Manoharchari, Chendrashekar, Madusudan, Arun, Ashwitha, Chetana, Ramya, Datta, Dilip and my juniors Mahesh, Salma, Pradeep, Amrutha, Sujata, and Sindhu.

I take this opportunity to place on the record my sincere thanks to Mr. Kalliyavar, Parakale, Tippanna, Manju, Sangaya, Suresh, Department of Soil Science and Agricultural Chemistry College of Agriculture, Dharwad for their cooperation and support in the perusing of the study.

I hereby sincerely acknowledge the Nodal Officer of SUJALA-III Project, for providing field and laboratory facilities.

I am very grateful to Mr. Arjun and Mr. Kalmesh (Arjun Computers, Dharwad), for their kind co-operation and Mr. M. I. Kumbhar (Binder), for his neat binding of the manuscript.

Finally I sincerely acknowledge those who helped me directly or indirectly, without exception during the course of the study and my stay at Agriculture College boy's hostel, College of Agriculture, Dharwad.

**DHARWAD
JULY, 2016**

(SURESH BIRANI)

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Sl. No.	Abbreviation	Description
1.	%	Per cent
2.	°C	Degree Celsius or centigrade
3.	AAS	Atomic Absorption Spectrophotometer
4.	AIS&LUS	All India Soil and Land Use Survey
5.	c. mole	Centi mole
6.	CEC	Cation Exchange Capacity
7.	cm	centimeter
8.	cm ³ / cc	Cubic centimeter
9.	DTPA	Diethylene Triamine Penta Acetic acid
10.	EC	Electric Conductivity
11.	EDTA	Ethylene Di-amine Tetra Acitic acid
12.	ESP	Exchangeable Sodium Percentage
13.	FAO	Food and Agricultural Organization
14.	FCC	False Colour Composite
15.	Fig.	Figure
16.	g	gram
17.	GIS	Geographical Information System
18.	H ₂ O	Water
19.	ha	Hectare
20.	IRS	Indian Remote Sensors
21.	kg	kilogram
22.	l	Litre
23.	LCC	Land capability classification
24.	LIC	Land Irrigability classification
25.	LISS	Linear Image Self Scanners
26.	LULC	Land Use Land Cover

Contd....

Sl. No.	Abbreviation	Description
27.	m	meter
28.	m ²	Square meter
29.	m ³	Cubic meter
30.	Mg	Megagram
31.	mg	milligram
32.	ml	millilitre
33.	mm	millimeter
34.	MU	Mapping Unit
35.	MWHC	Maximum Water Holding Capacity
36.	NBSS&LUP	National Bureau of Soil Survey and Land Use Planning
37.	No.	Number
38.	OC	Organic Carbon
39.	pH	Potential hydrogen
40.	SOI	Survey of India
41.	TGA	Total Geographical Area
42.	USA	United States of America

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1. INTRODUCTION

Soil is one of the most important natural resources on which the sustenance of life depends. It performs the important function of meeting the basic needs such as food, fibre, fodder and fuel of humans and animals. With increase in human and animal population, there is increasing demand for more food production. The scope of increasing the land area under agriculture is very limited. Therefore, we have a challenge of producing more food per unit area. However, the capacity of the soil to produce is limited and limits to production are set by intrinsic soil characteristics, agro-ecological setting, use and management. The per capita cultivable land has declined from 0.48 ha in 1951 to 0.16 ha in 2008-09 (Anon, 2013). This demands systematic appraisal of our soil resources with respect to their extent, distribution, characteristics, behaviour and use potential, which is very important for developing an effective land use system for augmenting agricultural production on sustainable basis.

Soil, as the name expresses “Soul of Infinite Life” supports all life-forms directly or indirectly. A country’s development depends on the development of human resources but it has been deemed that human resource depends upon soil as it feeds and becomes source of livelihoods to most of the human population on earth. In the recent years, productivity of agricultural soils worldwide in general, is on the decline.

The natural resources of any country are the national treasure and need proper planning to make best use of them. Therefore, sustainable management practices are urgently needed all over the world to preserve the production potential of agricultural lands. Efficient management and maintenance of soil health is the key to accomplish sustained high productivity, food security and environment safety. No possibility of further horizontal expansion in the cultivated area seems to exist. It has also been reported that 57 per cent of the total geographical area in India is suffering from various types of land degradation problems.

Soil fertility affects considerably the land use of any agro-ecosystem. The inherent fertility of soil is controlled by the set of pedogenic factors that vary from soil to soil and declining soil fertility is the main cause for low land productivity. Present day exploitive agriculture, which involved efforts to increase crop yield has not only depleted our soils of their nutrient reserve, but also resulted in the emergence of a number of nutrient deficiencies.

In the recent past, concept of watershed based holistic development has emerged as one of the potential approaches in rainfed areas, which can lead to higher productivity and sustainability in agricultural production. Different measures are adopted and executed carefully in each of toposequences according to their capability.

Soil survey constitutes a valuable resource inventory linked with the survival of life on the earth. It provides an accurate and scientific inventory of different soils, their kind and nature and extent of distribution so that one can make prediction about their characters and potentialities. It also provides adequate information in terms of land form, slope, land use as well as characteristics of soils (*viz.*, texture, depth, structure, stoniness, drainage, acidity, salinity *etc.*) which can be utilized for the planning and development

Since soils in general are degrading due to poor management and faulty land use at a rate faster than their natural regeneration, it becomes imperative to protect them from further degradation as there is a concomitant decline in soil quality to produce healthy crops. Hence, a detailed study of the soil resources is needed to realize the concept of watershed development approach successfully.

Information of soil and related properties obtained from the soil survey and soil classification can help in better delineation of soil and land suitability for irrigation and efficient irrigation water management. So, depending on the suitability of the mapped agro-ecological units for a set of crops, optimum cropping patterns have to be suggested taking into consideration the present cropping systems and the socio-economic conditions of the farming community (Sehgal *et al.*, 1989).

Land use planning evaluates land and alternative land use patterns for the purpose of selecting the best choice. Planning decisions deal sometimes with interest of competing land users and may therefore be questioned and/or criticized. Hence, it is recommended that those plans and the different scenarios taken into consideration are based on scientifically sound approaches and objective of suitability assessments. Resource management activities concern basically soil and water conservation. Although, being primarily site-specific, these activities also affect the soil properties and use potential of land which is away from the operational site. Hence, it influences living conditions of the rural community as a whole. The users should obviously be associated to all land use planning decisions which directly or indirectly affect the area.

The selected area of Dambal-2 micro-watershed covers an area of 401.07 ha. It majorly comprises of black soils and to some extent red soils differing in their physical, chemical and agronomic characteristics. However, red soils are confined invariably to the hill-tops. The valley region comprises of only black soils. Their characterization and classification is crucial for productive and sustainable management of soils. Knowledge about morphological, chemical, physical and preparing crop suitability map for the area, these properties of soils would helps in better crop planning.

Keeping these considerations in view, an investigation was carried out at Dambal-2 micro-watershed in Gadag district with the following objectives;

1. To characterize, classify and map the soil resources of Dambal-2 micro-watershed in Gadag district.
2. To evaluate the soils of the micro-watershed for land capability, irrigability and soil site suitability for selected crops and
3. To assess soil fertility status of the micro-watershed.

2. REVIEW OF LITERATURE

Soil is a major part of the natural environment, alongside air and water and is vital to the existence of life on the planet. Soil may be characterized in terms of the properties they inherit from the underlying parent material and the properties resulting from the alteration of the original parent material by pedogenic processes.

In order to map and identify different types of soil, it is necessary to have a system of soil classification. Soils are allocated to a type according to their profile characteristics including abundance of organic matter in the top soil, texture, colour, structure *etc.*

Soil surveying and soil mapping, are the process of classifying soil types based on soil properties in a given area and geo-encoding such information. It applies the principles of soil science and draws heavily from geomorphology, theories of soil formation, physical geography and analysis of vegetation and land use patterns. Primary data for the soil survey are acquired by field sampling and remote sensing.

The information in a soil survey can be used by farmers to determine whether a particular soil type is suited for crops or livestock and what type of soil management might be required. This data further suggests the great diversity among and within the soils. Based on the available information the literature is reviewed under the following headings

- 2.1 Soil survey for land evaluation /land use planning
- 2.2 Soil properties
- 2.3 Land capability classification
- 2.4 Soil-site suitability for crops

2.1 Soil survey for land evaluation /land use planning

The tasks of soil survey are description, classification and mapping of soils. Most countries have organizations with the responsibility of carrying out such studies.

Challa *et al.* (2000) characterized and classified four representative problematic *Vertisols* occurring on upper and lower Maharashtra plateau distributed in continuously irrigated zone of Ahmed Nagar and Akola districts under semi-arid ecosystem. Based on the properties, the soils were classified as Halic Haplusterts while other soils were grouped under Sodic Haplusterts.

A studied by Mahapatra *et al.* (2000) in sub humid soils of Kashmir region spreading over Anantnag, Badgam, Baramulla, Kupwara and Srinagar districts. They vary greatly in their morphological features, physical and chemical characteristics and a well established soils physiographic relation exists in this hilly region. Varying degree of profile development from A-C to A-B-C profiles on steep slopes to piedmont plains was observed. Soils of summits and side slopes are severely eroded, shallow and less developed where as in piedmont plains, karewas and valleys they are deep and well developed. The soil texture varied from sandy/loamy skeletal to fine loamy and fine, the soil reaction ranged from acidic to slightly alkaline and organic matter content was generally high. As per soil classification major soils belonged to *Entisols* followed by *Inceptisols*, *Alfisols* and *Mollisols*.

Sawhney *et al.* (2000) found that the soils of southeastern part of submontane tract of Punjab in relation topography by remote sensing followed by ground survey and laboratory analysis. The soils on relatively unstable landforms indicated young and immature A-C profile whereas those from stable landforms showed distinct profile development having A-Bw-C and A-Bt-C horizon sequence. Topography and parent material were found to be the major factors governing the soil characteristics specially on unstable surfaces whereas time as an additional factor on stable surfaces during which pedogenic processes were responsible for their differences in the profiles. The soils on upper piedmont plain were classified as *Typic Ustorthents*, 'choe' beds as *Typic Ustipsamments*, recent flood plain as *Aquic Ustifluvents*, lower piedmont as *Typic Haplustepts* and old alluvial plain as *Typic Haplustalfs*.

A study was under taken by Patel *et al.* (2001) in a part of Solani watershed of Haridwar and Saharanpur districts in Uttaranchal and Uttar Pradesh, respectively to assess the land capability, to adopt suitable soil conservation majors and suggest appropriate land use through remote sensing and GIS approaches. Thematic information on soils slope and land use was generated from remotely sensed data, survey of India toposheets and field survey. This special information were integrated by using GIS techniques for generating basic resource map such as composite land use and land capability. Present composite land use and land capability maps and the suitability criteria were framed to prepare land use adjustment plan for appropriate soil conservation needs and proper land utilization parts of Solani watershed.

Four Vertisol pedons in the western zone of Orissa were studied for morphological and physico-chemical properties, characterization and classification by Sahu *et al.* (2001). The soils are very deep, colour ranged from black to grayish brown in different horizons, crack of 2 to 3 cm wide extend beyond 1 meter. Slickensides, wedge shaped aggregates, iron and manganese concretions are observed in the subsurface horizons of the soils. The soils were imperfectly drained, slightly acidic to moderately alkaline and the pH value increased with depth. The soils are saturated and high in CEC: clay ratio (0.65 to 0.75) and classified as *Typic/Chromic Haplusterts*.

Sharma *et al.* (2001) reported that the seven soil series belonging to *Entisols*, *Inceptisols* and *Vertisols* occurring on residual hummocks and ridges, pediment, pediment/valley, flood plain and coastal plain in Rajkot district of central Kathiawar region of Gujarat state were studied. The soils differed widely in their morphological, physical and chemical characteristics. Significant variations in soil depth, drainage, colour and structure were observed in relation to toposequence. Soils occurring on upper elements of topography are shallow to moderately deep, somewhat excessively drained, clay loam to clay in texture and reddish brown to dark brown in colour, whereas soils occurring on lower elements of topography are deep to vary deep, moderately drained to poorly drained, clay in texture and grayish brown to dark grayish brown in colour. Soils in general, were low in organic carbon but high in clay content, cation exchange capacity and base saturation, irrespective of their physiographic position. Calcium dominated the exchange complex. Soils occurring on lower element of topography were strongly calcareous and showed mottling.

Sarkar *et al.* (2002) characterized and classified the soils of Loktak catchment area for sustainable land use planning on the basis of the major soil constraints. The high hill soils were classified into capability class VI due to very steep slope, very severe erosion including landslides. The medium hill soils are classified into capability class IV due to moderate steep slope, very severe erosion and low moisture holding capacity gravelly subsoil and high soil acidity. The foothills soils are classified into capability class III due to moderate steep slope, moderate erosion and runoff, moderately well drained soils with slow permeability and moderate water holding capacity.

Tomer *et al.* (2002) studied that site specification action plan of upper Shipra watershed in Ri-Bhoi district of Meghalaya. The forest was the main land use (76.4 per cent) of the watershed followed by agriculture (shifting cultivation) and remaining land was under settlement, pasture, barren hills, ponds, quarry *etc.*

Gebrekidan and Mishra (2005) characterized and classified the soils of Hirna watershed. Soils in the steep slopes were shallow whereas they became deep along the topographic lows. The clay texture was common due to basaltic parent material. Soil colour often changed towards red hue on moistening. These soils were neutral to alkaline in reaction. The C:N ratio for all the soils was relatively high and in some cases, it was much higher than the optimal. The soils on mountainous landscape (backslope) were gravelly and eroded particularly on steep slopes. All soils had appreciable amount of organic carbon showing mollic features in the surface horizons. Biotic activities were prominent in some soils. Vertic features under differing moisture regimes were recorded particularly in soils of the foothill and lowlying areas.

Joshi *et al.* (2005) reported that the land use and land cover change had an impact on the soil erosion process resulting in declining productivity of land. They also showed that the land cover dynamics is dependent on the aspect due to sun illumination.

Shamsudheen *et al.* (2005) characterized the forest soils of north Karnataka for their morphological, physical and chemical properties. The texture and colour of soils varied from sandy loam to clay and 2.5 YR to 10 YR respectively associated with predominantly sub-angular blocky structure. The soils had high amounts of coarse fragments and sand fractions. The soils were acidic (pH 5.1 – 5.9), rich in organic carbon and were associated with low cation exchange capacity. Based on the characteristics, these forest soils were classified as *Dystric Haplustepts*, *Kanhaplic Haplustalfs*, *Ustic Haplohumults*.

A study was undertaken by Ravikumar (2006) to characterize and classify the soils under the distributory no. 48 A of Malaprabha right bank command of Karnataka. Soil survey was carried out to know the type and extent of soils prevailing in the area. Detailed soil survey for the study was carried out using IRS 1D LISS III image and cadastral map. Twelve pedons were selected based on the variation in surface features. At family level, the pedons under study were classified as very fine clayey, smectitic, calcareous, isohyperthermic; *Typic Haplusterts*, Kiresur and Hanchinal series were identified in the study area and the soils were mapped into six mapping units due to variation in slope, erosion and depth.

Sitanggang *et al.* (2006) characterized and classified the soils of Shikohpur watershed area. The soils on hill top and hill side experienced erosion and have depth of 35 to 75 cm, respectively slightly acidic with pH ranging from 6.4 to 6.5. Whereas, the soils on the ravenous areas, piedmont plain and alluvial plain have depth of 130 to >150 cm and slightly alkaline to alkaline in the range of 7.55 to 8.57. Soils in the ravenous area piedmont plain and alluvial plain have less redder hue as compared to those on hill top and hill side. Soils on the hill top and hill side have relatively higher clay content (23.40 per cent– 34.90 per cent) with 12.50 to 87.50 per cent coarse fragments. Soils were highly base saturated and CEC ranged from 6.00 to 12.57 cmol (p⁺) per kg.

Tripathi *et al.* (2006) characterized and classified the soils of Kiar-Nagali micro-watershed. The soils were neutral to slightly alkaline (pH 7.2 – 7.6), mixed in mineralogy, shallow to very deep and have thermic temperature and udic moisture regimes. Texture, organic carbon, CEC and base saturation ranged from silty loam to loam, 4.5 to 23.5 g per kg, 9.8 to 14.8 cmol (p⁺) per kg and 56.6 to 74.8 per cent, respectively. Evidences of clay illuviation in sub-soils was observed in majority of the soils. Soils were classified as *Typic Udorthents*, *Dystic Eutrudepts* and *Typic Dystrudepts*.

Mini *et al.* (2007) characterized and classified the soils of the Mirjan village of coastal agro-ecosystem of Karnataka in relation to topography by remote sensing techniques, ground survey and laboratory analysis. The colour varied from reddish in the higher topographic position to yellowish colour in the lower topographic position. Soil temperature and moisture regimes were isohyperthermic and Ustic, respectively. The pedons on hills and hill ranges and garden lands were classified as *Dystrustepts*. Pedons of low hills and mid lands showed a better development and were classified into *Haplustalfs*. The soils of low lands with deep water table were classified into *Dystrustepts*. The illuvial soils of low lands with shallow water table were classified as Ustifluvents.

Sankar *et al.* (2010) made a detailed soil survey (1:5000 scale) of Kutturavupatti village (537 ha) in Sivagangai district of Tamil Nadu. To delineate the area for agricultural suitability, four soil series, namely, Sivagangai, Melapoongudi, Tamarakki and Keelapoongudi were identified.

Characterization and evaluation of land resources in Khapri village of Nagpur district of Maharashtra were carried out using IRS-P6 LISS-IV and IRS-ID PAN sharpened LISS-III data and GILS coupled with field survey by Shweta *et al.* (2010). Six major landforms viz., isolated hillocks (15-30 per cent slope), plateau top (1-3 per cent slope), escarpments (8-15 per cent slope), pediment (3-8 per cent slope), upland (1-3 per cent slope) and valley plain (1-3 per cent slope) were identified. The major land use/land cover identified were agriculture, degraded forest and wasteland with scrub.

Characterization and evaluation of land resources of Taroda watershed were carried out using IRS-1D LISSIII and IRS-P6 LISS-IV data with filed survey by Rashmi *et al.* (2012). Five major physiographic units namely plateau (1-3 per cent slope), escarpment (8- 15 per cent slope), isolated hillock (15-30 per cent slope), pediment (1-3 per cent and 3-8 per cent slope) and valley (0-1 per cent slope) were identified. Visual interpretation of satellite data indicated that 54.8 per cent of the total geographical area (TGA) is under cultivation followed by wasteland with scrub (22.7 per cent) and degraded forest (21.1 per cent). Nine soil series were tentatively identified. The soils of plateau, escarpment and isolated hillock are very shallow (*Lithic Ustorthents/Typic Ustorthents*), soils of pediment are shallow (*Typic Ustorthents/Typic Haplustepts*) whereas, soils of valley are moderately deep to very deep (*Vertic Haplustepts/Typic Haplusterts*).

Nasre *et al.* (2013) reported that soils of plateau top-escarpments such as isolated hillocks and foot slopes were very shallow to shallow depth, loamy to clayey texture, well-drained and moderately to severely eroded. Soils of undulating lands such as alluvial plain and valley were deep to very deep, fine to very fine (texture), moderately well drained and slightly eroded. The soil color is 10YR in hue and at places of plateau top and foot slope exhibited 5YR with chroma 1 to 3 and value 3 to 5. Seventeen soil series were mapped as physiographic land use units. However, higher pH and ESP in sub-soils of Dharna and Kongara. At sub-group level, the soils were classified as *Lithic Ustorthents*, *Typic Ustorthents*, *Typic Haplustepts*, *Vertic Haplustepts* and *Sodic Haplusterts* in the soils of Karanji Watershed, Yavatmal District of Maharashtra

Selvaraj and Naidu (2013) conducted Reconnaissance soil survey in Reniguntamandal of Chittoor district Andhra Pradesh to evaluate the land capability classification and suitability of soils for paddy, groundnut, redgram, sugarcane, vegetables and mango. The soil belongs to *Inceptisols*, *Entisols* and *Alfisol*s. Soil texture was finer and recorded regular decrease in organic carbon with depth in *Typic Haplustepts*. Low organic carbon and base saturation are major limitation in *Typic Ustipsamments* and *Typic Ustifluvents* unlike *Typic Haplustalfs*. In general, soil texture, base saturation, pH and organic carbon are the major limitation for crop growth in all the soils.

Pulakeshi *et al.* (2014) characterized and classified the soil resources of Mantagani village in northern transitional agro-climatic zone (zone-8) of Karnataka. Fourteen profiles were studied for the morphological, physical and chemical properties. Eight representative pedons covering all the soil types were selected and their properties and classification is discussed in this paper. Soils under the study were silty clay in texture, alkaline reaction with low salt content. Calcium and magnesium were the dominant cations followed by sodium and potassium. Soils studied were classified up to family level according to revisions in Soil Taxonomy using morphological, physical and chemical properties. Major proportion of the soils in the village belonged to the order *Vertisols* (pedons 4 to 11) and others *Alfisols* (pedon 12), *Inceptisols* (pedon 13) and *Entisols* (pedons 1, 2, 3 and 14). Seven series were identified in the study area.

2.2 Soil properties

Diwakar and Singh (1994) studied that the fine textured soils of sedimentary and old alluvial origin are characterized by uniform colour (brown to very dark grey), mottles of various shades and intensities, neutral to slightly alkaline reaction, low organic carbon and high clay content, high CEC and SiO₂ content. These soils have developed on varied types of parent materials at different physiographic levels under basic environment and impeded drainage. The soils of young alluvial region are characterized by various shades of grey colour, clay to loam texture with lithological discontinuity, lower CEC and high SiO₂ content. They have developed in bowl shaped physiography on alluvium. The decrease in CEC, cations and clay with depth is suggestive of their younger origin. These soils have an average productivity and good potentiality. The productivity could be raised by 1.8 to 2.0 times by adopting appropriate measures.

Pradeep Kumar and Verma (2005) revealed that the seven representative pedons from rice growing soils of Palam valley, which were characterized and classified. Most of the pedons had mottles and sandy loam to silt clay loam in texture with low permeability. In general, the soils were

moderately acidic to neutral in reaction, high to very low in organic carbon, mixed in mineralogy and moderately deep to very deep. Bulk density decreased with depth and values ranged from 0.99 to 1.62 Mg m⁻³. Water retention at 33 and 1500 kPa of soils ranged from 19.9 to 47.2 per cent and 8.1 to 33.2 per cent, respectively. Cation exchange capacity decreased and soil pH, N increased with depth but no definite distribution pattern was observed for P and K. The status of N and P was low to medium and that of K was low to high. Based on soil characteristics, the soils were classified as *Typic Hapludalfs* and *Typic Dystrochrepts*.

2.2.1 Morphological properties

2.2.1.1 Soil colour

Soil colour being one of the important basic properties helps to identify the kinds of soils and recognize the successions of soil horizons / layers in soil profiles. The soil colour often relates to specific chemical, physical and biological properties of the soils in that area.

Sarkar *et al.* (2001) studied that the soils of upper slopes in toposequence of Chhotanagpur plateau were yellowish red (5 YR 4/6) in colour in the surface layer and dark red (2.5 YR 4/6) in the lower layers while the soils lower slope of the toposequence were light brownish gray to light gray in surface horizon and gray in the lower layers. The colour of the soils in red and laterite region of West Bengal varied from brown to dark red (Nayak *et al.*, 2002).

Sarkar *et al.* (2002) showed that the colour in the surface horizons of soils developed from shale parent material varied from very dark brown (10 YR 2/2) to dark yellowish brown (10 YR 3/4) while the subsurface horizons were dark brown (10 YR 3/3) to yellowish red (5 YR 4/6). According to Ramprakash and Seshagiri Rao (2002) the colour of the red soils developed on granite-gneiss parent material in Krishna district of Andhra Pradesh varied from dark reddish brown (5YR 3/4) to dark brown (7.5 YR 3/4).

Inceptisols and *Entisols* of Shahibi basin in Haryana and Delhi varied from dark yellowish brown (10 YR 4/6) to brown (7.5 YR 4/4). The variation in the colour appears to be the function of chemical and mineralogical composition of the soils (Swarnam *et al.*, 2004). Pillai and Natarajan (2004) observed that the colour of the soils in Garakahalli watershed in Karnataka varied from red to reddish brown in upland and reddish brown to grayish brown in the lowland. The strong brown colour in the surface horizons were due to high organic matter content whereas in deeper layers the dark colour may be influenced by the parent material or ferrous iron oxide.

The soils located on gently sloping topography exhibited yellowish brown (10 YR 5/6) to dark red (2.5 YR 3/6) while the soils found on nearly level topography showed light yellowish brown (10 YR 6/4) to very dark grayish brown (10 YR 3/2) in Sivagiri micro-watershed of Chittoor district in Andhra Pradesh. This variation in the soil colour was a function of chemical and mineralogical composition, topographic position, textural make up and moisture regimes of the soils (Thangasamy *et al.*, 2005).

A study by Ram *et al.* (2014) a rapid reconnaissance soil survey of Markapur mandal of Prakasam district Andhra Pradesh was carried out in 2009-10 using geo-referenced false colour composite image (IRS-P6, LISS-III) and Survey of India (SOI) topo-maps (1:50,000 scale) set. The soils of hill side slope and undulating pediments developed over quartzite, sandstone and shale complex was shallow to moderately deep, brown (7.5 YR 4/4) to dark brown (7.5 YR 3/4) in colour,

well drained with poor fertility. These soils are under forest, open scrub and rainfed farming in patches. The soils of pediplains and stream bank from shale was yellowish red (5 YR 4/6) to dark reddish brown (5 YR 3/3), deep to very deep low fertility and cultivated (rainfed) in pediplains but waste land in stream bank.

2.2.1.2 Texture

Soil texture is defined as the relative proportion of soil separates namely sand, silt and clay in a given soil. The proportion of each size group in a given soil cannot be altered easily, that is why texture is considered a basic property of a soil.

Sharma *et al.* (2004a) revealed that the illuviation process affected the vertical distribution of silt and sand contents in Neogal watershed in North-West Himalayas. These results were in agreement with the findings of Naidu (2002) who noticed an irregular trend in silt content with depth in sugarcane growing soils of Karnataka.

Arun Kumar *et al.* (2002) studied that the soils occurring on plains had loam to sandy loam texture and recorded higher clay content than upland soils because of deposition of finer fractions from the uplands. The soils of Chandragiri mandal showed wide textural variations *i.e.*, from sand to clay (plain), sandy loam to clay loam (upland) and sandy clay loam to clay loam (hill slope). These wide variations in soil texture may be due to differences in parent material, physiography in situ weathering and translocation of clay (Basavaraju *et al.*, 2005).

The soils in Sivagiri micro-watershed of Chittoor district in Andhra Pradesh showed wide textural variations (sandy to clay). This variation in soil texture was caused by parent material, topography, in situ weathering and translocation of clay (Thangasamy *et al.*, 2005). Textural variations in Shikohpur watershed area are mainly associated with variation in parent material and topography (Sitanggang *et al.*, 2006). The soils in Lingnhalli micro-watershed of Bangalore rural district in Karnataka showed Surface soil texture ranged from sandy, sandy loam, sandy clay loam to loamy sand (Rajendra Hegde *et al.*, 2008).

2.2.1.3 Structure

Sand, silt and clay particles are the building blocks from which the soil is constructed. The manner in which these building blocks are arranged together is called soil structure. Soil structure is as important as soil texture in governing water and air movement in soil. Soil structure greatly influences the tilth of soil which in turn affects growth of plant roots.

Fine, weak and sub-angular blocky to medium to coarse, moderate to strong and sub-angular blocky to angular blocky structure was observed in Kathiawar watershed of Gujarat (Sharma *et al.*, 2001). Whereas, structure of the soil of lower Palar-Manimuthar watershed in Tamil Nadu varied from weak to strong, fine to coarse and granular to subangular blocky (Arun Kumar *et al.*, 2002). The structure in the cultivated soils of Neogal watershed in North-West Himalayas was granular to sub-angular blocky in surface and sub-angular blocky in sub-surface horizons (Sharma *et al.*, 2004b). Sitanggang *et al.* (2006) reported that low clay and low organic carbon lead to the weak structure.

Sarade and Prasad (2008) studied that the structure of soils in a guava orchard was sub-angular blocky to angular blocky with different size and grade and the structure mainly depended upon clay. The soils in Lingnhalli micro-watershed of Bangalore rural district in Karnataka showed surface soil texture ranged from sandy, sandy loam, sandy clay loam to loamy sand (Rajendra Hegde *et al.*, 2007).

Based on variation in physiography and parent material, productivity of six orange growing pedons were characterized and evaluated in Nagpur district of Maharashtra the dominant structure was moderate, medium sub-angular blocky (P3, P4 and P5) to angular blocky in sub-soils - P1, P2 and P6 (Likhar and Prasad, 2011).

Sireesha and Naidu (2013) reported that the structure of the soils in a semi arid agro ecological region were crumb, sub-angular blocky and angular blocky. The blocky structure *i.e.*, angular and sub-angular blocky were attributed to the presence of higher quantities of clay fraction

2.2.1.4 Consistence

It is a term used to describe the action of physical forces of cohesion and adhesion on the attributes of soil material at various moisture contents that determines the resistance of soil material to crushing or rupture and its ability to change the shape or to be molded.

Sharma *et al.* (2004b) revealed that dry consistence varied from loose to hard in surface horizon and loose to very hard in sub-surface horizon in the *Entisols*, *Inceptisols* and *Alfisols* of Neogal watershed in North-West Himalayas.

Thangasamy *et al.* (2005) documented that the consistence of the soils in Sivagiri micro-watershed of Chittoor district in Andhra Pradesh was loose to very hard when dry, loose to very firm when moist and non-sticky and non-plastic to very sticky and very plastic when wet. Soils in Kymore plateau and Satpura hills had the dry consistency slightly hard to hard in surface layers and hard to very hard in middle and lower horizons (Tripathi *et al.*, 2009).

Sireesha and Naidu, 2013 studied that the consistence of the soils in a semi arid agro ecological region varied from slightly hard to very hard (dry), friable to very firm (moist) and non-sticky and non-plastic to very sticky and very plastic (wet). Presence of high clay content of the soil and also due to dominance of smectite clay mineral soils were sticky and plastic to very sticky and very plastic, firm to very firm and slightly hard to very hard consistence in wet, moist and dry conditions respectively.

2.2.2 Physical properties

2.2.2.1 Particle size distribution with depth

Verma *et al.* (2001) studied that the soils in different landscapes showed that the sand and silt constitute major portion in mechanical composition. Particle size distribution in *Alfisols* of some benchmark soils of West Bengal indicated a distinct increase in clay content in subsurface (Bt) horizons (Nayak *et al.*, 2002). Similarly the clay content ranged from 44.5 to 50.7 per cent and increased with depth in *Sal* growing soils of Dindori district in Madhya Pradesh. Further, these soils were developed over basalt or partly laterized basalt and hence produced higher amount of clay (Patil and Jagdish Prasad, 2004).

Subsurface horizons of Neogal watershed in North-West Himalayas exhibited higher clay content as compared to surface horizons due to the illuviation process occurring during soil development. Similarly, the illuviation process also affected the vertical distribution of silt and sand contents (Sharma *et al.*, 2004). The clay content ranging from 34.4 to 73.4 per cent and it increased with depth. The silt content ranged from 12.8 to 40.0 per cent and sand content was less than 10.0 per cent in soils of micro-watershed in Vidarbha region of Maharashtra (Gabhane *et al.*, 2006).

Tripathi *et al.* (2009) characterized six representative pedons of Banganala watershed of Kymore plateau and Satpura hills in Rewa district, Madhya Pradesh. The pedons were very deep and their textures varied from sandy loam to clay in surface horizons and clay loam to clay in sub-soils.

2.2.2.2 Water holding capacity and Bulk density

Swarnam *et al.* (2004) studied that the bulk density in the *Entisols* and *Inceptisols* of Shahibi basin in Haryana and Delhi varied from 1.48 to 1.87 Mg m⁻³ and 1.50 to 1.69 Mg m⁻³, respectively. The higher bulk density values could be due to their coarse texture and low organic matter content. The moisture retention 33 kPa was 8.20 to 19.00 per cent and at 1500 kPa were 3.20 to 8.89 per cent in surface horizons. The low moisture retention was due to lighter texture, low organic matter content and dominance of illite in the clay fraction.

The bulk density of the soils in Sivagiri micro-watershed of Chittoor district Andhra Pradesh varied from 1.32 Mg m⁻³ in *Typic Rhodustalfs* to 1.90 Mg m⁻³ in *Aquic Ustorthents* and the values increased with depth. The increase in bulk density with depth was due to compaction of finer particles in deeper layers caused by over head weight of the surface soils. Further, the low bulk density values of surface soils were due to high organic matter content (Thangasamy *et al.*, 2005). Similarly, the higher bulk density in soils of Shikohpur watershed of Gurgaon district, Haryana was due to their coarse texture and in some cases the presence of calcium carbonate and low organic carbon content (Sitanggang *et al.*, 2006).

2.2.2.3 Field capacity

Amara *et al.* (2015) Revealed that the field capacity followed an irregular trend in majority of the pedons. In the black soils, the field capacity ranged from 29.84 to 40.14 per cent, whereas in the red soils, the field capacity ranged from 11.1 to 32.34 per cent. The field capacity of the black soils was higher than the red soils. Correlation studies revealed that the field capacity was highly and significantly correlated with coarse fragments, coarse sand, total sand, clay and bulk density but non-significant correlation with fine sand. The highly significantly correlated nature of the different soil separates and other soil physical properties might have resulted to the higher field capacity of the red soils and lower field capacity of the black soils.

Pulakeshi *et al.* (2014) showed that the field capacity of soils in the transported pedons was comparatively lower than that in the black soils as they were predominated by silt content. In black soil pedons, the field capacity of the soils ranged between 25.55 to 31.7 per cent. In general, the field capacity of the upper solum was more than the lower solum. This low FC may be due to increase in calcium carbonate in the lower layers. In red soil pedons, the FC of the soils ranged between 7.45 to 29.35 per cent. These differences were due to the variation in the depth, clay, silt and organic carbon content of the pedons.

2.2.3 Physico-chemical properties

2.2.3.1 Soil reaction

The pH varied from slightly acidic (5.83) to moderately alkaline (8.47) in the soils of Sivagiri micro-watershed in Chittoor district of Andhra Pradesh. The variation in soil pH was related to parent material, rainfall and topography. Further, the KCl-pH values were lower than the water pH values, indicating the existence of net negative charge on colloidal particles (Thangasamy *et al.*, 2005).

The surface soils of Karanji watershed in Maharashtra generally exhibited neutral to slightly alkaline pH. The pH value ranged from 6.7 to 8.3 (Nasre *et al.*, 2013).

2.2.3.2 Electrical conductivity

Rudramurthy and Dasog (2001) studied that electrical conductivity was less in red soils compared to their black counterparts. This suggests that red soils were relatively better leached than black soils.

Pillai and Natarajan (2004) revealed that the electrical conductivity of the soils of Garakahalli watershed ranged from 0.02 to 0.20 dS m⁻¹ indicating non-saline nature of the soil. However, these soils did not show any relationship with depth. This may be due to the undulating nature of the terrain coupled with free drainage conditions, which favoured the removal of released bases by the percolating and drainage water.

Sireesha and Naidu (2013) revealed that pedons in a semi- arid agro ecological region had shown low to medium EC values ranging from 0.12 to 0.93 dS m⁻¹, indicating non-saline nature. The low EC may be due to good drainage conditions which favoured the removal of released bases by percolating and drainage water.

2.2.3.3 Organic carbon

Suresh Kumar *et al.* (2001) studied that low organic carbon status (0.42 to 0.50 per cent) in soils of residual and denuded hills of Dehradun. The soils which were moderately buried pediments and valley fills had medium organic carbon content (0.08 to 0.97 per cent). Sarkar *et al.* (2001) compared the organic carbon status in upper and lower slopes of a watershed. The organic carbon content in soils of upper slope varied from 0.90 to 2.80 g kg⁻¹ whereas in the soils of lower slope varied from 0.50 to 5.00 g kg⁻¹

Sarkar *et al.* (2002) revealed higher organic carbon content in surface soils of Loktak catchment area in Manipur which ranged from 24.7 to 45.4 mg kg⁻¹ and decreased with depth. Kadao *et al.* (2003) observed medium to high organic carbon (5.5 to 8.7 g kg⁻¹) in banana growing soils of Wardha district of Maharashtra.

According to Singh and Agrawal (2005), found that the organic carbon content was low (1.0 to 5.6 g kg⁻¹) in *Entisols* and *Inceptisols* of Chandauli district, Uttar Pradesh due to the existing rice-wheat cropping system and prevailing semi-arid environment.

The organic carbon content in soils of Chandragiri mandal of Chittoor district, Andhra Pradesh varied from 0.6 to 6.3 g kg⁻¹ in plains, 0.8 to 4.1 g kg⁻¹ in uplands and 3.7 to 6.6 g kg⁻¹ in hill slope. Irrespective of landforms and locations, generally, the organic carbon decreased with depth (Basavaraju *et al.*, 2005; Sanjeev *et al.*, 2005, Thangasamy *et al.*, 2005 and Surya and Singh, 2012).

Vara Prasad Rao *et al.* (2008) reported typical pedons representing major landforms of Ramahcandrapuram Mandal in Chittoor district of Andhra Pradesh. The soils were low to medium in organic carbon.

Sireesha and Naidu (2013) studied that the low organic matter content in the soils might be attributed to the prevalence of tropical condition, where the degradation of organic matter occurs at a faster rate coupled with low vegetation cover, thereby leaving less organic carbon in the soils.

2.2.3.4 Free calcium carbonate (CaCO₃)

A study on genesis and morphology of *Vertisols* developed on different parent materials was made by Subbaiah and Manickam (1992). They observed an increase in size and abundance of calcium carbonate concentrations with depth.

Maji *et al.* (2005) reported that the CaCO_3 increased with decreasing elevation and slope. The per cent calcium carbonate in north Gujarat soils increased with depth and the values were 0, 1.8, 6.7 and 20.5 per cent at 0-25, 25-50, 50-75 and 75-100 cm depth, respectively (Barde and Gowaikar, 1965).

Sarade and Prasad (2008) found that the CaCO_3 content in guava growing soils of Bhandara district Maharashtra was more in the surface. The calcium carbonate in the soils of Kymore plateau and Satpura hills varied from 4.0 to 102.0 g kg^{-1} of soil and it increased with depth (Tripathi *et al.*, 2009). Verma *et al.*, 2012 reported the soils from Trans Yamuna area had the calcium carbonate (equivalent) ranged from 0.40 to 34.4 per cent. The CaCO_3 increased with depth in some pedons which may be due to illuviation along with clay.

2.2.4 Electro-chemical properties

2.2.4.1 Cation exchange capacity

Pradeep Kumar and Verma (2005) revealed that the CEC values varied from 10.7 to 12.9 $\text{cmol (p}^+) \text{ kg}^{-1}$ in surface horizons and from 10.1 to 12.0 $\text{cmol (p}^+) \text{ kg}^{-1}$ in sub-surface horizons which could again be due to higher amount of organic carbon in surface layers. Shamsudheen *et al.* (2005) stated that the CEC values of some forest soils of Northern Karnataka ranged from 3.0 to 11.35 $\text{cmol (p}^+) \text{ kg}^{-1}$. In all the pedons, CEC was more than effective CEC due to the development of pH dependent charges on exchange complex

Thangasamy *et al.* (2005) studied that the soils in Sivagiri micro-watershed had CEC ranging from 1.50 to 45.14 $\text{cmol (p}^+) \text{ kg}^{-1}$ which corresponds to clay content in the respective horizons.

Shalima Devi and Anil Kumar (2009) revealed that coffee growing soils of forth Karnataka exhibited higher CEC in the surface ranged from 16.6 to 36.1 $\text{cmol (p}^+) \text{ kg}^{-1}$. The higher content of organic matter in the surface might be the reason for higher CEC. Tripathi *et al.* (2009) studied six representative pedons of Banganala watershed of Kymore plateau and Satpura hills in Rewa district of Madhya Pradesh. They related high CEC, Ca^{2+} and Mg^{2+} ions to the presence of high amount of clay.

The CEC of *Entisols* in Etawah district of Uttar Pradesh was low, varying from 3.20 to 10.50 $\text{cmol (p}^+) \text{ kg}^{-1}$ soil which might be due to the presence of low CEC bearing minerals while the CEC of *Inceptisols* was medium (10.00 to 19.00 $\text{cmol (p}^+) \text{ kg}^{-1}$ soil) because of comparatively higher clay content (Verma *et al.*, 2012).

Gill *et al.* (2012) studied an increase in CEC with depth in soils of Phalasia block of Udaipur district in Rajasthan. There observed no relationship between CEC and land forms.

2.2.4.2 Base saturation

Sarkar *et al.* (2001) studied that among the exchangeable bases, Ca^{2+} was the dominant cation followed by Mg^{2+} , Na^+ and K^+ and base saturation of these soils ranged from 49 to 77 per cent in the soils of Chhota Nagpur plateau. In Kathiawar region of Gujarat, the exchangeable calcium ranged from 0.1 to 8.8 $\text{cmol (p}^+) \text{ kg}^{-1}$ (Sharma *et al.* (2001). In *Entisols* (*Typic Ustipsamments*) and *Inceptisols* (*Typic Haplustepts*) of Nellore district (Andhra Pradesh), the exchangeable magnesium varied between 0.5 and 6.5 $\text{cmol (p}^+) \text{ kg}^{-1}$ (Venkatesu *et al.*, 2002).

The per cent base saturation of the soils in upper Maul Khad catchment of Himachal Pradesh ranged from 45 to 62 indicating moderate soil fertility status (Sharma and Anil Kumar, 2003). Pillai and Natarajan (2004) attributed medium to high base saturation in soils of Garakahalli watershed of Bangalore rural district to low to medium amount of rainfall. The base saturation in soils of Sivagiri micro-watershed in Chittoor district (Andhra Pradesh) varied from low (31 per cent) to high (92 per cent) (Thangasamy *et al.*, 2005).

Soils in watershed area of Sikohpur, Gurgaon district, Haryana were highly base saturated (70 to 93 per cent) indicating low degree of leaching. The base saturation increased with depth and followed the pattern of pH (Sitanggang *et al.*, 2006). Calcium was the dominant cation on the exchange complex followed by Mg^{2+} , Na^{+} and K^{+} in grape growing soils in Nasik district of Maharashtra Balpande *et al.* (2007).

2.2.4.3 Available N, P, K, S and Micronutrient

Basavaraju *et al.* (2005) while characterizing and classification of soils of Chandragiri mandal of Chittoor district in Andhra Pradesh found that soils were low in available nitrogen, medium in available phosphorus, high in available potassium but deficient in sulphur, iron and zinc.

Thangasamy *et al.* (2005) revealed that soils in Sivagiri micro-watershed of Chittoor district in Andhra Pradesh were low to medium in available nitrogen, phosphorus and potassium and high in sulphur.

Pradeep Kumar and Verma (2005) showed that the rice growing soils of Palam Valley in Himachal Pradesh. The available N in these soils varied from 188.1 to 392.0 kg ha⁻¹ in the surface horizons, whereas sub-surface horizons had available N in the range of 86.3 to 252.5 kg ha⁻¹. The available P varied from 8.0 to 18.3 kg ha⁻¹ in surface and 1.6 to 15.0 kg ha⁻¹ in sub-surface horizons. Available K ranged from 89.8 to 561.2 kg ha⁻¹ in surface horizons and 162.4 to 314.6 kg ha⁻¹ in sub-surface horizons. By considering the critical limit values, the soils fall under low to medium with respect to N and P and low to high with respect to K.

Sarade and Prasad (2008) studied that nitrogen, phosphorus, potassium, iron, manganese, copper and zinc concentration in the leaves of guava varied from 1.23 to 1.81 percent; 0.03 to 0.10 percent; 0.71 to 1.71 percent; 303 to 570 mg kg⁻¹; 50 to 150 mg kg⁻¹; 11.3 to 20.0 mg kg⁻¹ and 35 to 48 mg kg⁻¹, respectively at different sites in Bhandara district of Maharashtra.

Niranjana *et al.*, 2011 studied six pedons from the banana growing soils of Pulivendla region in Andhra Pradesh. The available nitrogen content of all the six pedons of banana-growing area was low (104 to 274 kg ha⁻¹). The available phosphorus content was medium to high (23-75 kg P₂O₅ ha⁻¹). The available potassium content was high in all the six pedons (337-936 kg K₂O ha⁻¹). The available iron content was sufficient in all the pedons. The available zinc content was marginal to high, except in pedons 1 and 5 which were deficient in this nutrient.

The available N, P and K of orange growing soils with different parent materials in Nagpur ranged from 50.2 to 250.9, 0.8 to 27.7 and 252 to 1030.4 kg ha⁻¹, respectively in different pedons. In surface and sub-surface horizons, micronutrient cations were found to be optimum except DTPA-Cu (Likhar and Prasad 2011).

The soils of Trans Yamuna areas were low in available nitrogen and low to medium in available phosphorus and potassium content. Majority of the soils were low in DTPA extractable Zn, Fe and Cu but sufficient in Mn (Verma *et al.*, 2012).

Pulakeshi *et al.* (2012) found that the available nutrient status of soils of Mantagani village in north Karnataka by GIS technique. One hundred fifteen samples (0-30 cm) drawn from the farmers' fields were analysed for their fertility status and mapped by geographic information system (GIS) technique. The pH of soils ranged from slightly acidic to alkaline. Soil organic matter content was low. Available nitrogen (low; 93 per cent area), phosphorus (low; 24 per cent area, Medium; 76 per cent area) were generally low to medium and available potassium and sulphur were low to high. Regarding available micronutrients, zinc and iron were deficient (88 per cent and 72 per cent area, respectively) whereas, copper and manganese were deficient (54 per cent and 51 per cent area, respectively) to sufficient in these soils.

2.2.4.4 Exchangeable Cations

Basavaraju *et al.*, 2005 studied that the exchangeable bases in all the pedons irrespective of landforms in Chandragiri mandal of Chittoor district in Andhra Pradesh were in the order of $\text{Ca}^{2+} > \text{Mg}^{2+} > \text{Na}^+ > \text{K}^+$ and the concentration of these bases reduced with depth.

The exchangeable complex in forest soils of North Karnataka was dominated by Ca followed by Mg except in pedon 4 (Ajinkere series) where Mg dominated Ca. More exchangeable Mg than Ca indicates the preferential leaching of calcium than magnesium (Shamsudheen *et al.*, 2005).

Singh and Agarwal (2003) revealed that in rice growing soils of Eastern Varanasi Ca was the most dominant exchangeable cation followed by Mg, Na and K. Exchangeable Ca and Mg in all the soils showed higher accumulation in the sub-surface horizons. Relatively high exchangeable Ca^{+2} and Mg^{+2} in the lower layers might be due to the deposition of calcitic or dolomitic parent materials carried by the river during fluvial cycle in the past.

The clay micelle of orange growing soils in Nagpur was dominantly saturated with Ca followed by Mg, Na and K on exchange complex. The exchangeable cations tend to decrease with depth (Likhar *et al.*, 2011).

The exchangeable Ca, Mg, Na and K ranged between 7.27 and 14.54, 4.77 and 15.22, 0.99 and 2.04 and 0.26 and 0.53 $\text{cmol (p}^+) \text{ kg}^{-1}$ soils respectively in Phalasia block of Udaipur. It was observed that soils occurring on moderately sloping pediment had the highest Ca content followed by soils over very gently sloping pediment. In general, these cations increased with depth (Gill *et al.*, 2012).

2.2.4.5 Classification

The red and lateritic soils of Bangalore district (Karnataka state) were classified as Kandic Paleustalfs and Kandic Rhodustalfs by Reddy *et al.* (1993). Satyavathi and Suryanarayana Reddy (2003) studied fifty four soil samples from ten pedons of Telangana region Andhra Pradesh. The red soils were classified as *Typic Ustipsamments* and *Typic Haplustalfs*. The black soils were classified as *Vertic Calciustepts*, *Vertic Haplustepts* and *Typic Haplusterts* at subgroup level. At the family level, the soils qualified for sandy to clayey particle size classes, mixed and smectitic mineralogy class and isohyperthermic soil temperature class.

Challa *et al.* (2000) characterized and classified four representative problematic *Vertisols* occurring on upper and lower Maharashtra plateau distributed in continuously irrigated zone of Ahmed Nagar and Akola districts under semi-arid ecosystem. Khondwad and Kadambhe soils of piedmont plain are dark grayish brown while Amalnar and Valpi soils of flood plain are dark yellowish brown colour. Amalnar and Valpi soils of flood plain showed higher calcium carbonate content than the other soils. Khondwad and Amalnar soils showed high electrical conductivity at 1:2.5 soil water ratios while the other soils Khadambhe and Valpi showed high exchangeable sodium percentage. In all the pedons the sodium adsorption ratios increased with depth and attained maximum in slickenside-zone. In general chlorides, sulphates and bicarbonates dominated in soil environment. All the pedons have zone of slickenside. Based on these properties the Khondwad and Amalnar soils were classified as Halic Haplusterts while other soils were grouped under Sodic Haplusterts.

The soils of different landscapes in Etawah district of Uttar Pradesh were grouped into *Typic Ustipsamments*, *Typic Haplustepts* and *Typic Ustorthents* (Verma *et al.*, 2001). Sarkar *et al.* (2002) classified the soils of Loktak catchment area of Manipur into *Inceptisols* due to presence of diagnostic cambic horizon. Ramprakash and Seshagiri Rao (2002) classified the soils of Krishna district of Andhra Pradesh into *Vertic Haplustepts*, *Lithic Haplustepts* and *Typic Haplusterts*.

Sharma *et al.* (2004a) classified the salt-affected soils of Southern Rajasthan into *Typic Haplustepts*, *Typic Calcustepts* and *Aridic Ustorthents*. The soils of watershed area of Shikohpur, Gurgaon district, Haryana were classified as *Entisols* and *Inceptisols*. *Entisols* had no diagnostic horizons other than ochric epipedon, due to very slight degree of soil formation either because of limited available time for development or because of unfavourable pedoenvironment (Sitanggang *et al.*, 2006).

According to Marathe *et al.* (2003) the soils of mandarin orchards in Nagpur were classified into *Vertic Haplustepts*, *Typic Haplustepts*, *Typic Ustorthents* and *Typic Haplusterts*. The soils on fluvio – glacial terraces under croplands and tea gardens in upper Maul Khad catchment were classified as *Inceptisols* and *Alfisols* while those on hill slopes under pine forests and pastures as *Entisols* (Sharma and Anil Kumar, 2003).

Vara Prasad Rao *et al.* (2008) characterized and classified typical pedons representing major landforms of Ramahcandrapuram Mandal in Chittoor district of Andhra Pradesh. Pedons 1 and 3, occupying plains, showed cambic (Bw) subsurface diagnostic horizon and were classified as *Vertic Haplustepts* and *Typic Haplustepts*, respectively. Pedon 2 also occurring in plain did not exhibit any diagnostic horizon and was classified as *Typic Ustipsamment*. Pedon 3 on upland showed argillic (Bt) subsurface diagnostic horizon and was classified as *Typic Haplustalf*. In contrast, the pedon 5 on upland did not show any diagnostic horizon and was classified as *Typic Ustifluvent*. However, pedons 6 and 7 located on hill slope did not show any diagnostic horizon and were classified as *Typic Ustorthents*.

The soils of outer Himalayas were classified in the orders of *Alfisols*, *Mollisols*, *Inceptisols* and *Entisols* based on field morphology and physico-chemical properties. *Alfisols* with an argillic horizon having base saturation more than 35 per cent, *Mollisols* with mollic epipedon, *Inceptisols* with cambic B horizon and *Entisols* with only ochric epipedon (Sanjeev *et al.*, 2005).

2.3 Land capability classification

The land capability classification is the grouping of a land unit (s) into defined class (es) based on its capability. It is a broad grouping of soils based on their limitations and is designed to emphasize the hazards in different kinds of soils. It serves as a guide to assess suitability of the land for arable crops, grazing and forestry.

The capability classification consists of three categories namely i) capability classes ii) capability sub-classes and iii) capability units. In all eight capability classes, class-I, II, III, IV were suitable for cultivation and class V, VI, VII land unsuitable for cultivation but suitable for permanent vegetation (grazing). The capability sub-classes are based on kinds of dominant limitation, such as wetness or excess water (w), climate (c), soil (s), erosion (e) and topography (t). The capability unit includes soils which are sufficiently uniform in their characteristics. Potential and limitations and require fairly uniform conservation treatments and management practices.

Patil *et al.* (2008a) made an attempt to determine land capability, soil irrigability and land suitability for different crops of the soils under 48A Distributary of Malaprabha Right Bank Command (MRBC) in Karnataka. Detailed soil survey information was used for this exercise. The soils were classified at family level as very fine clayey, smectitic, calcareous, also isohyperthermic and superactive *Typic Haplusterts*. Two soil series *viz.*, Kiresur and Hanchinal were identified in the study area and mapped into six mapping units. Land capability classification showed that majority of soils belonged to class III, followed by class IV with limitations of erosion, wetness and soil properties. The soils were marginally suitable for irrigation due to soil textural limitation.

Patil *et al.* (2008 b) studied soil resources of Bhanapur micro-watershed (Koppal district) in Northern Dry Zone of Karnataka for sustainable land use planning. Eight soil profiles were included in the study. The micro-watershed consists of both red and black soils in association. Six soil series were identified in the study area and were mapped into six different mapping units as phases of soil series by GIS technique. Land capability classification showed that majority of soils belonged to class III and IV lands with limitations of erosion, drainage and soil properties.

Visual interpretation of False Colour Composites of IRS-ID LISS~III and PAN sharpened LISS-III in conjunction with Survey of India (SOI) toposheet (1: 50000 scale) followed by ground truth observations helped in establishing physiography-soil-land use/ land cover relationship and land evaluation in terms of land capability, land irrigability, soil productivity and soil site suitability for sorghum and cotton. The land use or land cover identified were single crop, double crop, scrub-land and moderately dense forest. Physiographically, the area has been characterized into three major units *viz.*, subdued table land, upper valley and isolated mound with pediments. Eight soil series were tentatively identified and mapped as series and association and grouped into five land capability sub-classes IIIs, IIIs, IVs, IVs and VIs and three land irrigability sub-classes 2d, 4s and 4st (Kashiwar *et al.*, 2009).

Ravikumar *et al.* (2009) studied the soils under 48A distributary of Malaprabha right bank command of Karnataka. Land capability classification showed that majority of land belonged to class III followed by class IV with limitations of erosion, wetness and soil properties. The soils were marginally suitable for irrigation due to soil texture limitation. Characterized and classified the land

resources of Khapri village of Nagpur district of Maharashtra were carried out by Shweta *et al.* (2010). These soils were grouped into IIs, IIIs, IVs and Ives capability sub classes with poor to extremely poor soil productivity.

Patil *et al.* (2011) classified the five soils series of Bhanapur micro-watershed (Koppal district) in northern dry zone of Karnataka for sustainable land use planning. These soil series were tentatively identified and mapped into six mapping units using GIS technique. These mapping units were grouped into land capability class III and IV with limitations of erosion, drainage and soil.

Denis *et al.* (2014) conducted study in Singhanhalli-Bogur micro-watershed through remote sensing and GIS and revealed that 17 land units were identified, with an area of 760.6 ha. Four land capability classes were identified with seven subclasses to which the seventeen mapping units belonged. Three land units belonged to land capability class II having one subclass. These soils had none to slight limitations ranging from slope, erosion, drainage, permeability, depth, texture, coarse fragments, CaCO₃, pH, organic carbon and base saturation. Six land units belonged to land capability class III having one subclass. These soils had slight to moderate limitations ranging from slope, erosion, depth, texture, coarse fragments, organic carbon and base saturation. Seven land units belonged to land capability class IV. These soils had moderate to severe limitations ranging from slope, erosion, permeability, depth, texture and base saturation. In addition, one mapping unit was non-cultivable land and therefore belonged to land capability class VI with very severe limitation of slope.

2.3.1 Soil-site suitability for irrigation

As a case study, Kanadi village of Dadra and Nagar Haveli were studied. The soils are clayey, cracking and have fairly high water holding capacity. Based on land features and soil characteristics the soil units were evaluated by quantitative and parametric methods. As per the former, about 98 per cent area were moderately suitable for irrigation with limitations of topography, erosion and compactness in surface soil layers. About 1.3 per cent area were severe limitations and about 0.7 per cent area were marginal land with deficiency of depth. Based on the parametric method 35 per cent area were not suitable for irrigation whereas, 45.0 and 51.5 per cent area were moderately and marginally suitable, respectively (Challa *et al.*, 2000).

Patil *et al.* (2008b) studied the soils under 48A Distributary of Malaprabha Right Bank Command (MRBC) in Karnataka. The Land capability classification showed that majority of soils belonged to class III, followed by class IV with limitations of erosion, wetness and soil properties. The soils were marginally suitable for irrigation due to soil texture limitation.

2.4 Soil-site suitability for different crops

The most recent evaluation procedure has been introduced since the mid-seventies by FAO (1993). It is a crop specific suitability system that is based on the comparison of plant growth and production requirements with prevailing environmental conditions. Five phases can here be distinguished 1) identification of the land utilization type 2) definition of its growth requirements 3) compilation of basic climatic, soils and physiological data of the study area 4) matching of those field data with the crop requirements and 5) determination of the suitability classes on the basis of the nature and degree of crop growth constraints (Varade *et al.*, 1994).

The soils of Mandya (*Typic Haplustepts*), Bhadravathi (*Typic Topaquepts*) and Chikodi (*Vertic Haplustepts*) were moderately suitable for growing sugarcane with moderate limitations of nutrient status and relative humidity. However, the Jamkhandi soils (*Typic Haplustults*) were marginally suitable for growing sugarcane in Karnataka (Naidu and Hunsigi, 2001).

Tamgadge *et al.* (2002) evaluated the soil suitability for paddy cultivation in Chattisgarh and reported that *Udic Haplusterts*, *Entic Haplusterts*, *Chromic Haplusterts*, *Typic Haplusterts* and *Udic Haplustepts* were highly suitable (S_1) whereas *Vertic Haplustepts* and *Typic Haplustepts* were moderately suitable (S_2) for growing paddy. Further, *Plinthustalfs*, *Udic Haplustalfs*, *Typic Haplustalfs* and *Typic Rhodustalfs* were marginally suitable (S_3), *Lithic Haplustepts* and *Typic Ustorthents* were not suitable temporarily (N_1) and *Lithic Ustorthents* was not suitable permanently (N_2) for growing paddy in Chattisgarh.

The soil suitability evaluation revealed that the soils of a micro-watershed in Vidarbha region of Maharashtra such as *Typic Haplusterts* and *Vertic Haplustepts* were found to be moderately suitable (S_2) for growing cotton, sorghum and pigeonpea (Gabhane *et al.*, 2006).

Leelavathi (2007) evaluated soils of Yerpedu mandal of Chittoor district Andhra Pradesh for soil suitability for six major crops (groundnut, sorghum, maize, sugarcane, paddy and mango) grown in that area and reported that *Ultic Haplustalfs*, *Typic Haplustepts*, *Ultic Haplustalfs*, *Typic Haplustepts* and *Typic Ustifluvents* were moderately suitable (S_2) for growing groundnut and sugarcane. *Ultic Haplustalfs* and *Typic Haplustepts* were marginally suitable (S_3) for growing rice crop, while *Ultic Haplustalfs*, *Typic Ustipsamments*, *Typic Haplustepts* and *Typic Ustifluvents* were permanently not suitable (N_2) for growing paddy. Shweta *et al.* (2010) characterized and evaluated the land resources in Khapri village of Nagpur district of Maharashtra. The very shallow soils were marginally to not suitable and very deep soils of valley plain were moderately suitable for growing cotton, sorghum and soybean. Suitable conservation measures and interventions have been suggested to improve the productivity of these soils.

Patil *et al.* (2008a) studied that soil resources of Bhanapur micro-watershed (Koppal district) in northern dry zone of Karnataka for sustainable land use planning. Eight soil profiles were included in the study. Soil site, suitability evaluation for wheat, cotton, sorghum, sunflower, maize, chilli, pigeonpea and pearl millet showed that red soils were moderately suitable (S_2) for groundnut and marginally suitable (S_3) for other crops and wheat were not suitable. The black soils were moderately suitable for pearl millet and sunflower. Remaining crops were marginally suitable.

Patil *et al.* (2008b) an attempt were made to determine land capability, soil irrigability and land suitability for different crops of the soils under 48A Distributary of Malaprabha Right Bank Command (MRBC) in Karnataka. The soils were highly suitable for Maize and cotton, wheat, soybean, sorghum were moderately suitable. According to Meena *et al.* (2012a) the major soils of Banswara district in Rajasthan were evaluated for their suitability for maize cultivation using limitation method regarding number and intensity of limitations. The study suggests that maize is highly suitable in soils of Pedon P9 but moderately suitable in soils of Pedon P4, P7 and Pedon P8. Whereas soils of Pedon P1, P2 and Pedon P6 were marginally suitable and soils of pedon P3 and Pedon P5 were not suitable for maize cultivation. Soil depth, drainage, erosion and organic carbon were the major limitations for crop growth in the most of soils of Aravalli landscape.

Amin Sharififar (2012) reported that to protect soil resources and also to achieve optimal crop production, it is essential to dedicate the most suitable land to a specific land use. In this study a land suitability evaluation were carried out for wheat (*Triticum aestivum*) cultivation and were performed in the Bastam region located in the north east of Iran. 104 soil profiles were sampled and 11 land units were separated. The maximum limitation method was found to be the best method and was used for classification of the suitability of the study area lands for wheat cultivation. The varying results of applying different ways of evaluation in this study indicated that the accuracy of the method of land evaluation adopted should be checked before using the results for any purposes.

Meena *et al.* (2012b) revealed that the soil-site suitability evaluation of Malwa plateau of Banswara district in southern Rajasthan for chickpea. The study suggests that chickpea (*Cicer arietinum* L.) is moderately suitable in soils of Pedon P8 but marginally suitable in soils of Pedon P1, P2, P3, P4 and P5 whereas, soils of Pedon P6 and P10 are not suitable for chickpea (*Cicer arietinum* L.) cultivation. Soil depth, wetness (drainage), erosion, texture and organic carbon are the major limitations for crop growth

Selvaraj and Naidu (2013) carried out reconnaissance soil survey of Renigunta mandal of Chittoor district Andhra Pradesh to evaluate the land capability classification and suitability of soils for paddy, groundnut, redgram, sugarcane, vegetables and mango. In general, soil texture, base saturation, pH and organic carbon are the major limitations for crop growth in all the soils. Kiran Reddy *et al.* (2014) studied the twelve typical pedons of Nalgonda district Andhra Pradesh were evaluated for their soil-site suitability to paddy, groundnut, sorghum, red gram, soyabean and cotton. Soil-site suitability evaluation for crops forms an essential part of land use planning programme. As per the developed criteria Thummadam pedon was marginally suitable, Nandipadu, Kukadam and J. P. Gudam pedons were moderate to marginally suitable, Dugapalli, Regulagada and T. R. Gudam pedons were highly to moderately suitable, Topcherla and Devulapalli pedons were highly to marginally suitable and Vemulapalli, Molkacherla and Wadapalli were moderately to unsuitable for above crops.

3. MATERIAL AND METHODS

The particulars relating to the general description of the area, geographical setting of the study area viz., relief, drainage, climate, geology, collection and preparation of soil samples and the analytical methods adopted in the investigation are briefly presented in this chapter.

3.1 General description of the area

The selected Dambal-2 micro-watershed is in Gadag District. The study area falls under northern dry zone (zone no-03) of Karnataka, which receives annual average rainfall of 671 mm, during *kharif* and *rabi* seasons. Black soils occupy major portion of the area and some red soils with varied structure occur in association with black soils.

3.2 Location of the study area

The selected Dambal-2 micro-watershed lies 20 km away from Gadag District. The micro-watershed is located between 15° 16' 53.0" and 15° 18' 6.0" N latitude and 75° 46' 55.0" and 75° 48' 28.0" E longitude, with an average elevation 572.90 m above Mean Sea Level (MSL).

3.3 Relief and drainage

The selected Dambal-2 micro-watershed having nearly level to undulating topography with frequent mound like features. Soils on the rolling topography are slight to severely affected by erosion. The relief is nearly level to very gently sloping in the domain of black soils (valley area) but hill-tops possess strong steep slope.

3.4 Geology

The Dharwad schist covers the Dambal-2 micro-watershed area. The predominant minerals noticed in the Dharwad schist are oligoclase and orthoclase feldspar and besides these minerals, some of dark coloured minerals are also observed.

3.5 Climate

The climate of the area is semi-arid type. The summer season starts from third week of February and continues up to middle of June. Winter commences from first or second week of November and continues up to middle of February or sometimes up to the end of February. The monsoon starts from end of June and continues upto end of October (Appendix I).

3.6 Natural vegetation and land use

Dambal-2 micro-watershed area is mainly comprised of important species of both shrubs and trees. Shrubs are *Butea superba*, *Gardenia gummifers*, *Zypus xylopora*, *Cassia auriculata*. Tree species are *Cassia fistula*, *Tamarindus indica*, *Pongamia glabra*, *Terminilla tomentosa*, *Prosopis juliflora*. *Acacia Arabica* and *Azadirachta indica* are the common species on black and red soil, respectively. The important crops grown in the area are; maize, cotton, chilli, groundnut, chickpea, cowpea, pigeon pea, green gram, sorghum, wheat, pearl millet, pulses and sunflower.

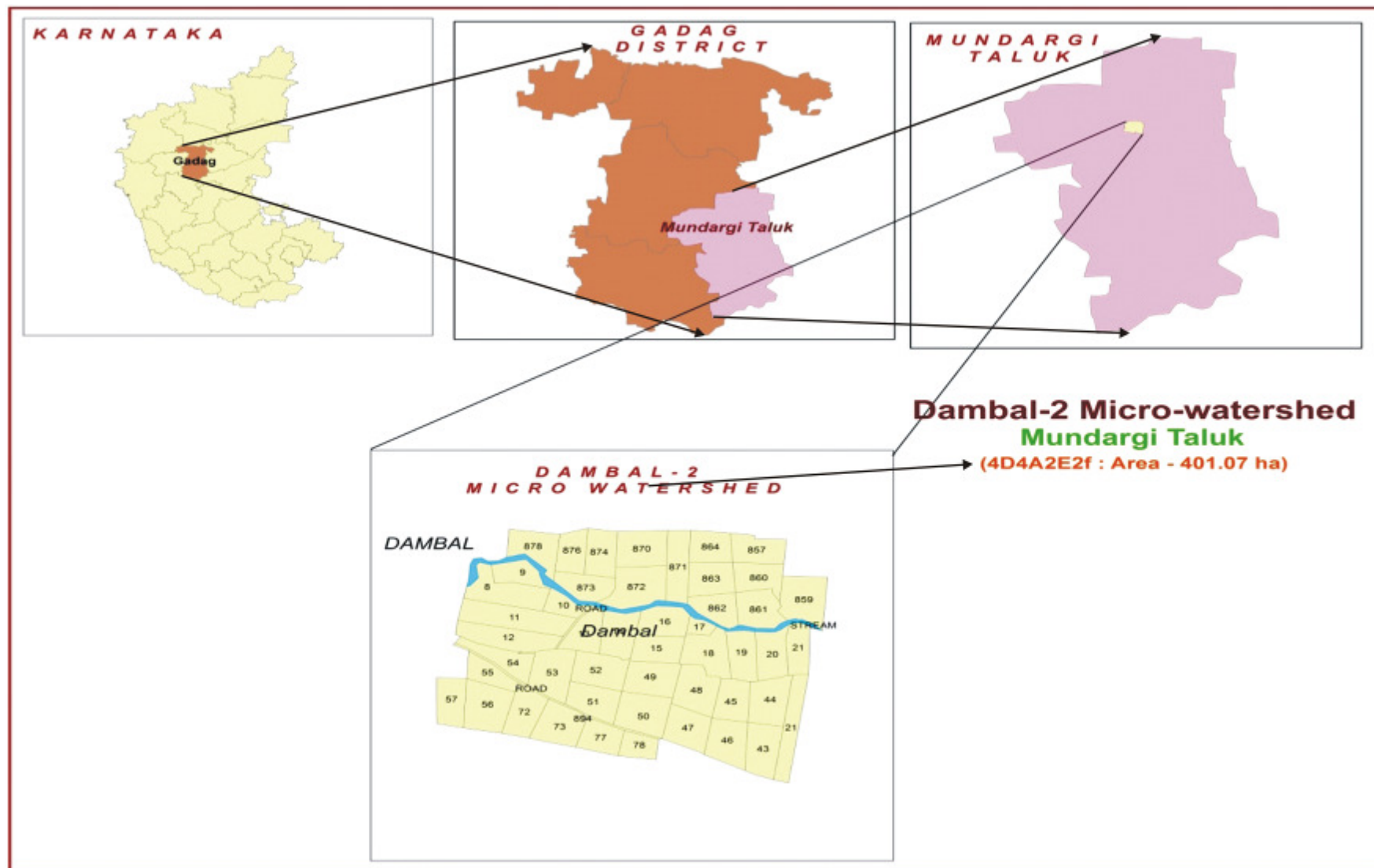


Fig. 1. Location of the study area

Table 1: Geographical locations of soils of pedons in Dambal-2 micro-watershed

Pedon No.	location	
	Latitude	Longitude
1.	15 ⁰ 17' 43.585" N	75 ⁰ 47' 05.223" E
2.	15 ⁰ 17' 21.626" N	75 ⁰ 47' 15.070" E
3.	15 ⁰ 17' 46.858" N	75 ⁰ 47' 47.772" E
4.	15 ⁰ 17' 51.514" N	75 ⁰ 47' 59.182" E
5.	15 ⁰ 17' 12.255" N	75 ⁰ 47' 46.690" E
6.	15 ⁰ 17' 35.700" N	75 ⁰ 47' 25.288" E
7.	15 ⁰ 17' 37.754" N	75 ⁰ 47' 36.820" E
8.	15 ⁰ 17' 37.980" N	75 ⁰ 47' 47.568" E
9.	15 ⁰ 17' 52.435" N	75 ⁰ 47' 32.217" E
10.	15 ⁰ 17' 09.443" N	75 ⁰ 47' 58.000" E
11.	15 ⁰ 17' 55.220" N	75 ⁰ 47' 24.157" E



Plate 1. Landscape of the study area

3.7 Soil sampling

The detailed soil survey of Dambal-2 micro-watershed area was carried out using IRS-P6, LISS-IV image and cadastral map as base maps (Fig. 1). The survey was carried out by the standard soil survey procedures as described in the Soil Survey Manual (Anon., 2006). At first instance, traversing of the study area was done to have a resource inventory of physiography, stream lines, geology, vegetation and land use. Based on soil surface heterogeneity features like break in slope, erosion, gravels, stones etc, locations were fixed to study pedons. Eleven pedons were studied in the field for their morphological features. Soil samples from identified horizons of each pedon were collected for analysis of physico-chemical properties

3.8 Site characters and description of pedons

The terminology used for the description of study site and pedons are as per the Anon. (1951) (Table 1).

Morphological features of the pedons under study is presented below,

Pedon : 1

Location	15° 17' 43. 585" N; 75° 45' 05. 223" E
Elevation above MSL (m)	577.70 m
Physiography	Side slope of midland
Geology	Schist
Soil slope gradient (per cent)	0 to 1
Erosion	Moderate
Drainage	Moderately well drained
<i>Land use / vegetation</i>	
Crop	Cotton – <i>Gossypium hirsutum</i>
Vegetation	Banni - <i>Prosopis cineraria</i> (L.)
	Bellary Jali- <i>Prosopis juliflora</i>

Horizon	Depth (cm)	Morphological description
Ap	0 - 10	Dark brown (10YR 3/3 dry and moist); clay; fine gravel moderate medium sub-angular blocky structure; slightly hard, friable, moderately sticky and moderately plastic; many medium roots between peds: strong effervescence with dilute HCl; clear smooth boundary.

A ₁	10-40	Very dark greyish brown (10YR 3/2 D) and dark brown (10YR 3/ 3); clay; fine gravel moderate medium sub-angular blocky structure; hard, firm very sticky and very plastic; few fine roots between peds strong effervescence with dilute HCl : gradual smooth boundary.
AB	40-80	Very dark brown (7.5YR 2.5/3 dry and moist); clay; fine gravel moderate medium sub-angular blocky structure; hard, firm, very sticky and very plastic; few fine roots between peds strong effervescence with dilute HCl: gradual diffuse boundary.
Bw ₁	80-130	Very dark brown (7.5YR 2.5/3 dry and moist); clay; fine gravel moderate medium crumb structure; hard, firm, very sticky and very plastic, strong effervescence with dilute HCl; gradual diffuse boundary.
Bw ₂	130-152	Brown (7.5YR 4/4 and 7.5YR 4/3, dry and moist); clay; fine gravel moderate medium sub-angular blocky; hard, firm, very sticky and very plastic, strong effervescence with dilute HCl.
C	150-175+	Weathered parent rock (schist). C -152-175+

Pedon : 2

Location	15° 17' 21.626" N; 75° 47' 15.070" E
Elevation above MSL (m)	501.21 m
Physiography	Side slope of upland
Geology	Schist
Soil slope gradient (per cent)	1 to 3
Erosion	Moderate
Drainage	Moderately well drained
<i>Land use / vegetation</i>	
Crop	Sorghum- <i>Sorghum bicolor</i>
Vegetation	Banni - <i>Prosopis cineraria</i> (L.)
	Bellary Jali- <i>Prosopis juliflora</i>



Plate 2. Pedon 1 of Dambal-2 Micro-watershed



Plate 3. Pedon 2 of Dambal-2 Micro-watershed

Horizon	Depth (cm)	Morphological description
Ap	0 - 19	Dark gray (10YR 4/1 D) and very dark greyish brown (10YR 3/2); clay; fine gravel, moderate medium sub-angular blocky structure; slightly hard, friable, very sticky and very plastic; few fine roots between peds: strong effervescence with dilute HCl, clear smooth boundary.
AB	19-30	Very dark gray (10YR 3/1 D) and very dark greyish brown (10YR 3/2); clay; fine gravel moderate medium sub-angular blocky structure; slightly hard, firm, very sticky and very plastic; few fine roots between peds strong effervescence with dilute HCl: diffuse smooth boundary.
Bw	30-67	Black (10YR 2/1D) and very dark brown (10YR 2/2); clay; fine gravel moderate medium sub-angular blocky structure; hard,firm, very sticky and very plastic; few fine roots between peds strong effervescence with dilute HCl : gradual diffuse boundary.
C	67-133+	Weathered parent rock (schist).

Pedon : 3

Location	15° 17' 46.852" N; 75° 47' 47.772" E
Elevation above MSL (m)	499.37 m
Physiography	Mid slope of midland
Geology	Schist
Soil slope gradient (per cent)	1 to 3
Erosion	Severe
Drainage	Moderately well drained
<i>Land use / vegetation</i>	
Crop	Chickpea – <i>Cicer arietinum</i>
Vegetation	Bellary Jali- <i>Prosopis juliflora</i>

Horizon	Depth (cm)	Morphological description
A	0 - 10	Very dark gray (10YR 3/1 D) and black (10YR 2/1); clay loam; coarse gravel, weak medium crumb structure; slightly hard, friable, moderately sticky and moderately plastic; many fine roots between peds: strong effervescence with dilute HCl; clear smooth boundary.
AC	10-46	Very dark gray (7.5YR 3/1 D) and black (7.5YR 2/1); clay loam; coarse gravel weak medium crumb structure; slightly hard, friable moderately sticky and moderately plastic; few fine roots between peds strong effervescence with dilute HCl: clear smooth boundary.
C	46-80+	Para <i>Lithic</i> contact with schist.

Pedon : 4

Location	15° 17' 51.514" N; 75° 47' 59.182" E
Elevation above MSL (m)	500.74 m
Physiography	Mid slope of upland
Geology	Schist
Soil slope gradient (per cent)	1 to 3
Erosion	Moderate
Drainage	Moderately well drained
<i>Land use / vegetation</i>	
Crop	Chilli – <i>Capsicum annuum</i> L
Vegetation	Bellary Jali- <i>Prosopis juliflora</i>
	Neem- <i>Azadirachta indica</i>

Horizon	Depth (cm)	Morphological description
Ap	0 - 23	Dark gray (10YR 4/1 D) and very dark gray (10YR 3/1); clay; fine gravel, moderate medium sub-angular blocky structure; slightly hard, friable, very sticky and very plastic; few fine roots between peds: strong effervescence with dilute HCl; clear smooth boundary.
Bw	23-60	Black (10YR 2/1 dry and moist); clay; fine gravel moderate medium sub-angular blocky structure; hard, firm, very sticky and very plastic: strong effervescence with dilute HCl; clear smooth boundary.
C	60-90+	Weathered Schist.



Plate 4. Pedon 3 of Dambal-2 Micro-watershed



Plate 5. Pedon 4 of Dambal-2 Micro-watershed

Pedon : 5

Location	15° 17' 12.255" N; 75° 47' 46.690" E	
Elevation above MSL (m)	510.51 m	
Physiography	Mid slope of upland	
Geology	Schist	
Soil slope gradient (per cent)	1 to 3	
Erosion	Moderate	
Drainage	Moderately well drained	
<i>Land use / vegetation</i>		
Crop	Maize – <i>Zea mays</i>	
Vegetation	Bellary Jali- <i>Prosopis juliflora</i>	
	Neem- <i>Azadirachta indica</i>	
Horizon	Depth (cm)	Morphological description
Ap	0 - 25	Dark greyish brown (10YR 4/2 D) and greyish brown (10YR 5/2); clay; fine gravel, moderate medium sub-angular blocky structure; slightly hard, friable, very sticky and very plastic; few fine roots between peds: slight effervescence with dilute HCl; clear smooth boundary.
Bw	25-110	Dark brown (7.5YR 3/3 dry and moist); clay; fine gravel weak medium crumb structure; hard, firm, very sticky and very plastic.
C	110-140+	Weathered parent material (schist).

Pedon : 6

Location	15° 17' 35.700" N; 75° 47' 25.288" E
Elevation above MSL (m)	576.55 m
Physiography	Low land of the middle side slope
Geology	Schist
Soil slope gradient (per cent)	0 to 1
Erosion	Slight
Drainage	Moderately well drained
<i>Land use / vegetation</i>	



Plate 6. Pedon 5 of Dambal-2 Micro-watershed



Plate 7. Pedon 6 of Dambal-2 Micro-watershed

Crop Cotton – *Gossypium hirsutum*

Vegetation Banni -*Prosopis cineraria* (L.)

Bellary Jali- *Prosopis juliflora*

Coconut -*Cocos nucifera*

Horizon	Depth (cm)	Morphological description
Ap	0 - 25	Dark greyish brown (10YR 4/2 D) and very dark greyish brown (10YR 3/2); clay; fine gravel moderate medium sub-angular blocky structure; slightly hard, friable, very sticky and very plastic; common medium throughout roots: strong effervescence with dilute HCl; clear smooth boundary.
Bw ₁	25-58	Black (10YR 2/1 D) and very dark brown (10YR 2/2); clay; fine gravel strong medium sub-angular blocky structure; hard, friable very sticky and very plastic; common medium throughout roots: strong effervescence with dilute HCl; clear smooth boundary.
Bw ₂	58-99	Greyish brown (10YR 5/2 D) and very dark brown (10YR 2/2); clay; fine gravel strong medium sub-angular blocky structure; hard, firm very sticky and very plastic; few fine roots between peds: strong effervescence with dilute HCl; clear smooth boundary.
C	99-150+	Weathered parent rock (schist).

Pedon : 7

Location 15° 17' 37.754" N; 75° 47' 36.820" E

Elevation above MSL (m) 574.01 m

Physiography Low land of the lower side slope

Geology Schist

Soil slope gradient (per cent) 0 to 1

Erosion Slight

Drainage Moderately well drained

Land use / vegetation

Crop Sunflower -*Helianthus annuus*

Vegetation Banni -*Prosopis cineraria* (L.)

Bellary Jali- *Prosopis juliflora*

Neem - *Azadirachta indica*

Ber- *Ziziphus mauritiana*

Horizon	Depth (cm)	Morphological description
Ap	0 - 31	Dark greyish brown (10YR 4/2 D) and very dark greyish brown (10YR 3/2); clay; fine gravel moderate medium sub-angular blocky structure; slightly hard, friable, very sticky and very plastic; common medium throughout roots: strong effervescence with dilute HCl; clear smooth boundary.
Bw ₁	31-78	Black (10YR 2/1 D) and very dark brown (10YR 2/2); clay; fine gravel strong medium sub-angular blocky structure; hard, friable very sticky and very plastic; common medium throughout roots: strong effervescence with dilute HCl; clear smooth boundary.
Bw ₂	78-125	Very dark brown (7.5YR 2.5/3 and 7.5YR 2.5/2, dry and moist).clay; fine gravel strong medium sub-angular blocky structure; hard, firm very sticky and very plastic; few medium throughout roots between peds: strong effervescence with dilute HCl; clear smooth boundary.
C	125-170+	Weathered parent rock (schist).

Pedon : 8

Location	15° 17' 37.980" N; 75° 47' 47.568" E
Elevation above MSL (m)	582.49 m
Physiography	Low land of the lower side slope
Geology	Schist
Soil slope gradient (per cent)	0 to 1
Erosion	Slight
Drainage	Moderately well drained

Land use / vegetation

Crop	Sunflower - <i>Helianthus annuus</i> Banni - <i>Prosopis cineraria</i> (L.) Bellary Jali- <i>Prosopis juliflora</i>
Vegetation	Coconut - <i>Cocos nucifera</i> Neem- <i>Azadirachta indica</i> A. Juss. Ber- <i>Ziziphus mauritiana</i>



Plate 8. Pedon 7 of Dambal-2 Micro-watershed



Plate 9. Pedon 8 of Dambal-2 Micro-watershed

Horizon	Depth (cm)	Morphological description
Ap	0 - 29	Dark brown (7.5YR 3/3 D) and very dark brown (7.5YR 2.5/3); clay; fine gravel, moderate medium sub-angular blocky structure; slightly hard, friable, moderately sticky and moderately plastic; common medium throughout roots; strong effervescence with dilute HCl; clear smooth boundary.
Bw	29-77	Brown (7.5YR 4/4 and 7.5YR 4/3, dry and moist) clay; fine gravel, moderate medium sub-angular blocky structure; slightly hard, friable, moderately sticky and moderately plastic; common medium throughout roots; strong effervescence with dilute HCl; clear smooth boundary.
C	77-130+	Weathered parent rock (schist).

Pedon : 9

Location	15° 17' 52.435" N; 75° 47' 32.217" E
Elevation above MSL (m)	581.25 m
Physiography	Midland of upper side slope
Geology	Schist
Soil slope gradient (per cent)	0 to 1
Erosion	Moderate
Drainage	Moderately well drained

Land use / vegetation

Crop	Green gram – <i>Vigna radiata</i>
	Neem- <i>Azadirachta indica</i>
Vegetation	Ber- <i>Ziziphus mauritiana</i>
	Banni - <i>Prosopis cineraria</i> (L.)

Horizon	Depth (cm)	Morphological description
Ap	0 - 28	Very dark brown (7.5YR 2.5/2 and 7.5YR 2.5/3, dry and moist); clay; fine gravel, moderate medium sub-angular blocky structure; slightly hard, friable, moderately sticky and moderately plastic; common medium throughout roots: clear smooth boundary.
C	28-80+	Weathered Schist (strong effervescence with dilute HCl)

Pedon : 10

Location	15° 17' 09.443" N; 75° 47' 58.000" E
Elevation above MSL (m)	501.50 m
Physiography	Foot slope of upland
Geology	Schist
Soil slope gradient (per cent)	1 to 3
Erosion	Moderate
Drainage	Moderately well drained
<i>Land use / vegetation</i>	
Crop	Sunflower - <i>Helianthus annuus</i>
Vegetation	Bellary Jali- <i>Prosopis juliflora</i> Neem- <i>Azadirachta indica</i>

Horizon	Depth (cm)	Morphological description
Ap	0 - 20	Dark greyish brown (10YR 4/2 D) and greyish brown (10YR 5/2); clay; fine gravel moderate medium sub-angular blocky structure; slightly hard, friable, very sticky and very plastic; many medium roots between peds: strong effervescence with dilute HCl; clear smooth boundary.
Bw	20-50	Black (10YR 2/1 dry and moist); clay; fine gravel moderate medium sub-angular blocky structure; hard, friable very sticky and very plastic; few fine roots between peds: slight effervescence with dilute HCl; gradual smooth boundary
BC	50-65	Dark brown (7.5YR 3/3) and brown (7.5YR 4/3); clay; fine gravel weak medium sub-angular blocky structure; hard, firm very sticky and very plastic; slight effervescence with dilute HCl; gradual smooth boundary
C	65-110+	Weathered Schist.

Pedon : 11

Location	15° 17' 55.220" N; 75° 47' 24.157" E
Elevation above MSL (m)	523.92 m
Physiography	Side slope of midland
Geology	Schist
Soil slope gradient (per cent)	1 to 3
Erosion	Moderate
Drainage	Moderately well drained

Land use / vegetation

Crop	Maize – <i>Zea mays</i>
	Bellary Jali- <i>Prosopis juliflora</i>
Vegetation	Neem- <i>Azadirachta indica</i> A. Juss.
	Banni - <i>Prosopis cineraria</i> (L.)

Horizon	Depth (cm)	Morphological description
Ap	0 - 28	Brown (7.5YR 4/4 D) and brown (7.5YR 5/4); clay; fine gravel moderate medium sub-angular blocky structure; slightly hard, friable, very sticky and very plastic; many fine roots between peds; clear smooth boundary.
C	28-80+	Weathered Schist.

3.8.1 Morphological properties of pedons

Soil-colour of the pedons was measured using munsell soil-colour chart. Other morphological characteristics studied were depth of solum, boundary, rooting depth, depth of each horizon, texture, structure, consistency at dry, moist and wet conditions, size and quantity of lime nodules *etc.* The horizons were identified and designated according to revisions in Soil Taxonomy (Anon., 2014).

3.9 Preparation of soil samples

Soil samples collected from the each horizon of the pedons were dried in shade. The air-dried samples were ground with a wooden pestle and mortar and passed through 2 mm sieve to separate the coarse fragments (>2 mm). The fine earth samples were stored in separate containers and used for various analyses.

3.10 Methods of soil analysis

3.10.1 Physical properties

3.10.1.1 Particle size analysis

Particle size distribution of soil samples were determined by International pipette method as described by Piper (2002) using sodium hydroxide as dispersing agent. In this method, the rate of settling of silt and clay particles in the soil suspension was estimated by measuring directly the concentration of solids *viz.*, silt and clay in the suspension at given time intervals as settling occurs. That is, using a pipett, a known volume of aliquot is drawn from a given depth at specified time interval after sedimentation begun, and per cent of silt and clay is calculated by oven drying this aliquot.

3.10.1.2 Bulk density (Mg m^{-3})

Bulk density in each treatment was recorded by clod method as described by Black (1965).

3.10.1.3 Maximum water holding and field capacity

Maximum water holding capacity of the soils was determined by using Keen Raczkowaski brass cup as described by Piper (2002).



Plate 10. Pedon 9 of Dambal-2 Micro-watershed



Plate 11. Pedon 10 of Dambal-2 Micro-watershed



Plate 12. Pedon 11 of Dambal-2 Micro-watershed

3.10.2 Chemical properties

3.10.2.1 Soil reaction

The soil pH was determined in soil: water (1:2.5) suspension and in soil :1 N KCl by potentiometric method using glass electrode.

3.10.2.2 Electrical conductivity

Electrical conductivity was determined in soil: water (1:2.5) extract using conductivity bridge and expressed as dS m^{-1} (Jackson, 1967).

3.10.2.3 Organic carbon

The organic carbon content of a finely ground soil sample was determined by Walkely and Black's Wet Oxidation method as described by Jackson (1967) and expressed in per cent of soil.

3.10.2.4 Exchangeable cations

Exchangeable cations were extracted by neutral normal ammonium acetate. Calcium and magnesium in the extract were determined by Versenate titration and sodium and potassium were determined by flame photometry (Thomas, 1982).

3.10.2.5 Cation exchange capacity

The cation exchange capacity (CEC) of the soil was determined by equilibrating the soil, with neutral normal sodium acetate solution and the excess salts were removed by 95 per cent isopropyl alcohol (NBSS and LUP Staff, 1987). The adsorbed sodium was replaced by equilibrating with neutral normal ammonium acetate solution and the concentration of sodium in the leachate was measured by flame photometer and the CEC was calculated.

3.10.2.6 Free calcium carbonate

The free calcium carbonate of soil samples was determined by rapid titration method using standard HCl (Piper, 2002).

3.11 Soil classification

Based on the morphological, physical and chemical properties the soils were classified up to series level following USDA Soil Taxonomy (Anon., 2014 and 2006). Phases of soil series were mapped using GIS software.

3.12 Land evaluation

3.12.1 Land capability classification

The land capability is mainly based on the inherent soil characteristics, external land features and environmental factors. The land capability classes and sub classes were arrived at as per the guidelines in Soil Survey Manual (AISLUS, 1971).

3.12.2 Soil Suitability classification for irrigation

For irrigation projects, interpretations are required to indicate the areas suitable for irrigation, crops that may be grown and yields that may be expected *etc.* Soil site suitability classes for irrigation are useful to make groupings of soils according to their suitability for sustained use under irrigation. The classes were defined in terms of the degree of soil limitations. Soil site suitability classes for irrigation were decided as per the guidelines given by Sehgal (1996).

3.12.3 Soil-site suitability evaluation for crops

The structure of the classification is based on the FAO (1993) framework for land evaluation. The classification includes four categories: orders, class, sub-class and units. There are two orders (S and N), which reflect the kind of suitability (S for suitable and N for unsuitable). There are three classes (S-1 to 3) under the order S and two classes (N-1 and 2) under the order N, reflecting degree of suitability within the order. The appraisal of the classes, within an order is done according to evaluation of land limitations. The sub classes reflect the kinds of limitations or the main kinds of improvement measures required within a class. They are indicated by the symbol, using lower case letters following the Arabic numeral used for the class. The land suitability unit suggests the relative importance of land improvement works. It is indicated by Arabic numerals enclosed in parenthesis following the sub class symbol. Soil site suitability for some of the major crops like maize, cotton, sorghum, wheat, groundnut, pearl millet, pigeon pea, chilli, onion and chickpea were evaluated based on the criteria suggested by Sehgal (1996) and Naidu *et al.* (2006).

3.13 Assessment of soil fertility

3.13.1 Collection of samples

Composite soil samples (0-30 cm) were collected at 250 m grid interval. The exact sample location was recorded using a GPS (Appendix II). Processed soil samples were analyzed for nutrient availability by following standard analytical techniques.

3.13.2 Soil analysis for soil fertility evaluation

3.13.2.1 pH, electrical conductivity and organic carbon

Soil pH (soil: water suspension), electrical conductivity and organic carbon were estimated as described in section 3.10.2.1, 3.10.2.2 and 3.10.2.3.

3.13.2.2 Available nitrogen

Available nitrogen of soil was estimated by modified alkaline KMnO_4 method, where the organic matter in soil was oxidized with hot alkaline KMnO_4 solution. The ammonia (NH_3) evolved during oxidation was distilled and trapped in boric acid mixed indicator solution. After cooling the contents of distillation flask, nitrate nitrogen reduced to NH_3 using devardas alloy, the total amount of NH_3 was estimated by titrating with standard acid (Sharawat and Burford, 1982)

3.13.2.3 Available phosphorus

Available phosphorus in soil samples was extracted by Olsen's method for black soils (0.5 NaHCO_3) and Brays and Kurtz method for red soils ($0.03 \text{ N NH}_4\text{F} + 0.025 \text{ N HCl}$) as described by Jackson (1967), phosphorus in the extractant was complexed by molybdenum and reduced by ascorbic acid in presence of H_2SO_4 and estimated by spectrophotometry at 660 nm.

3.13.2.4 Available potassium

Available potassium was extracted with neutral normal ammonium acetate (pH 7.0) and the content of potassium in the solution was estimated by flame photometer (Jackson, 1967).

3.13.2.5 Exchangeable calcium and magnesium

Exchangeable calcium and magnesium were determined in neutral normal ammonium acetate extract by Versenate Titration as described by Jackson (1967).

3.13.2.6 Available sulphur

Available sulphur was extracted from the soil using 0.15 per cent calcium chloride solution and sulphur in solution was determined by turbidometry as outlined by Black (1965) using spectrophotometer at 420 nm.

3.13.2.7 Available zinc, copper, iron and manganese

Available zinc, copper, iron and manganese were extracted by using DTPA extractant as explained by Lindsay and Norvell (1978). The concentration of zinc, copper, iron and manganese in the extract was estimated using atomic absorption spectrometer (AAS Shimadzu model).

3.14 Preparation of thematic maps using GIS technique

3.14.1 Soil map

Based on field survey and laboratory investigation the soil series map of Dambal-2 micro-watershed was prepared using Arc GIS software.

3.14.2 Soil-site suitability for crops

By comparing soil-site characteristics and soil-site suitability requirements for different crops, the suitability of the soils of the study area for different crops were identified. A database file (dbf) consisting of these information was created in Arc GIS to prepare thematic maps for crop suitability.

3.14.3 Soil-fertility maps

A dbf file consisting of data for X and Y co-ordinates in respect of sampling site location was created. A shape file (Vector data) showing the outline of Dambal-2 micro-watershed area was created in Arc GIS. The dbf file was opened in the project window and in X-field, "X-co-ordinates" was selected and in Y-field, "Y-coordinates" were selected. The Z field was used for different nutrients.

The Dambal-2 micro-watershed file was also opened and from the “Surface menu” of Arc GIS Spatial Analyst “Interpolate grid” option was selected. On the output “grid specification dialogue”, output grid extend chosen was same as Dambal-2 micro-watershed and the interpolation method employed was spline. Then map was reclassified based on the following ratings of the respective nutrients.

Nutrients	Fertility rating		
	Low	Medium	High
Nitrogen (kg/ha)	<280	280 – 560	>560
Phosphorus (P ₂ O ₅) (kg/ha)	<23	23-56	>56
Potassium (K ₂ O) (kg/ha)	<140	140 – 330	>330
Sulphur (mg/kg)	<15	15-20	>20
Micronutrients	Deficient		Sufficient
Zinc (mg/kg)	<0.6		>0.6
Iron (mg/kg)	<2.5		> 2.5
Copper (mg/kg)	<0.2		>0.2
Manganese (mg/kg)	<1.0		>1.0
Boran (mg/kg)	<0.5 Low, 0.5-1.0 medium		>1.0 high

4. EXPERIMENTAL RESULTS

Results of the analysis of morphological, physical and chemical characteristics of the selected 11 pedons and 65 surface samples representing different physiographic units are presented under the following headings.

- 4.1 Morphological features of pedons
- 4.2 Physical properties of pedons
- 4.3 Chemical properties of pedons
- 4.4 Soil classification and mapping
- 4.5 Land evaluation
- 4.6 Soil fertility status of the micro-watershed

4.1 Morphological features of pedons

Eleven pedons from Dambal-2 micro-watershed of Gadag district were studied for their morphology, physical and chemical properties. Pedons were classified following soil taxonomy and evaluated for land capability and suitability for crops. The results are presented below in Table 2.

Pedons were classified into three categories upland (Pedon 2, 4, 5 and 10), midland (Pedon 1, 3, 9 and 11) and lowland pedons (Pedon 6, 7 and 8). The detailed descriptions of pedons are given below.

In pedon 1, the surface horizon extends to a depth of 10 cm with the solum depth of 130 cm. The soil colour was dark brown (10 YR 3/3 dry and moist), in Ap and very dark grayish brown (10 YR 3/2 dry) to dark brown (10 YR 3/3) when wet at subsurface horizon. The soils of surface and subsurface horizons were clay in texture and structure was moderate, medium and sub-angular blocky. The consistency of surface and subsurface horizon soils was slightly hard when dry but hard in case of subsurface horizon, friable and firm when moist, moderately sticky and moderately plastic when wet. Many medium roots between peds in Ap, whereas few and fine sized roots in A₁, AB and Bw horizons, strong effervescence with dilute HCl was observed in surface and subsurface horizons, wide deep cracks up to 40 cm were observed. clear smooth boundary in Ap, gradual smooth boundary in A₁ and gradual diffuse boundary in both AB and Bw horizons were observed.

In pedon 2, the surface horizon extends to a depth of 19 cm with the solum depth of 67 cm. The soil colour was dark gray (10YR 4/1) when dry and very dark greyish brown (10YR 3/2) when moist in Ap horizon. Whereas very dark gray (10 YR 3/1 dry), very dark grayish brown (10 YR 3/2 moist) in AB horizon. The soils of surface and subsurface horizons were clay in texture and structure was moderate, medium and sub-angular blocky. The consistency of surface and subsurface horizon soils was slightly hard when dry, friable and firm when moist, very sticky and very plastic when wet. Few fine roots between peds were observed upto 30cm depth. Strong effervescence with dilute HCl was observed in surface and subsurface horizons, wide deep cracks up to 25 cm was observed in Ap horizon. Clear smooth boundary in Ap and diffuse smooth boundary in AB and gradual diffuse boundary in Bw₁ was observed. CaCO₃ concretions were observed upto a depth of 40-140 cm.

Table 2: Morphological characteristics of the soils of pedons in Dambal-2 micro-watershed

Pedon No.	Horizon	Depth (cm)	Colour		Texture	Structure	Consistency			Root	Boun-dary	Special features
			Dry	Moist			Dry	Moist	Wet			
Pedon 1	Ap	0-10	10 YR 3/3	10 YR 3/3	c	2 m sbk	sh	fr	ms & mp	mmp	cs	Wide and deep cracks up to 48 cm violent effervescences with dilute HCl was observed.
	A ₁	10-40	10 YR 3/2	10 YR 3/3	c	2 m sbk	h	fi	vs & vp	ffp	gs	
	AB	40-80	7.5YR2.5/3	7.5YR2.5/3	c	2 m sbk	h	fi	vs & vp	ffp	gd	
	Bw ₁	80-130	7.5YR2.5/3	7.5YR2.5/3	c	2 m cr	h	fi	vs & vp	ffp	gd	
	Bw ₂	130-152	7.5YR 4/4	7.5YR 4/3	c	2 m cr	h	fi	vs & vp	ffp	gd	
	C	152-175+	Weathered parent rock (schist).									
Pedon 2	Ap	0-19	10 YR 4/1	10 YR 3/2	c	2 m sbk	sh	fr	vs & vp	ffp	cs	Wide and deep cracks up to 30 cm. . violent effervescences with dilute HCl, many and fine sized prominent CaCO ₃ concretions were observed from 40-140cm.
	AB	19-30	10 YR 3/1	10 YR 3/2	c	2 m sbk	sh	fr	vs & vp	ffp	gs	
	Bw	30-67	10 YR 2/1	10 YR 2/2	c	2 m sbk	h	fi	vs & vp	-	ds	
	C	67-133+	Weathered parent rock (schist).									
Pedon 3	A	0-10	10 YR 3/1	10 YR 2/1	cl	1 m cr	sh	fr	ms & mp	mfp	cs	Violent effervescences with dilute HCl was observed.
	AC	10-46	7.5 YR 3/1	7.5 YR 2/1	cl	1 m cr	sh	fr	ms & mp	ffp	Cs	
	C	46-80 ⁺	Paralithic contact with schist									
Pedon 4	Ap	0-23	10 YR4/1	10 YR3/1	c	2 m sbk	sh	fr	vs & vp	ffp	cs	Strong effervescences with dilute HCl, many and fine sized prominent CaCO ₃ concretions were observed from 30-90 cm.
	Bw	23-60	10YR2/1	10YR2/1	c	2 m sbk	h	fi	vs & vp	-	cs	
	C	60-90+	Paralithic contact with schist									
Pedon 5	Ap	0-25	10 YR 4/2	10 YR 5/2	c	2 m sbk	sh	fr	vs & vp	ffp	cs	Slight effervescences with dilute HCl was observed.
	Bw	25-110	7.5YR3/3	7.5YR3/3	c	1 m cr	h	fi	vs & vp	-	-	
	C	110-140+	Weathered parent rock (schist).									
Pedon 6	Ap	0-25	10 YR 4/2	10 YR 3/2	c	2 m sbk	sh	fr	vs & vp	cmt	cs	Strong effervescences with dilute HCl was observed.
	Bw ₁	25-58	10 YR 2/1	10 YR 2/2	c	3 m sbk	h	fr	vs & vp	cmt	cs	
	Bw ₂	58-99	10YR5/2	10YR2/2	c	3 m sbk	h	fi	vs & vp	ffp	cs	
	C	99-150+	Weathered parent rock (schist).									

Contd.....

Pedon No.	Horizon	Depth (cm)	Colour		Texture	Structure	Consistency			Root	Boun-dary	Special features
			Dry	Moist			Dry	Moist	Wet			
Pedon 7	Ap	0-31	10 YR 4/2	10 YR 3/2	c	2 m sbk	sh	fr	vs & vp	cmt	cs	Deep cracks up to 30 cm depth and strong effervescences with dilute HCl was observed.
	Bw ₁	31-78	10 YR 2/1	10 YR 2/2	c	2 m sbk	sh	fr	vs & vp	cmt	cs	
	Bw ₂	78-125	7.5 YR 2.5/3	7.5 YR 2.5/2	c	3 m sbk	h	fi	vs & vp	fmt	cs	
	C	125-170+	Weathered parent rock (schist).									
Pedon 8	Ap	0-29	7.5 YR 3/3	7.5 YR 2.5/3	c	2 m sbk	sh	fr	ms & mp	cmt	cs	Strong effervescences with dilute HCl was observed.
	Bw	29-77	7.5 YR 4/4	7.5 YR 4/3	c	2 m sbk	sh	fr	ms & mp	cmt	cs	
	C	77-130+	Weathered parent rock (schist).									
Pedon 9	Ap	0-28	7.5 YR 2.5/2	7.5 YR 2.5/3	c	2 m sbk	sh	fr	ms & mp	cmt	cs	Slight to strong effervescences with dilute HCl was observed.
	C	28-80+	Paralithic contact with schist									
Pedon 10	Ap	0-20	10 YR 4/2	10 YR 5/2	c	2 m sbk	sh	fr	vs & vp	mmp	cs	Strong to slight effervescences with dilute HCl, many and fine sized prominent CaCO ₃ concretions were observed from 0-110 cm was observed.
	Bw	20-50	10 YR 2/1	10 YR 2/1	c	2 m sbk	h	fi	vs & vp	ffp	gs	
	BC	50-65	7.5YR3/3	7.5YR4/3	c	1 m sbk	h	fi	vs & vp	-	gs	
	C	65-110+	Weathered parent rock (schist).									
Pedon 11	Ap	0-28	7.5 YR 4/4	7.5 YR 5/4	c	2 m sbk	sh	fr	vs & vp	mfp	cs	Many fine roots between peds was observed.
	C	28-80+	Paralithic contact with schist									

In pedon 3, the surface horizon extends to a depth of 10 cm with solum depth 46cm. The soils of surface horizon (Ap) was very dark gray (10YR 3/1 dry) and black (10YR 2/1 moist) and in subsurface (AC) very dark gray (7.5YR 3/ 1 dry) to black (7.5YR 2/1 moist) in colour. The soils of surface and subsurface horizons were clay loam in texture and the structure was weak medium crumb. The consistency of surface horizon soils was slightly hard when dry, friable when moist, moderately sticky and moderately plastic when wet. Many fine to few fine roots between peds, strong effervescence with dilute HCl and clear smooth boundary were observed in soils of surface and subsurface horizons.

In pedon 4, the surface horizon extends to a depth of 23 cm with the solum depth of 60 cm. The soil colour was dark gray (10YR 4/1 dry) and very dark gray (10YR 3/1 moist) in Ap and black (10YR 2/1 dry and moist) in C horizons. The soils of surface and subsurface horizons were clay in texture and structure was moderate, medium and sub-angular blocky in Ap and Bw horizons. The consistency of surface horizon soils was slightly hard when dry, friable when moist, very sticky and very plastic when wet whereas in subsurface hard when dry, firm when moist, very sticky and very plastic when wet. Few fine roots between peds in Ap horizon. Strong effervescence in surface and in subsurface horizons with dilute HCl and clear smooth boundary were observed in soils of surface and subsurface horizons. CaCO₃ concretions were observed up to a depth of 30-90 cm.

In pedon 5, the surface horizon extends to a depth of 25 cm with solum depth 110cm. The soil colour was dark greyish brown (10YR 4/2 dry) and greyish brown (10YR 5/2 moist) in Ap horizon. The soils of surface and subsurface horizon were clay in texture and structure was moderate, medium and sub-angular blocky. The consistency of surface horizon soils was slightly hard when dry, friable when moist, very sticky and very plastic when wet. Few fine roots between peds in Ap horizon. Clear smooth boundary was observed surface horizon (Ap).

In pedon 6, the surface horizon extends to a depth of 25 cm with the solum depth of 99 cm. The soil colour of surface horizon were dark greyish brown (10YR 4/2 dry) and very dark greyish brown (10YR 3/2 moist). Whereas black (10YR 2/1), greyish brown (10YR 5/2 dry) and very dark brown (10YR 2/2 moist) in both Bw₁ and Bw₂ horizons. The soils of surface and subsurface horizons were clay in texture and structure was moderate, medium and sub-angular blocky. The consistency of surface and subsurface horizon soils was slightly hard to hard when dry, friable but firm in Bw₂ horizon, when moist, very sticky and very plastic when wet. Common medium throughout roots in Ap and Bw₁ horizons, whereas few and fine sized roots between peds in Bw₁ horizon, strong effervescence with dilute HCl was observed in all horizons, surface cracks were observed. Clear smooth boundary were observed all horizons.

In pedon 7, the surface horizon extends to a depth of 31 cm with the solum depth of 125 cm. The soil colour of surface horizon were dark greyish brown (10YR 4/2 dry) and very dark greyish brown (10YR 3/2 moist). Whereas Black (10YR 2/1 dry) and very dark brown (10YR 2/2 moist) in Bw₁ horizon and very dark brown (7.5YR 2.5/3 and 7.5YR 2.5/2, dry and moist) in Bw₂ horizon. The soils of surface and subsurface horizons were clay in texture and structure was moderate, medium and sub-angular blocky. The consistency of surface and subsurface horizon soils was slightly hard to hard when dry, friable but firm in Bw₂ horizon, when moist, very sticky and very plastic when wet. Common medium throughout roots in Ap and Bw₁ horizons, whereas few medium throughout roots between

peds in Bw₂ horizon, strong effervescence with dilute HCl was observed in all horizons, surface cracks were observed. Clear smooth boundary was observed in all horizons.

In pedon 8, the surface horizon extends to a depth of 29 cm with the solum depth of 77 cm. The soil colour was dark brown (7.5YR 3/3 dry) and very dark brown (7.5YR 2.5/3 moist) in Ap horizon and brown (7.5YR 4/4 and 7.5YR 4/3, dry and moist) in Bw horizon. The soils of surface and subsurface horizons were clay in texture and structure was moderate, medium and sub-angular blocky. The consistency of surface and subsurface horizon soils was slightly hard when dry, friable, when moist, moderately sticky and moderately plastic when wet. Common medium throughout roots between peds in Ap and Bw horizons, whereas few and fine sized roots in Bt₂ horizon, strong effervescence with dilute HCl was observed in all horizons, clear smooth boundary in all horizons was observed.

In pedon 9, the surface horizon extends to a depth of 28 cm. The soils of surface horizon (Ap) was very dark brown (7.5YR 2.5/2 and 7.5YR 2.5/3, dry and moist) in colour. The soils of surface horizons were clay in texture and the structure was moderate, medium and sub-angular blocky. The consistency of surface horizon soils was slightly hard when dry, friable when moist, moderately sticky and moderately plastic when wet. Common medium throughout roots, strong effervescence with dilute HCl in C horizon and clear smooth boundary were observed in soils of surface horizon.

In pedon 10, the surface horizon extends to a depth of 20 cm with the solum depth of 65 cm. The dry soil colour of Ap horizon dark greyish brown (10YR 4/2) and greyish brown (10YR 5/2) when moist. Black (10YR 2/1 dry and moist) in Bw and Dark brown (7.5YR 3/3 dry) to brown (7.5YR 4/3 moist) in BC horizons soil colour. The soils of surface and subsurface horizons were clay in texture and structure was moderate, medium and sub-angular blocky. The consistency of surface and subsurface horizon soils was slightly hard in Ap, hard in Bw and BC horizons when dry, friable, except in Bw and BC horizons (firm) when moist, very sticky and very plastic when wet. many medium roots between peds in Ap horizon, whereas few fine roots between peds in Bw horizon, strong effervescence with dilute HCl was observed in Ap horizon, slight effervescence with dilute HCl were observed in Bw and BC horizons. Clear smooth boundary was observed in Ap and horizon and gradual smooth boundary in Bw and Bc horizons. CaCO₃ concretions were observed at a depth of 0-110 cm.

In pedon 11, the surface horizon extends to a depth of 28 cm. The soil colour was brown (7.5YR 4/4 dry) and brown (7.5YR 5/4 moist) in Ap horizon. The soils of surface horizon were clay in texture and structure was moderate, medium and sub-angular blocky. The consistency of surface horizon soils was slightly hard when dry, friable when moist, very sticky and very plastic when wet. Many fine roots between peds in Ap horizon was observed. Clear smooth boundary was observed in surface horizon (Ap).

4.2 Physical properties of pedons

4.2.1 Particle size distribution

A certain trend in variation of particle size distribution was discernible. Clay content in the horizons ranged from 34.40 to 62.10 per cent (Table 3). The highest clay content (62.10 per cent) was observed in soils of pedon 7 and it was lowest (34.40 per cent) in soils of pedon 11. The clay content increased with the depth in all the pedons.

Table 3: physical characteristics of the soils of pedons in Dambal-2 micro-watershed

Pedon No.	Horizon	Depth (cm)	Coarse fragments (>2 mm)	Coarse sand (2-0.25 mm)	Fine sand (0.25-0.05 mm)	Total sand (2.0-0.05 mm)	Silt (0.05-0.002 mm)	Clay (<0.002 mm)	MWHC	FC	BD (mg m ⁻³)
			(.....%).....)								
Pedon 1	Ap	0-10	7.20	7.10	16.30	23.40	24.60	52.00	58.12	29.06	1.28
	A ₁	10-40	5.00	8.10	10.50	18.60	26.00	55.40	56.42	28.21	1.31
	AB	40-80	15.00	7.60	16.90	24.50	23.40	52.10	58.76	29.38	1.35
	Bw ₁	80-130	18.90	5.30	19.40	24.70	24.10	51.20	59.11	29.55	1.39
	Bw ₂	130-152	19.10	4.30	20.70	25.00	24.40	50.60	56.30	28.15	1.41
	C	152-175+		Weathered parent rock (schist).							
Pedon 2	Ap	0-19	19.20	11.40	8.50	19.90	28.40	51.70	58.31	29.15	1.38
	AB	19-30	18.40	10.10	5.90	16.00	29.80	54.20	59.69	29.84	1.41
	Bw	30-67	18.00	9.20	4.50	13.70	29.20	57.10	61.38	30.69	1.42
	C	67-133+		Weathered parent rock (schist).							
Pedon 3	Ap	0-10	32.80	20.30	12.80	33.10	20.60	46.30	58.20	29.10	1.38
	Ac	10-46	38.40	21.80	14.80	36.60	22.10	41.30	59.31	29.65	1.39
	C	46-80+		Paralithic contact with schist							
Pedon 4	Ap	0-23	25.50	7.80	9.90	17.70	28.10	54.20	53.69	26.84	1.36
	Bw	23-60	20.00	7.30	6.60	13.90	29.80	56.30	54.33	27.16	1.42
	C	60-90+		Paralithic contact with schist							
Pedon 5	Ap	0-25	22.40	14.30	10.50	24.80	25.00	50.20	54.82	27.41	1.44
	Bw	25-110	20.60	11.60	9.80	21.40	26.20	53.40	57.64	28.82	1.41
	C	110-140+		Weathered parent rock (schist).							
Pedon 6	Ap	0-25	12.80	8.40	13.60	22.00	19.40	58.60	57.61	28.80	1.36
	Bw ₁	25-58	5.00	8.10	11.10	19.20	21.60	59.20	59.19	29.59	1.38
	Bw ₂	58-99	4.00	7.60	9.00	16.60	22.10	61.30	60.11	30.05	1.40
	C	99-150+		Weathered parent rock (schist).							

The distribution of silt was in the range of 11.30 to 29.80 per cent (Table 3). The highest silt content (29.80 per cent) was observed in the soils of pedon 4 and it was lowest (11.30 per cent) in soils of pedon 11. The distribution of silt content did not follow definite trend in the soils of pedons under study.

The fine sand content of the soils of pedons under study ranged from 4.50 to 19.40 per cent. The highest fine sand was observed in soils of pedon 1 (19.40 per cent) and lowest fine sand in soils of pedon 2 (4.50 per cent). The fine sand content decreased with depth in all soils of pedons, except in soils of pedon 1 and 3 the fine sand content decreased upto A₁ and A in both horizons and increased thereafter.

The coarse sand content of the soils of pedons under study ranged from 4.90 to 21.80 per cent (Table 3). The highest coarse sand was observed in soils of pedon 3 (21.80 per cent) and lowest coarse sand in soils of pedon 7 (4.90 per cent). The total sand content of the soils of pedons under study ranged from 13.70 to 36.60 per cent. The highest total sand was observed in soils of pedon 3 (36.60 per cent) and lowest total sand in soils of pedon 2 (13.70 per cent). The distribution of coarse sand and total sand content did not follow definite trend in the soils of pedons under study.

4.2.2 Bulk density

The bulk density in surface layers (Ap) ranged from 1.28 to 1.46 Mg m⁻³ (Table 3). In the subsurface horizons, the bulk density varied between 1.31 to 1.48 Mg m⁻³. The lowest value was observed in soils of pedon 1 (surface and subsurface horizons) and the highest in soils of pedon 8 (surface layer and subsurface horizons).

4.2.3 Maximum water holding capacity (MWHC)

Water holding capacity of soils of pedons in the surface layer ranged from 45.40 to 61.68 per cent being the lowest in soils of pedon 11 (45.40 per cent) and the highest in the soils of pedons 7 (61.68 per cent) (Table 3). The water holding capacity of subsurface horizons varied between 54.33 to 65.40 per cent. The lowest in soils of pedon 4 (54.33 per cent) and highest in the soils of pedons 10 (65.40 per cent). MWHC increased from surface to the lower horizons and followed the trend in clay variation in soils of pedons.

4.2.4 Field moisture capacity/ Field capacity (FC)

Field capacity of soils of pedons in the surface layer ranged from 22.70 to 30.84 per cent being lowest in soils of pedon 11 (22.70 per cent) and highest in the soils of pedons 7 (30.84 per cent). The field capacity of subsurface horizons varied between 27.16 to 32.70 per cent. The lowest in soils of pedon 4 (27.16 per cent) and highest in the soils of pedons 10 (32.70 per cent). Field capacity increased from surface to the lower horizons and followed the trend in clay variation in soils of pedons. The results are presented in Table 3.

4.3 Chemical properties of pedons

4.3.1 Soil reaction (pH)

Soil pH in water (1:2.5) ranged from 8.24 to 9.24 (alkaline to strongly alkline) in the surface layers. The highest pH was recorded in soils of pedon 5 (9.24) and lowest in soils of pedon 9 (8.24). The soil pH ranged from 8.39 to 9.24 (Table 4), highest pH was recorded in soils of pedon 10 (9.24) and lowest in soils of pedon 3 (8.39) in subsurface horizons. The pH increased with increasing depths, except in soils of pedon 1.

Table 4: Chemical properties of the soils of pedons in Dambal-2 micro-watershed

Pedon No.	Horizon	Depth (cm)	pH (1:2.5)		EC (dS m ⁻¹)	O.C. (g kg ⁻¹)	Free CaCO ₃ (%)
			Water	KCl			
Pedon 1	Ap	0-10	8.88	6.21	0.21	4.8	8.12
	A ₁	10-40	9.10	6.54	0.46	4.3	11.87
	AB	40-80	8.98	6.41	0.53	3.1	14.37
	Bw ₁	80-130	9.21	6.58	0.69	2.0	14.87
	Bw ₂	130-152	8.98	6.38	0.49	1.6	14.85
	C	152-175 ⁺	Weathered parent rock (schist).				
Pedon 2	Ap	0-19	8.44	6.20	0.24	5.6	04.75
	AB	19-30	8.60	6.33	0.41	4.2	07.25
	Bw	30-67	8.98	6.28	0.52	2.8	06.87
	C	96-125 ⁺	Weathered parent rock (schist).				
Pedon 3	Ap	0-10	8.32	6.21	0.16	2.2	14.0
	AC	10-46	8.39	6.23	0.13	1.2	14.75
	C	46-80 ⁺	Paralithic contact with schist				
Pedon 4	Ap	0-23	8.51	6.10	0.54	4.6	7.25
	Bw	23-60	8.56	6.10	0.59	3.1	8.12
	C	60-90 ⁺	Paralithic contact with schist				
Pedon 5	Ap	0-25	9.24	6.43	0.14	3.6	8.12
	Bw	25-110	9.26	6.40	0.16	3.2	8.18
	C	110-140 ⁺	Weathered parent rock (schist).				
Pedon 6	Ap	0-25	8.68	6.23	0.16	5.8	6.12
	Bw ₁	25-58	8.87	6.30	0.58	4.1	6.87
	Bw ₂	58-99	8.99	6.33	0.61	2.6	9.37
	C	99-150 ⁺	Weathered parent rock (schist).				

Contd.....

Pedon No.	Horizon	Depth (cm)	pH (1:2.5)		EC (dS m ⁻¹)	O.C. (g kg ⁻¹)	Free CaCO ₃ (%)
			Water	KCl			
Pedon 7	Ap	0-31	8.84	6.42	0.13	6.2	10.50
	Bw ₁	31-78	8.80	6.31	0.19	4.1	11.87
	Bw ₂	78-125	8.91	6.44	0.17	3.0	14.37
	C	117-158 ⁺	Weathered parent rock (schist).				
Pedon 8	Ap	0-29	8.96	6.34	0.13	3.1	3.87
	Bw	29-77	8.98	6.38	0.25	2.0	5.62
	C	77-130 ⁺	Weathered parent rock (schist).				
Pedon 9	Ap	0-28	8.24	6.21	0.11	4.8	5.62
	C	28-80 ⁺	Paralithic contact with schist				
Pedon 10	Ap	0-20	9.12	6.23	0.21	5.2	10.75
	Bw	20-50	9.20	6.41	0.28	4.1	12.25
	BC	50-65	9.24	6.43	0.32	3.0	14.87
	C	65-110 ⁺	Weathered parent rock (schist).				
Pedon 11	Ap	0-28	8.60	6.10	0.20	2.3	8.12
	C	28-80 ⁺	Paralithic contact with schist				

Soil pH in KCl (1:2.5) ranged from 6.10 to 6.42 (Table 4) in the surface layers. The highest pH was recorded in soils of pedon 7 (6.42) and lowest in soils of pedons 4 and 11 (6.10). The soil pH ranged from 6.10 to 6.58, highest pH was recorded in soils of pedon 1 (6.58) and lowest in soils of pedon 4 (6.10) in subsurface horizons. The pH increased with increasing depths, except in soils of pedons 1, 2 and 7 the pH did not follow definite trend with depth.

4.3.2 Electrical conductivity (EC)

The electrical conductivity of the soil water extract (1:2.5) ranged from 0.11 to 0.54 dS m⁻¹ (Table 4), the highest electrical conductivity was observed in soils of pedon 4 and lowest in soils of pedon 9 of surface layer. However, in subsurface horizon the EC (1:2.5) ranged from 0.13 to 0.69 dS m⁻¹ and the highest electrical conductivity was recorded in soils of pedon 1 and the lowest in soils of pedon 3.

4.3.3 Free calcium carbonate

The calcium carbonate content in surface layers ranged from 3.87 to 14.0 per cent and in subsurface layers, it ranged from 5.62 to 14.87 per cent (Table 4). The highest calcium carbonate content in surface layer was recorded in soils of pedon 3 (14.0 per cent) and lowest in soils of pedon 8 (3.87 per cent), whereas in subsurface the highest calcium carbonate content was observed in soils of pedon 1 (14.87 per cent) and the lowest in soils of pedon 8 (5.62 per cent).

4.3.4 Organic carbon

The organic carbon content ranged from 0.22 to 0.62 per cent in surface layer and 0.12 to 0.43 per cent the subsurface horizons (Table 4). The minimum value (0.22 per cent) in pedon soils of 3 and maximum values (0.62 per cent) in soils of pedon 7 recorded in surface layer, whereas in subsurface horizon, minimum value (0.12 per cent) observed in soils of pedon 3 and maximum value (0.43 per cent) in soils of pedon 1. Decreasing trends of organic carbon with depth was observed in all soils of pedons.

4.3.5 Exchangeable cations

In general, the exchangeable calcium and magnesium were the dominant cations followed by sodium and potassium ion. The exchangeable calcium and magnesium in surface soils ranged from 23.11 (pedon 11) to 38.90 (pedon 7) cmol (p⁺) per kg and 7.12 (pedon 11) to 17.0 (pedon 1) cmol (p⁺) per kg, respectively (Table 5). In subsurface soils, Ca and Mg ranged from 27.94 (pedon 3) to 41.70 (pedon 10) cmol (p⁺) per kg and 6.96 (pedon 3) to 16.60 (pedon 6) cmol (p⁺) per kg, respectively.

The exchangeable sodium content of soils ranged from 1.82 (pedon 5) to 5.05 (pedon 9) cmol (p⁺) per kg in surface horizons and 2.30 (pedon 8) to 5.08 (pedon 1) cmol (p⁺) per kg in subsurface horizons. The exchangeable potassium content of soils ranged from 0.27 (pedon 2) to 0.83 (pedon 1) cmol (p⁺) per kg in surface horizons and 0.26 (pedon 2) to 0.70 (pedon 1) cmol (p⁺) per kg in subsurface horizons (Table 5).

4.3.6 Exchangeable sodium percentage (ESP)

The exchangeable sodium percentage of soils ranged from 3.28 to 9.04 in surface horizons and 4.12 to 9.35 (Table 5) in subsurface horizon. The highest exchangeable sodium percentage in surface horizons was observed in soils of pedon 2 (9.04) and lowest was observed in soils of pedon 5 (3.28). Whereas in subsurface horizons highest was recorded in soils of pedon 3 (9.3) and lowest was observed in soils of pedon 8 (4.12). Exchangeable sodium percentage values were did not follows any definite trend throughout the depth in all soils of pedons.

Table 5: Exchangeable cations of the soils of pedons in Dambal-2 micro-watershed

Pedon No.	Horizon	Depth (cm)	Ca	Mg	Na	K	CEC	BS	ESP
			(.....c mol (p ⁺) kg ⁻¹)					(.....%.....)	
Pedon 1	Ap	0-10	32.00	17.00	4.66	0.83	57.93	94.06	8.04
	A ₁	10-40	34.20	14.00	4.56	0.70	58.59	91.24	7.78
	AB	40-80	30.80	12.40	4.72	0.39	56.55	85.42	8.34
	Bw ₁	80-130	29.20	10.10	5.08	0.34	55.57	80.47	9.14
	Bw ₂	130-152	28.60	9.80	4.78	0.31	54.25	80.16	8.81
	C	152-175 ⁺	Weathered parent rock (schist)						
Pedon 2	Ap	0-19	36.20	10.40	4.95	0.27	54.74	94.66	9.04
	AB	19-30	34.80	10.80	5.00	0.26	57.61	88.28	8.67
	Bw	30-67	34.60	13.00	5.07	0.31	59.90	88.44	8.46
	C	67-133 ⁺	Weathered parent rock (schist).						
Pedon 3	A	0-10	26.89	7.92	4.17	0.48	46.81	84.29	8.90
	AC	10-46	27.94	6.96	4.22	0.51	45.11	87.85	9.35
	C	46-80 ⁺	Paralithic contact with schist						
Pedon 4	Ap	0-23	36.80	12.10	3.57	0.32	57.64	91.58	6.19
	Bw	23-60	37.88	12.50	3.39	0.35	59.55	90.88	5.69
	C	60-90 ⁺	Paralithic contact with schist						
Pedon 5	Ap	0-25	35.80	11.80	1.82	0.36	55.44	89.79	3.28
	Bw	25-110	36.00	11.90	1.82	0.39	56.10	93.83	3.24
	C	110- 140 ⁺	Weathered parent rock (schist).						
Pedon 6	Ap	0-25	37.60	14.40	4.80	0.37	62.88	90.09	7.63
	Bw ₁	25-58	38.11	15.12	5.06	0.35	63.67	92.09	7.94
	Bw ₂	58-99	37.80	16.60	4.65	0.34	64.86	91.56	7.16
	C	99-150 ⁺	Weathered parent rock (schist).						

contd..

Pedon No.	Horizon	Depth (cm)	Ca	Mg	Na	K	CEC	BS	ESP
			(.....c mol (p ⁺) kg ⁻¹)						(.....%......)
Pedon 7	Ap	0-31	38.90	12.60	3.28	0.41	61.82	89.27	5.30
	Bw ₁	31-78	37.20	13.00	3.50	0.44	63.89	84.74	5.47
	Bw ₂	78-125	38.80	11.20	3.90	0.47	63.68	85.38	6.12
	C	125-170 ⁺	Weathered parent rock (schist).						
Pedon 8	Ap	0-29	32.91	10.24	2.13	0.37	53.51	85.31	3.98
	Bw	29-77	33.40	11.28	2.30	0.35	55.82	84.79	4.12
	C	77-130 ⁺	Weathered parent rock (schist).						
Pedon 9	Ap	0-28	30.80	10.40	4.05	0.49	51.16	89.40	7.91
	C	28-80 ⁺	Paralithic contact with schist						
Pedon 10	Ap	0-20	35.50	12.40	4.17	0.46	59.54	88.22	7.00
	Bw	20-50	39.80	13.89	3.88	0.34	65.70	88.14	5.90
	BC	50-65	41.70	14.50	3.56	0.35	66.44	90.47	5.35
	C	65-110 ⁺	Weathered parent rock (schist).						
Pedon 11	Ap	0-28	23.11	7.12	2.80	0.37	37.40	89.30	7.48
	C	28-80 ⁺	Paralithic contact with schist						

4.3.7 Base saturation

The base saturation percentage of soils ranged from 84.29 to 94.66 per cent in surface horizons and 80.47 to 93.83 per cent in subsurface horizon (Table 5). The highest base saturation percentage in surface horizons was observed in soils of pedon 2 (94.66 per cent) and lowest was observed in soils of pedon 3 (84.29 per cent). Whereas in subsurface horizons highest was recorded in soils of pedon 5 (93.83 per cent) and lowest was observed in soils of pedon 1 (80.47 per cent). The base saturation followed indefinite trend throughout the whole profile depth.

4.3.8 Cation exchange capacity (CEC)

The cation exchange capacity of soils ranged from 37.40 to 62.88 cmol (p⁺) per kg in surface horizons and 45.11 to 66.44 cmol (p⁺) per kg in subsurface horizon (Table 5). The highest cation exchange capacity in surface horizons were recorded in soils of pedon 6 (62.88 cmol (p⁺) per kg) and lowest was observed in soils of pedon 11 (37.40 cmol (p⁺) per kg). Whereas in subsurface horizons the highest was observed in soils of pedon 10 (66.44 cmol (p⁺) per kg) and the lowest was recorded in soils of pedon 3 (45.11 cmol (p⁺) per kg). The cation exchange capacity was also followed the trend of clay variation in soils of pedons.

4.4 Soil classification and mapping

4.4.1 Soil classification

The pedons under study are classified based on morphological, physical and chemical properties according to Keys to Soil Taxonomy (Anon., 2014). At higher categories (order) the presence or absence of diagnostic horizons which are indications of pedogenic process were considered. At sub-order level, the moisture and temperature regimes were used. At lower categories (great group, sub-group and family), diagnostic subsurface horizons, soil depth, mineralogy, texture, soil chemical properties and drainage are considered. The classification of the pedons under study is given below.

The overall classification of selected pedons is given below.

Pedon No.	Soil classification
1, 2, 4, 5, 6, 7, 8 and 10	Fine, mixed, super active, isohyperthermic, <i>Typic Haplustepts</i> .
3 and 9	Clayey, mixed, super active, isohyperthermic, <i>Lithic Ustorthents</i> ..
11	Fine-loamy, mixed, super active, isohyperthermic, <i>Lithic Ustorthents</i> .

4.4.2 Soil mapping unit

A soil map is designed to show the distribution of soil types or other soil mapping units in relation to other prominent physical and cultural features of earth surface. After soil survey, the first step is the establishment of the unit of classification to be shown on the map. The mapping units are phases of soil series. Seven soil series were identified under the study area. The soils of Dambal-2 micro-watershed are designated as Dmb-1 to Dmb-7 and are represented by pedons.

The soils of Dambal-2 micro-watershed were mapped into 7 mapping units based on observations from the pedons representing them. Mapping units are derived from name of the series, soil depth, soil texture, slope class, erosion class and gravelliness are presented in Table 6.

4.5 Land evaluation

4.5.1 Land capability classification (LCC)

Land capability classification in an interpretative grouping of soils mainly based on the inherent soil characteristics, external land features and environmental factors that limit the use of the land. The classification of soil units provide information on the nature of parent material, colour, texture, structure of soil, type of clay, mineral, consistence, permeability, depth of soil and soil reaction. Each of the above factor have definite role to play in behavior of soil and management.

Soil site characteristics of soil units (Table 7) and the criteria (Appendix III) or land capability classification for each soil units were arrived by matching with prescribed properties. The detail description of Land capability classification is presented below.

Land capability sub-class	Mapping unit	Area (ha)
III tsf	Dmb-1-m-B-2, Dmb-2-m-B-2, Dmb-3-m-B-2, Dmb-4-m-B-2 and Dmb-5-m-B-2-g1	339
IV sf	Dmb-6-f-B-2-g2 and Dmb-7-h-B-2-g2	53

Suffixes in the LCC sub-class indicate limitations (s; soil properties, t; topography, f; fertility, w; drainage/wetness)

There is no class I and class II land in the study area. The mapping units belong to two land capability classes namely III and IV with different limitations for land-use (Table 8).

4.5.2 Soil-site suitability classification for irrigation

The soils of the study area which are un-irrigated and already under irrigation have been surveyed, evaluated and grouped according to their suitability for irrigation.

After examining the soil site characteristics of the surveyed area, the soil irrigation capability classification was done according to ratings based on kind and degree of limitation for surface irrigation (Appendix IV). Out of the 7 mapping units, the mapping unit 6 and 7 are marginally suitable (S3s) whereas 1, 2, 3, 4 and 5 are moderately suitable (S2tws) for irrigation (Table 9) with major limitations of soil depth, soil erosion, soil drainage outlets, coarse fragments and soil texture. Area of marginally and moderately suitable class for irrigations was 53 and 339 ha, respectively

4.5.3 Soil-site suitability for crops

The optimum requirement of a crop was always region specific. Climate and soil site parameters play significant role to maximize crop yields. The soil properties from the study area were matched with the soil site suitability criteria (Appendix V to XXV) for a few important selected crops that are being grown in Gadag district. The kind and degree of limitations were evaluated and the results are presented below.

Table 6: Soil mapping units and their classifications

Sl. No.	Mapping unit	Pedon No.	Classifications	Description
01	Dmb-1-m-B-2	1	Fine, mixed, super active, isohyperthermic, Typic Haplustepts.	Soils are very deep with clay texture on nearly level to very gently sloping lands with slight to moderate erosion.
02	Dmb-2-m-B-2	2, 6	Fine, mixed, super active, isohyperthermic, Typic Haplustepts.	Soils are moderately deep with clay texture on very gently to gently sloping lands with moderate erosion.
03	Dmb-3-m-B-2	5, 7&8	Fine, mixed, super active, isohyperthermic, Typic Haplustepts.	Soils are deep with clay texture on very gently to gently sloping lands with moderate erosion.
04	Dmb-4-m-B-2	10	Fine, mixed, super active, isohyperthermic, Typic Haplustepts.	Soils are moderately shallow with clay texture on very gently to gently sloping lands with moderate erosion.
05	Dmb-5-m-B-2-g1	4	Fine, mixed, super active, isohyperthermic, Typic Haplustepts.	Soils are moderately shallow with clay texture on very gently to gently sloping lands with moderate erosion and slightly gravellines.
06	Dmb-6-f-B-2-g2	3, 9	Clayey, mixed, super active, isohyperthermic, Lithic Ustorthents.	Soils are shallow with clay texture on very gently to gently sloping lands with moderate erosion and gravelly to very gravelly.
07	Dmb-7-h-B-2-g2	11	Fine-loamy, mixed, super active, isohyperthermic, Lithic Ustorthents.	Soils are shallow with fine-loamy texture on very gently to gently sloping lands with moderate erosion and gravelly to very gravelly.

Table 7: Soil-site characteristics of mapping unit

Mapping units	Average Rainfall (mm)	Mean Temperature in growing season (0 ⁰ c)	Mean RH (%)	Depth (cm)	Slope (%)	Erosion	Drainage	Text-ure	Weighted averages						
									pH	EC (dS m ⁻¹)	OC (g kg ⁻¹)	CEC [c mol (P ⁺) kg ⁻¹]	BS (%)	ESP	Free CaCO ₃ (%)
Dmb-1-m-B-2	671	25	65	130	0-1	moderate	moderately well	c	9.04	0.47	3.5	57.16	87.79	8.32	12.30
Dmb-2-m-B-2	671	25	65	99	1-3	moderate	moderately well	c	8.76	0.42	4.1	60.61	90.85	8.15	6.87
Dmb-3-m-B-2	671	25	65	125	1-3	moderate	moderately well	c	8.95	0.16	3.6	59.026	86.54	4.71	9.05
Dmb-4-m-B-2	671	25	65	65	1-3	moderate	moderately well	c	9.18	0.27	4.1	63.89	88.94	6.08	12.62
Dmb-5-m-B-2-g1	671	25	65	60	1-3	moderate	moderately well	c	8.53	0.56	3.8	58.595	91.23	5.94	7.68
Dmb-6-f-B-2-g2	671	25	65	46	1-3	moderate	moderately well	c	8.31	0.13	2.8	48.36	87.31	8.62	11.45
Dmb-7-h-B-2-g2	671	25	65	28	1-3	moderate	moderately well	scl	8.60	0.2	2.3	38.4	89.58	7.29	8.12

4.5.3.1 Wheat

Soil Mapping Unit No 7 is not suitable due to very severe depth limitation and mapping unit 6 had severe limitations of depth, coarse fragments and OC, hence this mapping unit is marginally suitable for cultivation of wheat (Table 10). Mapping units 1, 2, 3, 4 and 5 were moderately suitable due to moderate limitations of depth, texture, OC and pH. Area of marginally suitable 44 ha and moderately suitable class for wheat was 339 ha. And 9 ha was not suitable.

4.5.3.2 Maize

All soil mapping units were marginally suitable for cultivation of maize due to severe limitation of climate, depth, pH, organic carbon and texture (Table 11). Area of marginally suitable class for maize was 392 ha.

4.5.3.3 Sorghum

Soil mapping unit no.7 (Dmb) is not suitable for sorghum cultivation due to very severe limitations of depth and 6 (Dmb) were marginally suitable for sorghum cultivation (Table 12) with limitations of soil properties. Other mapping units 1, 2, 3, 4 and 5 were moderately suitable with moderate limitations of soil properties (depth, pH, OC, ESP, climate and erosion. Area of marginally and moderately suitable class for sorghum was 44 and 339 ha, respectively and 9 ha was not suitable.

4.5.3.4 Pearl millet

Soil mapping unit 1, 4, 6 and 7 were marginally suitable for pearl millet cultivation (Table 13) with severe limitations of calcareousness, depth, pH and coarse fragments. Mapping unit 2, 3 and 5 were moderately suitable with moderate limitation of depth, pH, drainage, texture. Coarse fragments, erosion and CaCO_3 . Area of marginally and moderately suitable class for pearl millet was 114 and 278 ha, respectively.

4.5.3.5 Bengal gram

Mapping units no.1, 4, 6 and 7 were marginally suitable with severe limitations of depth, pH and coarse fragments. And mapping unit 2, 3 and 5 moderately suitable with moderate limitations of climate, erosion, pH, drainage and texture to bengal gram cultivation (Table 14). Area of marginally and moderately suitable class for bengal gram was 114 and 278 ha, respectively.

4.5.3.6 Pigeonpea

Mapping unit no. 7 were potentially unsuitable for pigeonpea cultivation with very severe limitation of depth and remaining mapping units 1, 4, 5 and 6 were marginally suitable due to severe limitations of depth, climate and pH (Table 15). Mapping unit 2 and 3 were moderately suitable for pigeonpea cultivation with moderate limitations of drainage, texture, depth, climate, erosion and pH properties. Area of marginally and moderately suitable class for pigeonpea was 167 and 216 ha, respectively and 9 ha was not suitable.

4.5.3.7 Green gram

Mapping unit no. 1, 4, 6 and 7 were marginally suitable for green gram cultivation with severe limitations of pH, depth and climate (Table 16). Mapping units 2, 3 and 5 are moderately suitable with moderate limitations of erosion pH, drainage, climate and texture. Area of marginally and moderately suitable class for green gram was 114 and 278 ha, respectively.

Table 8: Land capability classification of mapping units in Dambal-2 micro-watershed

Mapping units	Landform/topography (t)		Wetness (w)		Physical properties (s)				Chemical properties and fertility status (f)				LCC
	Slope	Erosion	Drainage	Flood	Depth	Surface stoniness	Texture	Coarse fragment	EC	OC	CEC	BS	
Dmb-1-m-B-2	I	III	II	I	I	I	III	I	I	III*	I	I	III t, s, f
Dmb-2-m-B-2	II	III	II	I	III	I	III	I	I	III*	I	I	III t, s, f
Dmb-3-m-B-2	II	III	II	I	II	I	III	I	I	III*	I	I	III t, s, f
Dmb-4-m-B-2	II	III	II	I	III	I	III	I	I	III*	I	I	III t, s, f
Dmb-5-m-B-2-g1	II	III	II	I	III	I	III	III	I	III*	I	I	III t, s, f
Dmb-6-f-B-2-g2	II	III	II	I	IV	I	III	IV	I	IV	I	I	IV s, f
Dmb-7-h-B-2-g2	II	III	II	I	IV	I	IV	IV	I	IV	I	I	IV s, f

Table 9: Land irrigability classification of mapping units in Dambal-2 micro-watershed

Mapping units	Landform/ topograph (t)		Wetness (w)		Physical properties (s)				Chemical properties and fertility status (f)			LICs and limitations	Suitability for irrigation
	Slope	Erosion	Drainage	Drainage outlets	Depth	Rock outcrops	Texture	Coarse fragment	EC	ESP	CaCO ₃		
Dmb-1-m-B-2	I	I	II	II	I	I	III	II	I	II	II	III (s)	S2 (s)
Dmb-2-m-B-2	II	I	II	II	I	I	III	III	I	II	II	III (s)	S2 (s)
Dmb-3-m-B-2	II	I	II	II	I	I	III	III	I	II	II	III (s)	S2 (s)
Dmb-4-m-B-2	II	I	II	II	II	I	III	III	I	II	II	III (s)	S2 (s)
Dmb-5-m-B-2-g1	II	I	II	II	II	I	III	III	I	II	II	III (s)	S2 (s)
Dmb-6-f-B-2-g2	II	I	II	II	II	I	III	IV	I	II	II	IV (s)	S3 (s)
Dmb-7-h-B-2-g2	II	I	II	II	III	I	II	IV	I	II	II	IV (s)	S3 (s)

Table 10: Soil site suitability for wheat

Mapping units	Climate (c)	Landform/ topography (t)		Wetness (w)	Physical properties (s)			Chemical properties and fertility status (f)				Overall Limitation	Suitability class
	MAT	Slope	Erosion hazard	Drainage	Depth	Texture	Coarse fragment	pH	EC	OC	ESP		
Dmb-1-m-B-2	S1	S1	S2	S1	S1	S2	S1	S3	S1	S2	S1	S3x1	S3 f
Dmb-2-m-B-2	S1	S1	S2	S1	S1	S2	S1	S3	S1	S2	S1	S3x1	S3 f
Dmb-3-m-B-2	S1	S1	S2	S1	S1	S2	S1	S3	S1	S2	S1	S3x1	S3 f
Dmb-4-m-B-2	S1	S1	S2	S1	S2	S2	S1	S3	S1	S2	S1	S3x1	S3 f
Dmb-5-m-B-2-g1	S1	S1	S2	S1	S2	S2	S2	S3	S1	S2	S1	S3x1	S3 f
Dmb-6-f-B-2-g2	S1	S1	S2	S1	S3	S2	S3	S2	S1	N1	S1	N1x1	N1 f
Dmb-7-h-B-2-g2	S1	S1	S2	S1	N2	S1	S3	S3	S1	N1	S1	N2x1	N2 s

Table 11: Soil site suitability for maize

Mapping units	Climate (C)		Landform/ topography (t)		wetness (w)	Physical properties (s)			Chemical properties and fertility status (f)					Overall Limitation	Suitability class
	RF	MAT	Slope	Erosion Hazard	Drainage	Depth	Texture	Coarse fragment	pH	EC	OC	CEC	ESP		
Dmb-1-m-B-2	S3	S1	S1	S2	S2	S1	S3	S1	S3	S1	S2	S1	S1	S3X3	S3 csf
Dmb-2-m-B-2	S3	S1	S1	S2	S2	S1	S3	S1	S3	S1	S2	S1	S1	S3X3	S3 csf
Dmb-3-m-B-2	S3	S1	S1	S2	S2	S1	S3	S1	S2	S1	S2	S1	S1	S3X2	S3 cs
Dmb-4-m-B-2	S3	S1	S1	S2	S2	S2	S3	S1	S3	S1	S2	S1	S1	S3X3	S3 csf
Dmb-5-m-B-2-g1	S3	S1	S1	S2	S2	S2	S3	S2	S3	S1	S2	S1	S1	S3X3	S3 csf
Dmb-6-f-B-2-g2	S3	S1	S1	S2	S2	S3	S1	S3	S3	S1	S3	S1	S1	S3X5	S3 csf
Dmb-7-h-B-2-g2	S3	S1	S1	S1	S2	S3	S3	S3	S3	S1	S3	S1	S1	S3X6	S3 csf

Table 12: Soil site suitability for sorghum

Mapping units	Climate (C)		Landform/ topography (t)		Wetness (w)	Physical properties (s)			Chemical properties and fertility status (f)						Overall Limitation	Suitability class
	RF	MAT	Slope	Erosion Hazard	Drainage	Depth	Texture	Coarse fragment	pH	EC	OC	CEC	CaCO ₃	ESP		
Dmb-1-m-B-2	S1	S2	S1	S2	S1	S1	S1	S1	S2	S1	S1	S1	S2	S2	S2X5	S2 ctf
Dmb-2-m-B-2	S1	S2	S1	S2	S1	S1	S1	S1	S2	S1	S1	S1	S1	S2	S2X4	S2ctf
Dmb-3-m-B-2	S1	S2	S1	S2	S1	S1	S1	S1	S2	S1	S1	S1	S1	S1	S2X3	S2ctf
Dmb-4-m-B-2	S1	S2	S1	S2	S1	S2	S1	S1	S2	S1	S1	S1	S2	S1	S2X5	S2ctf
Dmb-5-m-B-2-g1	S1	S2	S1	S2	S1	S2	S1	S2	S2	S1	S1	S1	S1	S1	S2X5	S2ctf
Dmb-6-f-B-2-g2	S1	S2	S1	S2	S1	S3	S1	S3	S2	S1	S2	S1	S2	S2	S3X2	S3 s
Dmb-7-h-B-2-g2	S1	S2	S1	S2	S1	N2	S2	S3	S2	S1	S2	S1	S1	S1	N2X1	N2 s

Table 13: Soil site suitability for bajra

Mapping units	Climate (C)		Landform/ topography (t)		wetness (w)	Physical properties (s)			Chemical properties and fertility status (f)				Overall Limitation	Suitability class
	RF	MAT	Slope	Erosion Hazard	Drainage	Depth	Texture	Coarse fragment	pH	EC	Free CaCO ₃	ESP		
Dmb-1-m-B-2	S1	S2	S1	S2	S2	S1	S2	S1	S3	S1	S3	S1	S3x2	S3f
Dmb-2-m-B-2	S1	S2	S1	S2	S2	S1	S2	S1	S2*	S1	S2	S1	S2x6	S2ctsf
Dmb-3-m-B-2	S1	S2	S1	S2	S2	S1	S2	S1	S2*	S1	S2	S1	S2x6	S2ctsf
Dmb-4-m-B-2	S1	S2	S1	S2	S2	S2	S2	S1	S3	S1	S3	S1	S3x2	S3f
Dmb-5-m-B-2-g1	S1	S2	S1	S2	S2	S2	S2	S2	S2*	S1	S2	S1	S2x8	S2ctsf
Dmb-6-f-B-2-g2	S1	S2	S1	S2	S2	S3	S2	S3	S2	S1	S3	S1	S3x2	S3sf
Dmb-7-h-B-2-g2	S1	S2	S1	S2	S2	S3	S1	S3	S3	S1	S2	S1	S3x3	S3sf

* - shifted to higher class due to potentially manageable property

MAT- mean annual temperature in °C

Table 14: Soil site suitability for bengal gram

Mapping units	Climate (C)		Landform/ topography (t)		wetness (w)	Physical properties (s)			Chemical properties and fertility status (f)			Overall Limitation.	Suitability class
	RF	MAT	Slope	Erosion Hazard	Drainage	Depth	Texture	Coarse fragment	pH	EC	ESP		
Dmb-1-m-B-2	S2	S1	S1	S2	S2	S1	S2	S1	S3*	S1	S1	S3x1	S3f
Dmb-2-m-B-2	S2	S1	S1	S2	S2	S1	S2	S1	S2*	S1	S1	S2x5	S2ctsf
Dmb-3-m-B-2	S2	S1	S1	S2	S2	S1	S2	S1	S2*	S1	S1	S2x5	S2ctsf
Dmb-4-m-B-2	S2	S1	S1	S2	S2	S2	S2	S1	S3*	S1	S1	S3x1	S3f
Dmb-5-m-B-2-g1	S2	S1	S1	S2	S2	S2	S2	S2	S2*	S1	S1	S2x7	S2ctsf
Dmb-6-f-B-2-g2	S2	S1	S1	S2	S2	S3	S2	S3	S3	S1	S1	S3x3	S3sf
Dmb-7-h-B-2-g2	S2	S1	S1	S2	S2	S3	S1	S3	S3	S1	S1	S3x3	S3sf

* - shifted to higher class due to potentially manageable property

MAT- mean annual temperature in °C

Table 15: Soil site suitability for tur or redgram

Mapping units	Climate (C)		Landform/ topography (t)		Wetness (w)	Physical properties (s)			Chemical properties and fertility status (f)			Overall Limitation	Suitability class
	RF	MAT	Slope	Erosion Hazard	Drainage	Depth	Texture	Coarse fragment	pH	EC	ESP		
Dmb-1-m-B-2	S2	S1	S1	S2	S2	S1	S2	S1	S3*	S1	S1	S3x1	S3f
Dmb-2-m-B-2	S2	S1	S1	S2	S2	S2	S2	S1	S2*	S1	S1	S2x6	S2ctsf
Dmb-3-m-B-2	S2	S1	S1	S2	S2	S1	S2	S1	S2*	S1	S1	S2x5	S2ctsf
Dmb-4-m-B-2	S2	S1	S1	S2	S2	S3	S2	S1	S3*	S1	S1	S3x3	S3sf
Dmb-5-m-B-2-g1	S2	S1	S1	S2	S2	S3	S2	S2	S3	S1	S1	S3x2	S3sf
Dmb-6-f-B-2-g2	S2	S1	S1	S2	S2	S3	S2	S3	S3	S1	S1	S3x3	S3sf
Dmb-7-h-B-2-g2	S2	S1	S1	S2	S2	N2	S1	S3	S3	S1	S1	N2x1	N2s

* - shifted to higher class due to potentially manageable property

MAT- mean annual temperature in °C

Table 16: Soil site suitability for green gram

Mapping units	Climate (C)		Landform/ topography (t)		wetness (w)	Physical properties (s)			Chemical properties and fertility status (f)			Overall Limitation	Suitability class
	RF	MAT	Slope	Erosion Hazard	Drainage	Depth	Texture	Coarse fragment	pH	EC	ESP		
Dmb-1-m-B-2	S2	S1	S1	S2	S2	S1	S2	S1	S3*	S1	S1	S3x1	S3f
Dmb-2-m-B-2	S2	S1	S1	S2	S2	S1	S2	S1	S2*	S1	S1	S2x5	S2ctsf
Dmb-3-m-B-2	S2	S1	S1	S2	S2	S1	S2	S1	S2*	S1	S1	S2x5	S2ctsf
Dmb-4-m-B-2	S2	S1	S1	S2	S2	S2	S2	S1	S3*	S1	S1	S3x1	S3f
Dmb-5-m-B-2-g1	S2	S1	S1	S2	S2	S2	S2	S2	S2	S1	S1	S2x7	S2ctsf
Dmb-6-f-B-2-g2	S2	S1	S1	S2	S2	S3	S2	S3	S3	S1	S1	S3x3	S3sf
Dmb-7-h-B-2-g2	S2	S1	S1	S2	S2	S3	S1	S3	S3	S1	S1	S3x3	S3sf

* - shifted to higher class due to potentially manageable property

MAT- mean annual temperature in °C

4.5.3.8 Groundnut

All mapping units of micro-watershed were marginally suitable for groundnut cultivation with severe limitations of depth, pH, texture and coarse fragments (Table 17). Area of marginally suitable class for groundnut was 392.0 ha.

4.5.3.9 Soybean

Mapping unit no. 1, 2, 3, 4 and 5 are moderately suitable with moderate limitations of wetness, pH, erosion and soil properties (Table 18). Remaining mapping units were marginally suitable with severe limitations of depth, pH and coarse fragments. Area of marginally and moderately suitable class for soybean was 53 and 339 ha, respectively

4.5.3.10 Sunflower

Mapping unit no 6 and 7 were not suitable with very severe limitations of depth and mapping units 1, 4 and 5 are marginally suitable for sunflower cultivation (Table 19) due to severe limitations of pH and depth. the remaining mapping units 2 and 3 are moderately suitable with moderate limitations of erosion, wetness, pH, texture, coarse fragments and depth. Area of marginally and moderately suitable class for sunflower was 123 and 216 ha, respectively and 53 ha were not suitable.

4.5.3.11 Sesamum

Mapping unit no 6 and 7 were not suitable with very severe limitations of coarse fragments and mapping units 1 and 4 are marginally suitable for Sesamum cultivation (Table 20) due to severe limitation of pH. Remaining mapping units 2, 3 and 5 are moderately suitable with moderate limitations of erosion, wetness, pH, texture, coarse fragments, climate, ESP, OC and depth. Area of marginally and moderately suitable class for Sesamum was 61 and 278 ha, respectively and 53 ha were not suitable.

4.5.3.12 Cotton

Mapping unit 6 and 7 were permanently not suitable due to very severe limitations of coarse fragments and remaining mapping units of 1, 4 and 5 were unsuitable for cotton cultivation (Table 21) with severe limitations of pH and coarse fragments. The mapping units 2 and 3 are marginally suitable with severe limitations of pH, OC and CaCO_3 . Area of permanently not suitable and temporarily not suitable class for cotton was 53 and 123 ha, respectively and 216 ha were marginally suitable.

4.5.3.13 Chilli

Soil mapping units of entire micro-watershed is marginally suitable for cultivation of chilli with moderate to severe limitations of climate, coarse fragments, depth and OC (Table 22). Area of marginally suitable class for chilli was 392 ha.

4.5.3.14 Sugarcane

Soil mapping units of 6 and 7 were not suitable for cultivation of Sugarcane with severe limitation of depth. Remaining mapping units 1, 2, 3, 4 and 5 are marginally suitable with severe limitation pH, climate and depth (Table 23). Area of marginally suitable class for Sugarcane was 339 ha and 53 ha were not suitable.

Table 17: Soil site suitability for groundnut

Mapping units	Climate (C)		Landform/ topography (t)		Wetness (w)	Physical properties (s)			Chemical properties and fertility status (f)				Overall Limitation.	Suitability class
	RF	MAT	Slope	Erosion Hazard	Drainage	Depth	Suitability class	Coarse fragment	pH	EC	ESP	CaCO ₃		
Dmb-1-m-B-2	S2	S1	S1	S2	S2	S1	S3	S1	S3	S1	S2	S2	S3x2	S3sf
Dmb-2-m-B-2	S2	S1	S1	S2	S2	S1	S3	S1	S3	S1	S2	S1	S3x2	S3sf
Dmb-3-m-B-2	S2	S1	S1	S2	S2	S1	S3	S1	S3	S1	S2	S1	S3x2	S3sf
Dmb-4-m-B-2	S2	S1	S1	S2	S2	S2	S3	S1	S3	S1	S2	S2	S3x2	S3sf
Dmb-5-m-B-2-g1	S2	S1	S1	S2	S2	S2	S3	S2	S3	S1	S2	S1	S3x2	S3sf
Dmb-6-f-B-2-g2	S2	S1	S1	S2	S2	S3	S3	S3	S2	S1	S2	S1	S3x3	S3s
Dmb-7-h-B-2-g2	S2	S1	S1	S2	S2	S3	S2	S3	S3	S1	S2	S1	S3x3	S3sf

Table 18: Soil site suitability for soybean

Mapping units	Climate (C)		Landform/ topography (t)		Wetness (w)	Physical properties (s)			Chemical properties and fertility status (f)			Overall Limitation.	Suitability class
	MAT	RF	Slope	Erosion Hazard	Drainage	Depth	Texture	Coarse fragment	pH	EC	ESP		
Dmb-1-m-B-2	S1	S1	S1	S1	S2	S1	S2	S1	S2*	S1	S2	S2x4	S2tsf
Dmb-2-m-B-2	S1	S1	S1	S2	S2	S1	S2	S1	S2*	S1	S2	S2x5	S2tsf
Dmb-3-m-B-2	S1	S1	S1	S2	S2	S1	S2	S1	S2*	S1	S1	S2x4	S2tsf
Dmb-4-m-B-2	S1	S1	S1	S2	S2	S2	S2	S1	S2*	S1	S2	S2x6	S2tsf
Dmb-5-m-B-2-g1	S1	S1	S1	S2	S2	S2	S2	S2	S2*	S1	S2	S2x7	S2tsf
Dmb-6-f-B-2-g2	S1	S1	S1	S2	S2	S3	S2	S3	S2	S1	S2	S3x2	S3s
Dmb-7-h-B-2-g2	S1	S1	S1	S2	S2	S3	S1	S3	S3	S1	S2	S3x3	S3sf

* - shifted to higher class due to potentially manageable property

MAT- mean annual temperature in °C

Table 19: Soil site suitability for sunflower

Mapping units	Climate (C)		Landform/ topography (t)		Wetness (w)	Physical properties (s)			Chemical properties and fertility status (f)			Overall Limitation	Suitability class
	RF	MAT	Slope	Erosion Hazard	Drainage	Depth	Texture	Coarse fragment	pH	EC	ESP		
Dmb-1-m-B-2	S1	S1	S1	S2	S2	S1	S2	S1	S3*	S1	S1	S3x1	S3f
Dmb-2-m-B-2	S1	S1	S1	S2	S2	S2	S2	S1	S2*	S1	S1	S2x5	S2tsf
Dmb-3-m-B-2	S1	S1	S1	S2	S2	S1	S2	S1	S2*	S1	S1	S2x4	S2tsf
Dmb-4-m-B-2	S1	S1	S1	S2	S2	S3	S2	S1	S3*	S1	S1	S3x2	S3sf
Dmb-5-m-B-2-g1	S1	S1	S1	S2	S2	S3	S2	S2	S3	S1	S1	S3x2	S3sf
Dmb-6-f-B-2-g2	S1	S1	S1	S2	S2	N2	S2	S3	S2	S1	S1	N2x1	N2s
Dmb-7-h-B-2-g2	S1	S1	S1	S2	S2	N2	S2	S3	S3	S1	S1	N2x1	N2s

* - shifted to higher class due to potentially manageable property

MAT- mean annual temperature in °C

Table 20: Soil site suitability for sesame

Mapping units	Climate (C)		Landform/ topography (t)		Wetness (w)	Physical properties (s)			Chemical properties and fertility status (f)				Overall Limitation.	Suitability class
	RF	MAT	Slope	Erosion Hazard	Drainage	Depth	Texture	Coarse fragment	pH	EC	ESP	OC		
Dmb-1-m-B-2	S1	S2	S1	S2	S2	S1	S2	S1	S3*	S1	S2	S2	S3x1	S3f
Dmb-2-m-B-2	S1	S2	S1	S2	S2	S1	S2	S1	S2*	S1	S2	S2	S2x7	S2ctsf
Dmb-3-m-B-2	S1	S2	S1	S2	S2	S1	S2	S1	S2*	S1	S2	S2	S2x7	S2ctsf
Dmb-4-m-B-2	S1	S2	S1	S2	S2	S2	S2	S1	S3*	S1	S2	S2	S3x1	S3f
Dmb-5-m-B-2-g1	S1	S2	S1	S2	S2	S2	S2	S2	S2*	S1	S2	S2	S2x9	S2ctsf
Dmb-6-f-B-2-g2	S1	S2	S1	S2	S2	S3	S2	N1	S3	S1	S2	S3	N1x1	N1s
Dmb-7-h-B-2-g2	S1	S2	S1	S2	S2	S3	S1	N1	S3	S1	S2	S3	N1x1	N1s

* - shifted to higher class due to potentially manageable property

MAT- mean annual temperature in °C

Table 21: Soil site suitability for cotton

Mapping units	Climate (C)		Landform/ topography (t)		Wetness (w)	Physical properties (s)			Chemical properties and fertility status (f)							Overall Limitation	Suitability class
	RF	MAT	Slope	Erosion Hazard	Drainage	Depth	Texture	Coarse fragment	pH	EC	OC	CEC	CaCO ₃	ESP	BS		
Dmb-1-m-B-2	S1	S1	S1	S2	S1	S1	S1	S1	N1	S1	S3	S1	N1	S1	S1	N1x2	N1f
Dmb-2-m-B-2	S1	S1	S2	S2	S1	S2	S1	S1	S3	S1	S3	S1	S3	S1	S1	S3x3	S3f
Dmb-3-m-B-2	S1	S1	S2	S2	S1	S1	S1	S1	S3	S1	S3	S1	S3	S1	S1	S3x3	S3f
Dmb-4-m-B-2	S1	S1	S2	S2	S1	S2	S1	S1	N1	S1	S3	S1	N1	S1	S1	N1x2	N1f
Dmb-5-m-B-2-g1	S1	S1	S2	S2	S1	S2	S1	N1	S3	S1	S3	S1	S3	S1	S1	N1x1	N1s
Dmb-6-f-B-2-g2	S1	S1	S2	S2	S1	S3	S1	N2	S3	S1	N1	S2	N1	S1	S1	N2x1	N2s
Dmb-7-h-B-2-g2	S1	S1	S2	S2	S1	N1	S3	N2	S3	S1	N1	S2	S3	S1	S1	N2x1	N2s

4.5.3.15 Mango

Mapping unit 4, 5, 6 and 7 were permanently not suitable for mango cultivation due to severe limitation of depth and mapping unit 1 was not suitable with severe limitation of pH and CaCO_3 . Remaining mapping units 2 and 3 are marginally suitable with severe limitations of depth, pH and CaCO_3 (Table 24). Area of permanently not suitable and potentially not suitable class for mango was 150 and 26 ha respectively and 127 ha were marginally suitable.

4.5.3.16 Sapota

Mapping unit 1, 4 and 5 are marginally suitable due to severe limitations of pH and depth. Mapping unit 2 and 3 are moderately suitable due to moderate limitations of drainage, pH, climate and soil properties, remaining mapping units are permanently not suitable with very severe limitations of depth for sapota cultivation (Table 25). Area of marginally and moderately suitable class for sapota was 123 and 216 ha, respectively and 53 ha were not suitable.

4.5.3.17 Guava

Mapping units 1, 2, 3, 4 and 5 are marginally suitable due to severe limitations of depth and pH. Mapping unit 6 and 7 are permanently not suitable due to severe limitation of depth (Table 26). Area of marginally and permanently not suitable class for guava was 339 and 53 ha, respectively.

4.5.3.18 Pomegranate

Soil mapping unit 6 and 7 are permanently not suitable for pomegranate cultivation due to very severe limitation of depth and mapping units 1, 2 and 3 are moderately suitable due to moderate limitations of drainage, depth, texture, climate, erosion and pH whereas 4 and 5 are marginally suitable severe limitations of depth and pH (Table 27). Area of marginally and moderately suitable class for pomegranate was 97 and 242 ha, respectively and 53 ha were not suitable.

4.5.3.19 Tamarind

Soil mapping unit 6 and 7 are permanently not suitable for tamarind cultivation due to very severe limitation of depth and coarse fragments. Remaining mapping units 1, 2, 3, 4 and 5 are marginally suitable due to severe limitations of depth and pH (Table 28). Area of marginally suitable class for tamarind was 339 ha and 53 ha were not suitable.

4.5.3.20 Rose

Mapping unit 1, 2 and 3 was moderately suitable with moderate limitations of drainage, erosion, texture, pH and depth. Other mapping units (4 and 5) were marginally suitable with severe limitations of depth and pH (Table 29). Remaining mapping units 6 and 7 were not suitable for rose cultivations due to very severe limitations of depth. Area of marginally and moderately suitable class for rose was 97 and 242 ha, respectively and 53 ha were not suitable.

4.5.3.21 Jasmine

Mapping units 1, 2, 3, 4 and 5 were moderately suitable owing to moderate limitations of temperature, erosion, depth drainage, texture, pH and coarse fragments. Mapping units 6 and 7 were marginally suitable with severe limitations of pH and depth (Table 30). Area of marginally and moderately suitable class for jasmine cultivation was 53 and 339 ha, respectively.

Table 22: Soil site suitability for chilli

Mapping units	Climate (C)		Landform/ topography (t)		Wetness (w)	Physical properties (s)			Chemical properties and fertility status (f)				Overall Limitation.	Suitability class
	RF	MAT	Slope	Erosion Hazard	Drainage	Depth	Suitabilit y class	Coarse fragment	pH	EC	OC	ESP		
Dmb-1-m-B-2	S3	S1	S1	S2	S2	S1	S2	S1	S3*	S1	S2	S2	S3x1	S3f
Dmb-2-m-B-2	S3	S1	S1	S2	S2	S1	S2	S1	S3	S1	S2	S2	S3x2	S3cf
Dmb-3-m-B-2	S3	S1	S1	S2	S2	S1	S2	S1	S3	S1	S2	S2	S3x1	S3c
Dmb-4-m-B-2	S3	S1	S1	S2	S2	S2	S2	S1	S3*	S1	S2	S2	S3x2	S3cf
Dmb-5-m-B-2-g1	S3	S1	S1	S2	S2	S2	S2	S2	S3	S1	S2	S2	S3x2	S3cf
Dmb-6-f-B-2-g2	S3	S1	S1	S2	S2	S3	S2	S3	S3	S1	S3	S2	S3x5	S3csf
Dmb-7-h-B-2-g2	S3	S1	S1	S2	S2	S3	S1	S3	S3	S1	S3	S2	S3x5	S3csf

* - shifted to higher class due to potentially manageable property

MAT- mean annual temperature in °C

Table 23: Soil site suitability for sugarcane

Mapping units	Climate (C)	Landform/topography (t)		Wetness (w)	Physical properties (s)			Chemical properties and fertility status (f)			Overall Limitation	Suitability class
	MAT	Slope	Erosion Hazard	Drainage	Depth	Texture	Coarse fragment	pH	EC	ESP		
Dmb-1-m-B-2	S3	S1	S2	S2	S1	S2	S1	S3	S1	S1	S3x2	S3 cf
Dmb-2-m-B-2	S3	S1	S2	S2	S2	S2	S1	S2	S1	S1	S3x1	S3 c
Dmb-3-m-B-2	S3	S1	S2	S2	S1	S2	S1	S2	S1	S1	S3x1	S3 c
Dmb-4-m-B-2	S3	S1	S2	S2	S3	S2	S1	S3	S1	S1	S3x3	S3 csf
Dmb-5-m-B-2-g1	S3	S1	S2	S2	S3	S2	S2	S2	S1	S1	S3x2	S3 cs
Dmb-6-f-B-2-g2	S3	S1	S2	S2	N2	S2	S3	S2	S1	S1	N2x1	N2 s
Dmb-7-h-B-2-g2	S3	S1	S2	S2	N2	S1	S3	S2	S1	S1	N2x1	N2 s

Table 24: Soil site suitability for mango

Mapping units	Climate (C)	Landform/topography (t)		Wetness (w)	Physical properties (s)			Chemical properties and fertility status (f)					Overall Limitation	Suitability class
	MAT	Slope	Erosion Hazard	Drainage	Depth	Texture	Coarse fragment	pH	EC	OC	CaCO ₃	ESP		
Dmb-1-m-B-2	S2	S1	S2	S2	S2	S2	S2	N1	S1	S2	N1	S1	N1x2	N1sf
Dmb-2-m-B-2	S2	S1	S2	S2	S3	S2	S2	S3	S1	S2	S3	S1	S3x3	S3sf
Dmb-3-m-B-2	S2	S1	S2	S2	S2	S2	S2	S3	S1	S2	S3	S1	S3x2	S3f
Dmb-4-m-B-2	S2	S1	S2	S2	N2	S2	S2	N1	S1	S2	N1	S1	N2x1	N2s
Dmb-5-m-B-2-g1	S2	S1	S2	S2	N2	S2	S3	S3	S1	S2	S3	S1	N2x1	N2s
Dmb-6-f-B-2-g2	S2	S1	S2	S2	N2	S2	N1	S2	S1	S3	N1	S1	N2x1	N2s
Dmb-7-h-B-2-g2	S2	S1	S2	S2	N2	S1	N1	S3	S1	S3	S3	S1	N2x1	N2s

Table 25: Soil site suitability for sapota

Mapping units	Climate (C)	Landform/ topography (t)		Wetness (w)	Physical properties (s)			Chemical properties and fertility status (f)			Over all limitation	Suitability class
	MAT	Slope	Erosion hazard	Drainage	Depth	Texture	Coarse fragment	pH	EC	ESP		
Dmb-1-m-B-2	S2	S1	S2	S2	S1	S2	S2	S3*	S1	S1	S3x1	S3f
Dmb-2-m-B-2	S2	S1	S2	S2	S2	S2	S2	S2*	S1	S1	S2x7	S2ctsf
Dmb-3-m-B-2	S2	S1	S2	S2	S2	S2	S2	S2*	S1	S1	S2x7	S2ctsf
Dmb-4-m-B-2	S2	S1	S2	S2	S3	S2	S2	S3*	S1	S1	S3x2	S3sf
Dmb-5-m-B-2-g1	S2	S1	S2	S2	S3	S2	S3	S3	S1	S1	S3x3	S3sf
Dmb-6-f-B-2-g2	S2	S1	S2	S2	N2	S2	N2	S3	S1	S1	N2x2	N2s
Dmb-7-h-B-2-g2	S2	S1	S2	S2	N2	S1	N2	S3	S1	S1	N2x2	N2s

* - shifted to higher class due to potentially manageable property

MAT- mean annual temperature in °C

Table 26: Soil site suitability for guava

Mapping units	Climate (C)	Landform/topography (t)		Wetness (w)	Physical properties (s)			Chemical properties and fertility status (f)				Over all limitation	Suitability class
	MAT	Slope	Erosion Hazard	Drainage	Depth	Texture	Coarse fragment	pH	EC	CaCO ₃	ESP		
Dmb-1-m-B-2	S2	S1	S2	S2	S1	S2	S2	S3*	S1	S3	S1	S3x2	S3f
Dmb-2-m-B-2	S2	S1	S2	S2	S2	S2	S2	S3*	S1	S2	S1	S3x1	S3f
Dmb-3-m-B-2	S2	S1	S2	S2	S1	S2	S2	S3*	S1	S2	S1	S3x1	S3f
Dmb-4-m-B-2	S2	S1	S2	S2	S3	S2	S2	S3*	S1	S3	S1	S3x3	S3sf
Dmb-5-m-B-2-g1	S2	S1	S2	S2	S3	S2	S3	S3*	S1	S2	S1	S3x3	S3sf
Dmb-6-f-B-2-g2	S2	S1	S2	S2	N2	S2	N2	S3	S1	S3	S1	N2x2	N2s
Dmb-7-h-B-2-g2	S2	S1	S2	S2	N2	S1	N2	N1	S1	S2	S1	N2x2	N2s

* - shifted to higher class due to potentially manageable property

MAT- mean annual temperature in °C

Table 27: Soil site suitability for pomegranate

Mapping units	Climate (C)	Landform/ topography (t)		Wetness (w)	Physical properties (s)			Chemical properties and fertility status (f)		Over all limitation	Suitability class
	MAT	Slope	Erosion hazard	Drainage	Depth	Texture	Coarse fragment	pH	EC		
Dmb-1-m-B-2	S2	S1	S2	S2	S1	S2	S1	S2*	S1	S2x5	S2ctsf
Dmb-2-m-B-2	S2	S1	S2	S2	S2	S2	S1	S2*	S1	S2x6	S2ctsf
Dmb-3-m-B-2	S2	S1	S2	S2	S1	S2	S1	S2*	S1	S2x5	S2ctsf
Dmb-4-m-B-2	S2	S1	S2	S2	S3	S2	S1	S3	S1	S3x2	S3sf
Dmb-5-m-B-2-g1	S2	S1	S2	S2	S3	S2	S2	S3	S1	S3x2	S3sf
Dmb-6-f-B-2-g2	S2	S1	S2	S2	N2	S2	S3	S2	S1	N2x1	N2s
Dmb-7-h-B-2-g2	S2	S1	S2	S2	N2	S1	S3	S3	S1	N2x1	N2s

* - shifted to higher class due to potentially manageable property

MAT- mean annual temperature in °C

Table 28: Soil site suitability for tamarind

Mapping units	Climate (C)	Landform/topography (t)		Wetness (w)	Physical properties (s)			Chemical properties and fertility status (f)				Over all limitation	Suitability class
	MAT	Slope	Erosion Hazard	Drainage	Depth	Texture	Coarse fragment	pH	EC	CaCO ₃	ESP		
Dmb-1-m-B-2	S2	S1	S2	S2	S1	S2	S2	S3*	S1	S3	S1	S3x2	S3f
Dmb-2-m-B-2	S2	S1	S2	S2	S2	S2	S2	S3*	S1	S2	S1	S3x1	S3f
Dmb-3-m-B-2	S2	S1	S2	S2	S1	S2	S2	S3*	S1	S2	S1	S3x1	S3f
Dmb-4-m-B-2	S2	S1	S2	S2	S3	S2	S2	S3*	S1	S3	S1	S3x3	S3sf
Dmb-5-m-B-2-g1	S2	S1	S2	S2	S3	S2	S3	S3*	S1	S2	S1	S3x3	S3sf
Dmb-6-f-B-2-g2	S2	S1	S2	S2	N2	S2	N2	S3	S1	S3	S1	N2x2	N2s
Dmb-7-h-B-2-g2	S2	S1	S2	S2	N2	S1	N2	N1	S1	S2	S1	N2x2	N2s

* - shifted to higher class due to potentially manageable property

MAT- mean annual temperature in °C

Table 29: Soil site suitability of rose

Mapping units	Climate (C)	Landform/topography (t)		Wetness (w)	Physical properties (s)			Chemical properties and fertility status (f)			Over all limitation	Suitability class
	MAT	Slope	Erosion Hazard	Drainage	Depth	Texture	Coarse fragment	pH	EC	ESP		
Dmb-1-m-B-2	S1	S1	S1	S2	S1	S2	S1	S2*	S1	S1	S2x3	S2tsf
Dmb-2-m-B-2	S1	S1	S2	S2	S2	S2	S1	S2*	S1	S1	S2x5	S2tsf
Dmb-3-m-B-2	S1	S1	S2	S2	S1	S2	S1	S2*	S1	S1	S2x4	S2tsf
Dmb-4-m-B-2	S1	S1	S2	S2	S3	S2	S1	S3	S1	S1	S3x2	S3sf
Dmb-5-m-B-2-g1	S1	S1	S2	S2	S3	S2	S2	S3	S1	S1	S3x2	S3sf
Dmb-6-f-B-2-g2	S1	S1	S2	S2	N2	S2	S3	S2	S1	S1	N2x1	N2s
Dmb-7-h-B-2-g2	S1	S1	S2	S2	N2	S1	S3	S3	S1	S1	N2x1	N2s

* - shifted to higher class due to potentially manageable property

MAT- mean annual temperature in °C

Table 30: Soil site suitability for jasmine

Mapping units	Climate (C)	Landform/topography (t)		Wetness (w)	Physical properties (s)			Chemical properties and fertility status (f)			Over all limitation	Suitability class
	MAT	Slope	Erosion Hazard	Drainage	Depth	Texture	Coarse fragment	pH	EC	ESP		
Dmb-1-m-B-2	S2	S1	S1	S2	S1	S2	S1	S2*	S1	S1	S2x4	S2ctsf
Dmb-2-m-B-2	S2	S1	S2	S2	S1	S2	S1	S2*	S1	S1	S2x5	S2ctsf
Dmb-3-m-B-2	S2	S1	S2	S2	S1	S2	S1	S2*	S1	S1	S2x5	S2ctsf
Dmb-4-m-B-2	S2	S1	S2	S2	S2	S2	S1	S2*	S1	S1	S2x6	S2ctsf
Dmb-5-m-B-2-g1	S2	S1	S2	S2	S2	S2	S2	S2*	S1	S1	S2x7	S2ctsf
Dmb-6-f-B-2-g2	S2	S1	S2	S2	S3	S2	S3	S2	S1	S1	S3x2	S3s
Dmb-7-h-B-2-g2	S2	S1	S2	S2	S3	S1	S3	S3	S1	S1	S3x3	S3sf

* - shifted to higher class due to potentially manageable property

MAT- mean annual temperature in °C

4.6 Soil fertility status of the micro-watershed

4.6.1 Soil reaction

The pH values of surface soil samples ranged from 7.06 to 9.27 and their mean and standard deviation were 8.67 and 0.38 (Table 31), respectively and coefficient of variance was 4.43 per cent. Most of the study area was under strongly alkaline.

4.6.2 Electrical conductivity

The EC values of surface soil samples ranged from 0.1 to 0.73 dS m⁻¹, their mean and standard deviation values were 0.24 and 0.13 respectively and coefficient of variance was 57.80 per cent (Table 31). The entire study area was free from salinity hazard or non saline in nature.

4.6.3 Organic carbon

The organic carbon content of surface soil samples ranged from 0.4 to 7.6 g kg⁻¹ (Table 31). The mean and standard deviation were 0.31 and 0.17, respectively and coefficient of variance was 54.86 per cent. All the soils of the study area fall under low to high category.

4.6.4 Available nitrogen

The available nitrogen status in surface soil samples ranged from 91.7 to 208.6 kg ha⁻¹ with mean and standard deviation of 138.1 and 25.12 (Table 32), respectively and coefficient of variance was 18.19 per cent. All the study area was low in available nitrogen status of micro-watershed.

4.6.5 Available phosphorus

The available phosphorus content in surface soil samples ranged from 16.16 to 64.63 kg ha⁻¹ with mean and standard deviation of 38.73 and 12.79, respectively and coefficient of variance was 33.03 per cent (Table 32). Entire micro-watershed area was medium in available phosphorus status.

4.6.6 Available potassium

The available potassium content in surface soil samples ranged from 263.1 to 817.1 kg ha⁻¹ with mean and standard deviation of 611.3 and 124.65, respectively and coefficient of variance was 20.39 per cent (Table 32). The area of available potassium under medium to high category was found to be 392 ha.

4.6.7 Available sulphur

The available sulphur content in surface soil samples ranged from 4.24 to 33.56 kg ha⁻¹ with mean and standard deviation of 14.29 and 7.23 (Table 33), respectively and coefficient of variance was 50.61 per cent. All the study area was low to medium in available sulphur. The area of available sulphur under low to medium category was found to be 3 and 389 ha respectively.

4.6.8 Exchangeable calcium and magnesium

The exchangeable calcium content in surface soil samples ranged from 12.1 to 39.9 cmol (p⁺) per kg with mean and standard deviation of 22.4 and 6.15 respectively and coefficient of variance was 27.51 per cent. All the study area was sufficient in exchangeable calcium.

The exchangeable magnesium content in surface soil samples ranged from 6.4 to 22.0 cmol (p⁺) per kg with mean and standard deviation of 13.9 and 4.52, respectively and coefficient of variance was 32.54 per cent (Table 33). All the study area were sufficient in exchangeable magnesium.

Table 31: Chemical properties of the soils of Dambal-2 micro-watershed

Sl. No.	pH	EC (dS m ⁻¹)	OC (g kg ⁻¹)	Sl. No.	pH	EC (dS m ⁻¹)	OC (g kg ⁻¹)
01	8.96	0.52	1.90	36	8.86	0.28	1.60
02	9.03	0.36	1.00	37	8.71	0.48	1.90
03	8.06	0.24	2.70	38	8.61	0.32	4.30
04	8.96	0.22	0.80	39	8.35	0.29	3.30
05	8.90	0.27	1.40	40	7.06	0.1	2.90
06	9.07	0.18	2.10	41	8.75	0.11	2.30
07	8.89	0.28	4.50	42	8.71	0.13	3.90
08	8.96	0.56	3.70	43	8.47	0.15	2.90
09	8.98	0.25	3.30	44	8.89	0.16	3.70
10	9.00	0.13	3.90	45	8.17	0.12	4.30
11	8.78	0.12	5.10	46	8.24	0.38	3.30
12	8.77	0.13	2.90	47	8.34	0.11	5.10
13	8.88	0.14	2.50	48	8.33	0.17	4.50
14	8.86	0.19	1.90	49	8.51	0.15	6.80
15	9.06	0.22	0.60	50	8.95	0.18	1.90
16	8.99	0.19	4.70	51	8.29	0.15	5.30
17	8.11	0.18	2.70	52	8.71	0.17	4.30
18	8.91	0.25	2.50	53	8.26	0.15	0.80
19	8.98	0.56	1.00	54	8.10	0.22	1.00
20	9.09	0.25	5.40	55	8.43	0.31	0.40
21	8.81	0.17	4.90	56	8.65	0.6	1.20
22	9.17	0.45	0.40	57	9.20	0.13	4.50
23	8.88	0.24	1.60	58	9.27	0.2	6.80
24	9.03	0.23	3.10	59	8.49	0.16	4.10
25	9.02	0.26	1.80	60	9.09	0.26	1.80
26	9.05	0.33	4.90	61	8.58	0.12	2.30
27	8.50	0.73	2.70	62	8.64	0.26	7.60
28	8.29	0.23	1.80	63	8.44	0.12	5.40
29	8.10	0.13	5.30	64	8.70	0.13	0.40
30	8.43	0.11	5.40	65	8.76	0.15	1.90
31	8.55	0.56	4.90	Mean	8.67	0.24	3.10
32	8.64	0.14	3.90	SD	0.38	0.13	1.70
33	8.55	0.24	3.10	Range	7.06- 9.27	0.1- 0.73	0.40-7.60
34	9.10	0.52	1.90	CV(%)	4.43	57.80	54.86
35	7.91	0.36	1.00				

Table 32: Available major nutrient status of the soils of Dambal-2 micro-watershed

Sl. No.	Nitrogen (kg ha ⁻¹)	Phosphorus (P ₂ O ₅) (kg ha ⁻¹)	Potassium (K ₂ O) (kg ha ⁻¹)	Sl. No.	Nitrogen (kg ha ⁻¹)	Phosphorus (P ₂ O ₅) (kg ha ⁻¹)	Potassium (K ₂ O) (kg ha ⁻¹)
01	126.0	45.40	506.2	36	112.7	40.01	626.0
02	119.0	30.78	437.6	37	156.8	49.24	757.2
03	208.6	50.78	507.3	38	190.4	59.25	747.5
04	103.6	24.62	414.2	39	142.1	43.86	720.5
05	114.1	53.86	612.8	40	119.0	23.08	318.3
06	135.1	45.40	503.1	41	147.7	21.54	662.0
07	106.4	26.16	522.3	42	137.9	26.16	557.3
08	175.7	44.63	653.6	43	141.4	23.85	465.3
09	196.7	47.71	607.7	44	163.1	19.24	638.4
10	117.6	58.48	660.9	45	172.2	48.47	519.8
11	135.1	16.16	481.2	46	131.6	26.93	513.8
12	145.6	51.55	792.0	47	144.2	58.48	795.9
13	107.8	47.71	737.10	48	145.6	57.71	381.9
14	91.7	21.54	587.0	49	184.1	64.63	502.8
15	124.6	24.62	688.4	50	153.3	43.86	395.4
16	116.2	37.70	749.7	51	141.4	50.01	526.8
17	138.6	63.86	633.2	52	151.2	37.70	584.4
18	112.0	26.93	563.1	53	133.0	36.16	263.1
19	138.6	32.32	797.4	54	167.3	39.24	635.7
20	109.9	22.31	630.3	55	119.7	33.09	603.6
21	139.3	23.85	757.8	56	122.5	48.47	549.2
22	153.3	23.08	767.0	57	109.9	21.54	387.9
23	137.9	37.70	801.6	58	123.9	23.85	657.8
24	149.8	23.85	515.3	59	121.1	49.24	730.5
25	172.2	56.17	579.3	60	98.0	27.70	630.0
26	153.3	45.40	570.3	61	143.5	31.55	663.6
27	112.7	50.78	746.0	62	126.7	34.62	598.5
28	177.1	36.93	710.9	63	133.7	43.09	650.6
29	100.1	43.09	761.4	64	110.6	26.93	687.9
30	161.0	37.70	631.2	65	139.3	36.93	602.9
31	119.0	35.39	764.1	Mean	138.1	38.73	611.3
32	147.0	45.40	633.6	SD	25.12	12.79	124.65
33	153.3	53.09	817.1	Range	91.7-208.6	16.16-64.63	263.1-817.1
34	126.0	27.70	633.2	CV(%)	18.19	33.03	20.39
35	119.0	58.48	589.8				

Table 33: Available secondary nutrients status of the soils of Dambal-2 micro-watershed

Sl. No.	Calcium [c mol (p ⁺) kg ⁻¹]	Magnesium [c mol (p ⁺) kg ⁻¹]	Sulphur (kg ha ⁻¹)	Sl. No.	Calcium [c mol (p ⁺) kg ⁻¹]	Magnesium [c mol (p ⁺) kg ⁻¹]	Sulphur (kg ha ⁻¹)
01	25.0	18.0	9.26	36	25.9	12.3	20.06
02	37.4	21.6	17.74	37	25.9	16.2	18.90
03	34.0	22.0	33.56	38	25.9	9.30	7.72
04	33.0	21.5	16.97	39	18.9	8.60	19.67
05	25.5	18.0	13.89	40	18.92	6.88	8.49
06	30.1	21.3	13.12	41	19.0	10.5	8.10
07	32.0	18.0	12.73	42	20.0	10.0	8.87
08	33.5	19.5	16.59	43	16.6	7.80	10.03
09	27.3	16.7	20.06	44	12.5	6.40	18.13
10	25.2	16.3	7.33	45	12.7	7.20	22.37
11	23.9	14.5	11.96	46	15.1	6.40	11.19
12	24.6	18.9	8.49	47	16.7	8.70	8.87
13	39.9	15.6	12.34	48	20.1	11.2	9.26
14	24.8	14.0	11.96	49	19.3	11.2	8.87
15	29.3	15.6	14.27	50	16.8	7.80	30.09
16	25.5	13.9	18.13	51	12.6	6.90	6.94
17	25.6	15.8	8.10	52	15.6	8.90	14.66
18	22.3	16.2	7.72	53	15.4	10.50	8.49
19	21.1	16.1	11.19	54	13.8	7.70	5.40
20	20.8	18.0	13.12	55	12.1	6.80	6.56
21	22.9	18.2	24.69	56	20.6	9.90	10.42
22	22.1	17.3	16.59	57	18.7	10.2	14.27
23	21.9	19.5	26.62	58	18.6	6.90	26.62
24	22.2	16.5	13.50	59	19.6	12.0	5.40
25	26.4	17.9	11.19	60	16.0	12.5	33.56
26	29.5	19.4	14.66	61	22.1	13.4	4.24
27	22.2	17.6	19.67	62	24.0	14.5	11.57
28	22.4	16.3	30.09	63	23.9	15.6	7.33
29	22.0	19.8	17.74	64	21.3	15.2	11.19
30	17.6	12.1	30.09	65	15.9	13.5	8.49
31	18.1	9.90	11.19	Mean	22.4	13.90	14.29
32	14.6	12.0	16.97	SD	6.15	4.52	7.29
33	32.3	19.2	5.40	Range	12.1-39.9	6.4-22.0	4.24-33.56
34	17.9	12.9	7.72	CV(%)	27.51	32.54	50.61
35	25.9	18.9	18.52				

4.6.9 Available micronutrient status

4.6.9.1 Available zinc

The available zinc content in surface soil samples ranged from 0.11 to 1.97 mg kg⁻¹ with mean and standard deviation of 0.54 and 0.24 (Table 34), respectively and coefficient of variance was 45.61 per cent. The study area was deficient and sufficient in zinc with 258.0 and 134.0 ha, respectively

4.6.9.2 Available iron

The available iron content in surface soil samples ranged from 1.59 to 4.78 mg kg⁻¹ with mean and standard deviation of 3.32 and 0.70 (Table 34), respectively and coefficient of variance was 21.28 per cent. All the study area were deficient in available iron.

4.6.9.3 Available copper

The available copper content in surface soil samples ranged from 0.24 to 2.14 mg kg⁻¹ with mean and standard deviation of 1.18 and 0.40, respectively and coefficient of variance was 34.61 per cent (Table 34). All the study area was sufficient in available copper.

4.6.9.4 Available manganese

The available manganese content in surface soil samples ranged from 1.61 to 8.23 mg kg⁻¹ with mean and standard deviation of 3.66 and 1.24, respectively and coefficient of variance was 33.92 per cent (Table 34). All the study area was sufficient in available manganese status.

4.6.9.5 Available boron

The available boron content in surface soil samples ranged from 0.20 to 1.10 mg kg⁻¹ with mean and standard deviation of 0.48 and 0.22, respectively and coefficient of variance was 43.75 per cent (Table 34). All the study area was low to medium in available boron status, 299 and 93 ha, respectively.

Table 34: Available micronutrient status of the soils of Dambal-2 micro-watershed (mg kg⁻¹)

Sl. No.	Fe	Mn	Zn	Cu	B	Sl. No.	Fe	Mn	Zn	Cu	B
01	4.15	3.48	0.36	0.80	0.40	36	3.92	3.37	0.59	1.72	1.10
02	4.25	2.57	0.43	0.81	0.30	37	3.30	3.08	0.51	1.70	0.90
03	4.38	2.10	0.24	0.79	0.40	38	2.47	3.74	0.57	1.60	0.40
04	3.30	2.86	0.39	0.83	0.90	39	4.70	5.22	0.39	1.36	0.60
05	2.96	2.20	0.23	0.51	0.40	40	1.59	3.88	0.47	1.43	0.40
06	3.43	2.41	0.34	0.63	0.50	41	3.62	3.78	0.52	1.17	0.30
07	3.24	1.61	0.11	0.24	0.30	42	2.96	4.86	0.50	1.21	0.50
08	2.66	1.98	0.32	0.43	0.40	43	3.86	4.82	0.72	2.14	0.70
09	3.71	2.78	0.22	0.82	0.50	44	3.96	4.23	0.57	1.83	0.40
10	3.90	2.94	0.31	0.71	0.30	45	2.65	3.57	0.49	0.71	0.70
11	2.37	1.80	0.30	0.96	0.50	46	3.57	3.88	0.61	0.71	0.30
12	4.58	1.96	0.28	0.90	0.40	47	3.32	5.44	0.53	1.76	0.40
13	2.26	2.86	0.37	1.06	0.80	48	4.35	4.68	0.64	1.77	0.30
14	2.51	3.17	0.39	1.03	0.40	49	3.29	3.33	1.97	1.71	0.60
15	3.29	3.38	0.90	0.92	0.30	50	2.51	3.78	0.75	1.72	0.30
16	3.67	3.16	0.62	0.79	0.50	51	4.21	8.23	0.53	1.49	0.40
17	2.38	3.38	0.36	0.72	0.40	52	3.15	7.47	0.76	1.31	0.50
18	2.96	3.46	0.41	0.77	0.60	53	3.49	4.22	0.39	0.83	0.80
19	3.64	3.33	0.46	1.32	0.40	54	3.62	5.43	0.54	0.84	0.40
20	2.87	3.45	0.43	0.88	0.30	55	3.29	6.24	0.47	1.32	0.60
21	4.34	3.48	0.51	1.04	0.50	56	2.46	6.99	0.77	1.31	0.90
22	3.50	3.67	0.48	0.96	0.90	57	3.01	4.61	0.42	1.05	0.60
23	2.70	3.06	0.53	1.16	0.50	58	3.70	4.35	0.53	1.04	0.80
24	3.36	3.36	0.56	1.20	0.20	59	1.97	3.08	0.62	1.10	0.40
25	2.34	3.50	0.65	1.37	0.40	60	2.37	3.79	0.75	1.11	0.50
26	3.46	2.85	0.63	1.40	0.50	61	3.92	2.94	0.32	1.10	0.60
27	3.23	2.58	0.46	0.93	0.80	62	3.16	3.59	0.41	1.32	0.70
28	4.78	2.73	0.58	0.94	1.10	63	3.83	2.94	0.38	1.29	0.50
29	2.25	4.49	0.89	1.40	0.40	64	2.83	3.75	0.55	1.19	0.80
30	3.68	3.97	0.76	1.33	0.60	65	3.83	2.65	0.55	1.27	0.80
31	2.56	3.69	0.66	1.89	0.50	Mean	3.32	3.66	0.54	1.18	0.52
32	3.90	3.47	0.63	1.88	0.40	SD	0.70	1.24	0.24	0.40	0.22
33	4.18	3.25	0.80	1.89	0.90	Range	1.59-4.78	1.61-8.23	0.11-1.97	0.24-2.14	0.20-1.10
34	3.37	3.50	0.75	1.63	0.50	CV(%)	21.28	33.92	45.61	34.61	43.75
35	2.85	3.85	0.74	1.71	0.60						

5. DISCUSSION

The most important basic natural resource that determines the ultimate sustainability of any agricultural system is the soil. The inherent ability of soils to supply nutrients for crop growth and maintenance of soil physical conditions to optimize crop yields is the most important component of soil fertility that virtually determines the productivity of agricultural system. A thorough and proper understanding of morphological, physical and chemical characteristics of soils gives greater insight of dynamics of the soils. All the above information could be available through systematic characterization and classification of soils of an area. Hence, in the present study eleven representative pedons were selected in Dambal-2 micro-watershed of Gadag district of Karnataka covering different physiographic units. Pedons were examined systematically for morphological features in the field and horizon wise samples were analyzed in the laboratory for physical and physico-chemical properties. Based on these characters, the soils were classified up to series level as per Keys to Soil Taxonomy (Anon., 2014). Land capability classes and sub-classes were also assessed for these soils. Further, the suitability of these soils were evaluated for growing different crops. The results obtained in the present study are discussed below.

5.1 Morphological features

5.1.1 Depth

Soil depth is a prime essential for the proper growth and development of crop roots. The mapping units of the micro-watershed ranged from shallow to very deep in depth.

The depth of pedons 3, 9 and 11 were shallow (25-50 cm) in depth. The pedons 4 and 10 were moderately shallow (50- 75 cm). Whereas, the pedons 2 and 6 were moderately deep (75-100 cm). Remaining 5, 7 and 8 pedons are (100-150 cm) deep in depth, pedon 1 was very deep in depth (>150 cm). The soil depth mainly depends on land forms or physiography. Deep soils were reported to occur near to valleys compared to upland land forms. The fact that two low lying soil mapping units having deep soils has further strengthened this finding. Similar results were reported by Denis and Patil (2015) in Singhanalli-Bogur micro-watershed, Karnataka. Soils of the semi arid region especially upland are characterized by shallow depth due to limitation of moisture for pedogenesis or weathering. Also similar observations were made by Vinay (2007) in Banapur micro-watershed of Koppal.

5.1.2 Soil colour

The rating of soil colour was high, medium and low in the mapping units. All the black soil pedons exhibited hue of 10 YR, except pedons 8, 9 and 11 (7.5 YR) throughout the profile and the dominant colour was dark grayish brown to very dark grayish brown due to the clay-humus complex in the presence of lime (Singh, 1956). Pedons at higher positions were dark brown to brown while those on lower locations were black which also indicated the gradation in the colour from higher topographic positions to the lower topographic units. Similar observations were made by Mini *et al.* (2007) for the soils of coastal agro-ecosystem of Karnataka. And Madhan Mohan (2008) and Pulakeshi *et al.* (2014).

5.1.3 Texture

Soil texture has profound effects on water holding capacity, aeration and porosity, hydraulic conductivity, compaction potential, resistance to root penetration and nutrient holding capacity of soil. All the pedons were clay in texture except pedon 11 (sandy clay loam) both in surface and subsurface and the increase in clay content through the soil depth was observed. It could be attributed to processes like illuviation of the finer fraction to the lower depth. Similar results were also recorded by (McGarry, 2005; Denis and Patil, 2015) and by Sumithra *et al.* (2013) in soils of Timanhal micro-watershed, Kushtagi taluk of Karnataka.

5.1.4 Structure

Structure is considered as a key factor of soil as its ability to support plant and animal life and moderate environmental quality (Bronick and Lal, 2005). Soil structure reflects the way in which individual soil particles clump, bind or aggregate together and measured as type, size and grade (McGarry, 2005). Structure in black soil pedons was predominantly moderate to strong medium sub-angular blocky in the surface and subhorizons. Murthy *et al.* (1972) also observed sub-angular blocky structure in the soils of Tungabhadra catchment. Sub-angular to angular blocky structure in the sub-soil horizons was due to slickensides formation in these soils. The dominant structure observed was moderate, medium, sub-angular blocky in soils of Timanhal micro-watershed, Kushtagi taluk of Karnataka by Sumithra *et al.* (2013).

5.1.5 Consistency

The consistency of all pedons varied from slightly hard to hard, friable to firm and slightly sticky, slightly plastic to very sticky, very plastic in dry, moist and wet ranges, this might be due to increased clay content in deeper horizons along with decreasing altitude of pedons. Pedon 3, 8 and 9 were dominated by coarse fragments so was moderately sticky and moderately plastic when wet. Similar findings were also reported by Thangasamy *et al.* (2005) in black soils of in Sivagiri micro-watershed of Chittoor district in Andhra Pradesh and Manojkumar (2011) in Bastwad micro-watershed on basalt parent rock in northern transition zone of Karnataka.

5.2 Physical properties

5.2.1 Particle size distribution

A perusal of the data on particle size distribution in soils revealed that all the soil pedons are clayey except pedon 11 (were fine loamy) in texture according to the USDA textural triangle. The clay and silt content varied with depth in most of the soils.

In black soil pedons, the increase in clay content through the soil depth observed in the study area could be attributed to several processes like illuviation of the finer fraction to the lower depth (Dasog, 1975 and Krishnamoorthy and Govindarajan, 1977). Similar trend was also observed by Parvatappa (1981) and Doddamani *et al.* (1994) in *Vertisols* of the Upper Krishna Command Area of Karnataka and Balpande *et al.* (1996) in the degraded *Vertisols* of the Purna valley of Maharashtra. Sand content was low compared to silt in all the pedons. High clay and silt content in some of the pedons of study area may be due to their formation on the transported parent material.

Silt and sand content of all pedons exhibited an irregular trend with depth. This might be due to variation in weathering of parent material. These results were in agreement with the findings of Naidu (2002), who observed an irregular trend in silt content with depth in sugarcane growing soils of Karnataka. Similar results were also reported by Arun Kumar *et al.* (2002) and Nagendra (2015).

5.2.2 Maximum water holding capacity

Water holding capacity of various pedons ranged from 45.42 to 65.40 per cent. These differences were due to the variation in clay and organic carbon content of the pedons. Similar results were reported by Ravikumar (2006) in soils of Malaprabha command of Karnataka and Thangasamy *et al.* (2005) in soils of Sivagiri micro-watershed in Chittoor district of Andhra Pradesh.

5.2.3 Field capacity

Field capacity of various pedons ranged from 22.70 to 32.70 per cent. These differences were due to the variation in clay and organic carbon content of the pedons. These results are in line with Thangasamy *et al.* (2005) observations in soils of Sivagiri micro-watershed in Chittoor district of Andhra Pradesh and Amara *et al.* (2015)

5.2.4 Bulk density

In black soil pedons, the bulk density varied from 1.28 to 1.48 mg per m³. In general, the bulk density of the lower solum was more than the upper. This could be attributed to clogging of pores by dispersed clays in sub-soil layers (Bharambe *et al.*, 1984 and Mathur and Mahendra, 1994) and reduction of organic carbon with depth. Similar results were quoted by Marathe *et al.* (2003) in mandarin orchards of Nagpur and Pulakeshi *et al.* (2014) for the soils of Mantagani village of Haveri district in Karnataka.

5.3 Chemical properties

5.3.1 Soil reaction (pH)

In black soil pedons, pH ranged from neutral to strongly alkaline. High pH in black soil pedons was due to their calcareous nature and the accumulation of bases in the solum as they were poorly leached (Satyanarayana and Biswas, 1970). Increase in soil pH with depth was evident in some of the pedons, which may be ascribed to increasing content of exchangeable and soluble sodium and calcium (Gundlur, 1991). pH increased with depth in both black and red soil pedons as the bases increased with depth. This increase in soil reaction down the slope could be due to leaching of bases from higher topography and getting deposited at lower elevations (Sitanggang *et al.*, 2006).

The lower pH value in surface horizons is mainly due to removal of bases by runoff water. The C horizon of all the pedons had higher pH which could be attributed to the accumulation of bases. Similar types of result were reported by Thangasamy *et al.* (2005) and Ravikumar (2006).

The KCl pH values were lower than the water pH values and the difference between KCl-pH and H₂O-pH values with large negative value (more than -0.5) indicated a high negative surface charge density in these soils (Sitanggang *et al.*, 2006).

5.3.2 Electrical conductivity (EC)

Electrical conductivity was more in black soil pedons, which indicated that black soil pedons were less leached. In soils EC ranged from 0.13 to 0.69 and 0.11 to 0.54 dS m⁻¹ in subsurface and surface horizon respectively, indicating non-saline nature of soils. These soils did not show any specific relationship of EC with depth. This may be due to free drainage conditions, which removed the released bases by the percolating and drainage water. These results are in confirmation with the findings of Sivasankaran *et al.* (1993). Similarly Sumithra *et al.* (2013) in soils of Timanhal micro-watershed, Kushtagi taluk of Karnataka.

5.3.3 Organic carbon

The organic carbon content ranged from 0.22 to 0.62 per cent in surface layer and 0.12 to 0.43 per cent in the subsurface horizons. Organic carbon content of surface soil was greater than subsurface soil in all the pedons and it decreased with depth. This was attributed to the addition of farmyard manure and plant residues to surface horizons which resulted in higher organic carbon content in surface horizons than that of lower horizons. These observations are in accordance with results of Basavaraju *et al.* (2005) in soils of Chandragiri Mandal of Chittor district of Andhra Pradesh. Similar observations were also made by Vinay (2007) in Bhanapur micro-watershed of Koppal district, Karnataka.

5.3.4 Free CaCO₃ content

Free CaCO₃ is an accumulation of precipitated calcium carbonate in the solum. This generally happens due to negative precipitation-evapotranspiration (P–ET) balance and some geological properties (parent material). The calcium carbonate content in surface layers ranged from 3.87 to 10.75 per cent and in subsurface layers, it ranged from 5.62 to 14.87 per cent. Krishnamoorthy and Govindarajan (1977) reported the abundance of CaCO₃ in black soils than in red soils. Similar observations were also made by Pulakeshi *et al.* (2014) for the soils of Mantagani village of Haveri district in Karnataka.

5.3.5 Exchangeable cations

The dominant cations on the clay complex were calcium followed by magnesium, sodium and potassium in black pedons. The exchangeable calcium and magnesium in surface soils ranged from 23.11 to 38.90 cmol (p⁺) per kg and 7.12 to 17.0 cmol (p⁺) per kg, respectively. In subsurface soils, Ca and Mg ranged from 27.94 to 41.70 cmol (p⁺) per kg and 6.9 to 16.6 cmol (p⁺) per kg, respectively. The exchangeable calcium decreased and that of magnesium increased with depth. Similar results were obtained in black soils by Dasog and Hadimani (1980).

The exchangeable sodium content ranged from 1.82 to 4.95 cmol (p⁺) per kg in surface horizons and 2.30 to 5.08 cmol (p⁺) per kg in subsurface horizons and varied with profile depth. Similar reports were made by Yeresheemi *et al.* (1997) in Upper Krishna Command Area.

The soils under investigation contained exchangeable potassium in quantities less than 1 cmol (p^+) per kg and the values exhibited a decreasing trend with depth in few pedons and increased with depth in others. The exchangeable potassium content ranged from 0.27 to 0.83 cmol (p^+) per kg in surface horizons and 0.31 to 0.70 cmol (p^+) per kg in subsurface horizons. Similar reports were made by Subbaiah and Manickam (1992) and Parvatappa *et al.* (1990).

In both black and red soil pedons, Ca^{2+} shows the strongest relationship with all the species, comparing these ions (Ca^{2+} , Mg^{2+} , K^+ and Na^+), it was clear that Mg^{2+} was present in low amount than Ca^{2+} because of its mobility. These results are in conformity with the findings of Sharma *et al.* (1996). The low value of exchangeable monovalents compared to divalent was due to preferential leaching of monovalents than divalent. These findings are in accordance with Roy and Barade (1962). Similar reports were made by Manojkumar *i* (2011) in Bastwad micro-watershed on basalt parent rock in northern transition zone of Karnataka.

5.3.6 Cation exchange capacity (CEC)

The values of cation exchange capacity increased with profile depths and followed the trend of clay. This is due to accumulation of clay and may be due to presence of mixed or smectic group of clay minerals (Landey *et al.*, 1982) and Das (1999). The cation exchange capacity of soils which had the lower amount of clay content had lowest CEC values in a micro-watershed of Vidharbha region in Maharashtra (Gabhane *et al.*, 2006).

The CEC of soil with a tendency to decrease with depth but it was found closely associated with clay and clay plus organic carbon in grape growing soils in Nasik district of Maharashtra (Balpande *et al.*, 2007). Similarly the CEC values were higher in horizons containing high clay and/or high organic carbon. Low values of CEC may be ascribed to the predominance of low CEC minerals, especially illite, in outer Himalayas (Sanjeev *et al.*, 2005).

5.3.7 Exchangeable sodium percentage (ESP)

The exchangeable sodium percentage ranged from 3.28 to 9.04 per cent in surface horizons and 4.12 to 9.35 per cent in subsurface horizon. A lower ESP (<15) throughout the depth in soils clearly indicated that these soils are not sodic in nature. Exchangeable sodium percentage values did not follow definite trend throughout the depth in all pedons. A measure of relative amounts of exchangeable sodium in comparison with the total cations in the soil are dependent on factors such as type of minerals, concentration of electrolytes and status of soluble cations. Similar findings were observed on soils derived from chlorite schist in north Karnataka by Pulakeshi *et al.* (2014).

5.3.8 Base saturation

The base saturation percentage ranged from 84.29 to 94.66 per cent in surface horizons and 84.79 to 92.09 per cent in subsurface horizon. Black soils showed high base saturation due to high exchangeable bases, CEC and restricted drainage. Similar observations were made by Mohan *et al.* (2013) in soils of Hanumanakoppa micro-watershed in northern transitional zone of Karnataka.

5.4 Soil survey and mapping

5.4.1 Soil classification

Soils are classified according to the revision in US Soil Taxonomy. All pedons key out as *Haplustepts* and *Ustorthents* at great group level as they do not have salic, gypsic or calcic horizons.

Pedons 1, 2, 4, 5, 6, 7, 8 and 10 were classified into *Inceptisols* owing to the absence of any other diagnostic horizon other than cambic horizon. As the moisture regime is Ustic and classified as *Ustepts* at sub-order level. Pedons 1, 2, 4, 5, 6, 7, 8 and 10 classified as *Haplustepts* and *Typic Haplustepts* at great group and subgroup level respectively.

Pedons 3, 9 and 11 were classified as *Entisols*, because there was no evidence of development of pedogenic horizons and followed none of the criteria established for sub-orders in the order *Entisols*. So it was classified as *Orthents*. At great group level these pedons classified as *Ustorthents* due to the prevailing soil moisture regime as “Ustic”. All Pedons, under *Entisols* had a *Lithic* contact within depth of 50 cm. Since they are classified as *Ustorthents* and *Lithic Ustorthents* at great group and subgroup level respectively.

In order to distinguish families of soils within subgroup, the following differentiae are used. They are listed in same sequence in which the descriptive adjective relating to each differentia appears in the family names.

1. Particle size class
2. Reaction class
3. Cation exchange activity class
4. Soil temperature class and
5. Mineralogy class

Based on the criteria of above classes in their respective soil control section (Anon., 2006 and 2014), the particle size class of pedons under study were fine, Clayey and Fine-loamy because of <60, >35 and <35 per cent clay content.

The soil reaction class was calcareous in nature and all the soils under study had isohyperthermic temperature regime. Since, the mean summer and winter temperatures differ by less than 6°C and mean annual temperature exceeds 22°C.

The overall classification of selected pedons are given below.

Pedon No.	Soil classification
1, 2, 4, 5, 6, 7, 8 and 10	Fine, mixed, super active, isohyperthermic, <i>Typic Haplustepts</i> .
3 and 9	Clayey, mixed, super active, isohyperthermic, <i>Lithic Ustorthents</i> .
11	Fine-loamy, mixed, super active, isohyperthermic, <i>Lithic Ustorthents</i> .

The majority of the soils of Bastwad micro-watershed are classified as *Typic Haplusterts* reported by Manojkumar Dabi (2011) on basalt parent rock in northern transition zone of Karnataka. Sahu *et al.* (2001) classified soils of Western Zone of Orissa into *Typic/Chromic Haplusterts*. Ramprakash and Seshagiri Rao (2002) classified the soils of Krishna district of Andhra Pradesh into *Typic Haplusterts*. Marathe *et al.* (2003) classified the soils of mandarin orchards in Nagpur into *Vertic Haplustepts*, *Typic Haplustepts*, *Typic Ustorthents* and *Typic Haplusterts*. The results are also supported by the observations of Vinay (2007) in Bhanapur micro-watershed (Koppal district) of Karnataka. Observations made by Ravikumar (2006) in a portion of Malaprabha Command Area under Distributary No. 48A in Zone-3 of Karnataka also support the findings. Similar observations also made by Nagendra (2015).

Rashmi *et al.* (2012) in Taroda watershed area were classified as soils of plateau, escarpment and isolated hillock are very shallow (*Lithic Ustorthents/Typic Ustorthents*), soils of pediment are shallow (*Typic Ustorthents/Typic Haplustepts*) whereas, soils of valley are moderately deep to very deep (*Vertic Haplustepts/Typic Haplusterts*). Similar classification was reported by Pulakeshi *et al.* (2014) and Tumbal and Patil (2015).

5.4.2 Soil map and mapping units

Soil map is designed to show the distribution of soil types or other soil mapping units in relation to other prominent physical and cultural feature of the earth's surface. Under the study area, seven soil series (Dmb-1 to Dmb-7) were identified based on physiography and drainage and were mapped into 7 mapping units (Fig. 2) as different phases of soil series with the help of the GIS software (ArcGIS 10.1). The mapping legend is presented as e.g., Dmb-1-m-B-2. It represents the name of the series (e.g.Dmb-1/Dambal-1) surface texture (m-clay), slope class (B-gently slope) and erosion class (2- moderate) and if gravellines e.g. (g1- <15 per cent) present in surface

The brief description and extent of soil series is given in Table 7. Maps of one or more soil feature may be made directly from field observations or by selection and generalization from a soil map. The first step of soil survey is the establishment of units of classification to be shown on the maps (Murthy *et al.*, 1972, Dent and Young, 1981, NBSS and LUP, 1984). The legend design or the kinds of mapping units for any given kind is determined by nature, procedure and kind of survey (Rourke, 1981).

5.5 Land evaluation

5.5.1 Land capability classification

Based on soil properties, the soils of Dambal-2 micro-watershed have been classified into two land capability classes viz., III and IV (Table 8). Mapping unit 6 and 7 classified into IVsf, which is fairly good cultivable lands with limitations of depth, coarse fragments and organic carbon content. Mapping units 1, 2, 3, 4 and 5 were classified as IIIstf owing to the limitations of texture, depth, erosion and organic carbon (Fig. 3). Similar work was carried out by Ravikumar *et al.* (2009) studied the soils under 48A distributary of Malaprabha right bank command of Karnataka. Land capability classification showed that majority of land belonged to class III followed by class IV with limitations of erosion, wetness and soil properties and also Nagendra (2015) showed similar results in Gadag district, Shirol West-1 microwatershed.

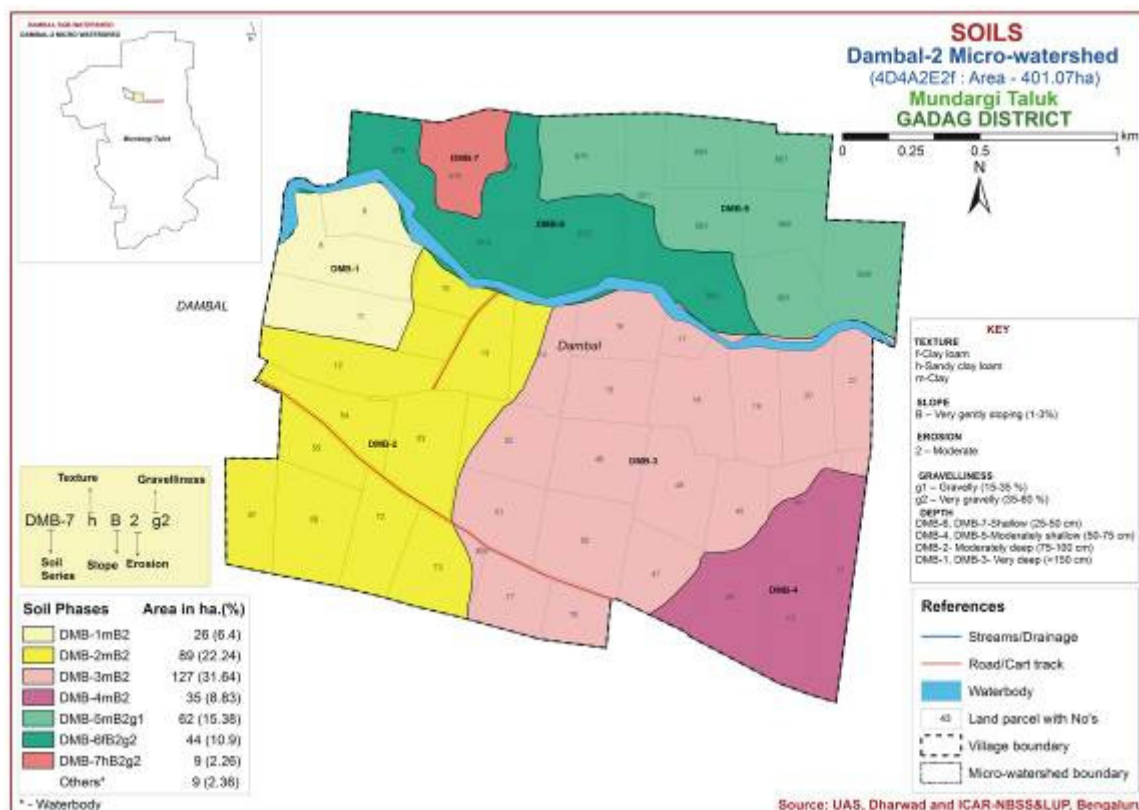


Fig. 2. Mapping units of Dambal-2 micro-watershed

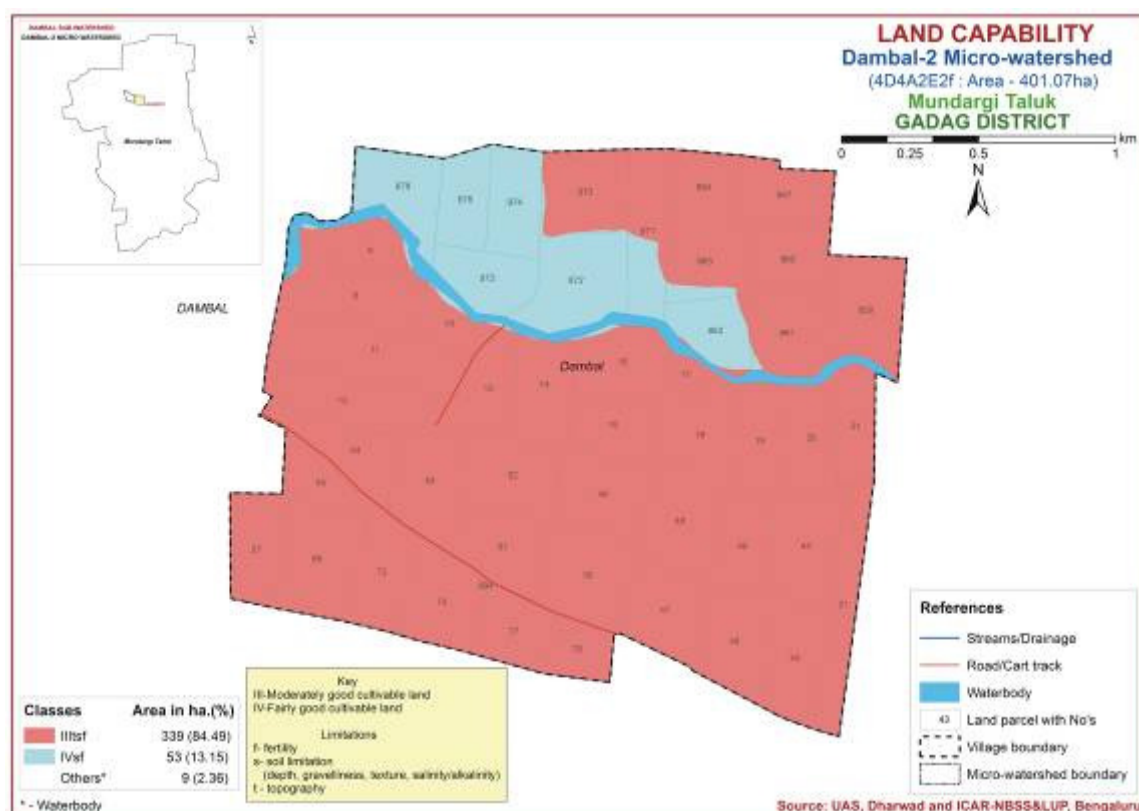


Fig. 3. Land capability classification of Dambal-2 micro-watershed

Thangasamy *et al.* (2005) assessed the suitability of soils of Sivagiri micro-watershed for arable crops, grazing and forestry. The grouping of soils into classes and subclasses is done mainly based on severity of limitations viz., erosion risk (e), wetness (w), rooting zone, soils (s) and climatic limitations (c). Based on these criteria, the soils of *Typic Haplustepts* and *Aquic Ustorthents* of Sivagiri micro-watershed were placed in the land capability class IIs, whereas, the soils of *Typic Ustifluvents*, *Typic Rhodustalfs* and *Typic Haplustalfs* were kept in IIIs, a soil of *Vertic Haplustepts* alone was placed in IIIw and *Typic Ustipsammments* was placed in IVs.

5.5.2 Soil- site suitability classification for irrigation

Soil site suitability for irrigation was evaluated as explained by Sehgal (1996) based on kind and degree of limitations for sustained use under irrigation to know the suitability of land for specific use. The lands covered under mapping unit 1, 2, 3, 4 and 5 were moderately suitable for irrigation as the moderate limitations of soil-depth, erosion, drainage outlets, texture and coarse fragments (Table 9). The mapping unit no. 6 and 7 are marginally suitable for irrigation (Fig. 4) due to severe limitation coarse fragments. Similar work was carried out by Patil *et al.* (2008b) for the soils under 48A Distributary of Malaprabha Right Bank Command (MRBC) in Karnataka. The soils were marginally suitable for irrigation due to soil texture, erosion, wetness and soil properties limitation.

5.5.3 Soil-site suitability for different crops

The performance of any crop is largely dependent on soil parameters (depth, drainage, texture, erosion, slope *etc.*) as conditioned by climate and topography. The study of soil-site characterization for predicting the crop performance of an area forms land evaluation. According to Van Wambeke and Rossiter (1987) land evaluation is the rating of soil for optimum returns per unit area. The yield influencing factors for important crops have to be evaluated and the results obtained may be applied for higher production of these crops through proper utilization of similar soils occurring elsewhere in same agro-climate sub-region under scientific management practices (Khadse and Gaikwad, 1995).

The studied soils vary in their suitability for different crops as per the criteria for the determination of soil-site suitability classes.

5.5.3.1 Wheat

It is observed that a well drained medium textured soil and factors like drainage, temperature, fertility status and salinity influence soil site suitability for wheat. Therefore mapping unit 7 was not suitable due to very severe depth limitation, mapping unit 6 were marginally suitable and mapping units 1, 2, 3, 4 and 5 are moderately suitable for cultivation of wheat (Fig. 5). The soils were favourable with respect to temperature, slope, drainage, ESP, but had the limitations of depth; OC, pH and texture affects during germination and vegetative stages. Tripathi *et al.* (2006) also reported similar results in landforms of Kiar-Nagali micro-watershed. Nagendra (2015) were also observed same result from Shirol-West-1 micro-watershed of Gadag district.

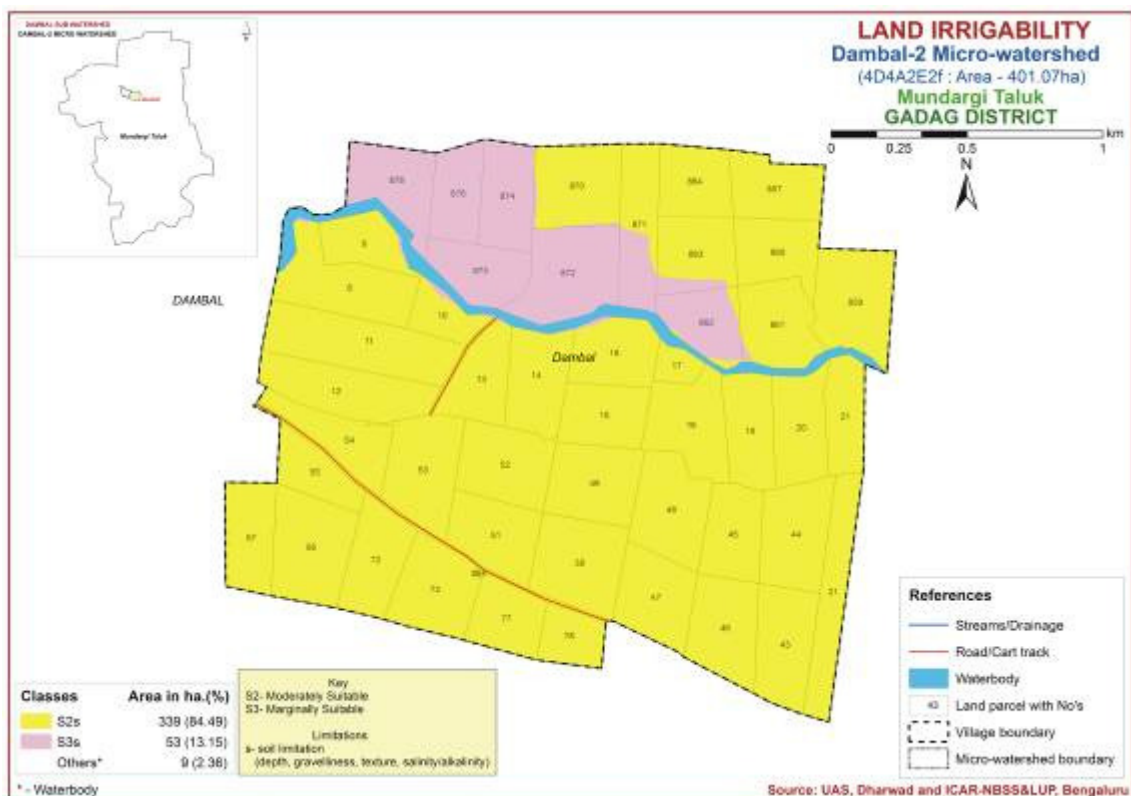


Fig. 4. Soil site suitability of Dabmal-2 micro-watershed for irrigation

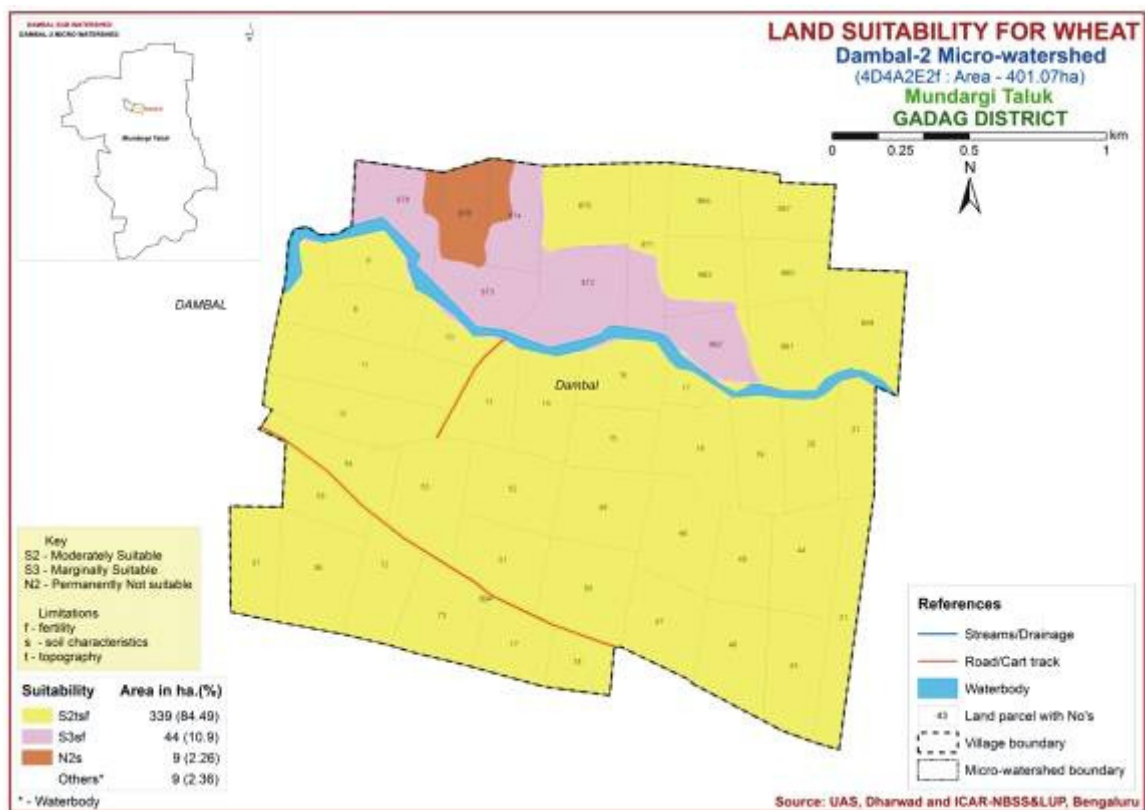


Fig. 5. Soil site suitability of Dabmal-2 micro-watershed for wheat

5.5.3.2 Maize

In general maize requires an annual rainfall of 900 mm; soil depth of 100 cm with sandy clay loam to clay texture (with 27 – 60 per cent) and good drainage is required. All the mapping units were marginally suitable with severe limitation of depth, climate, texture and soil fertility *i.e.* low organic matter content (Fig.6). Similar results were reported by Tripathi *et al.* (2006) in a micro-watershed of Kiar-Nagali for maize crop.

5.5.3.3 Sorghum

The factors that influence sorghum yields are soil depth, ESP, CEC, clay content, exchangeable cations, slope *etc.* Though, the soils were best with factors like slope, erosion, texture, CaCO_3 and drainage, the moderate limitation of climate, erosion, pH and fertility resulted in moderately suitable (S2) class in all the mapping unit for sorghum except mapping unit 6 and 7 because of severe limitation of depth and coarse fragments and are marginally suitable and unsuitable for sorghum cultivation respectively (Fig.7). Similar results have been reported by Mini *et al.* (2007) and Pulakeshi (2010) for maize cultivation in the Mantagani village of Haveri district Karnataka.

5.5.3.4 Pearl millet

Rainfall, depth, texture and free CaCO_3 showed significant impact on yields of pearl millet (Van Wambeke and Rossiter, 1987). The soil depth of >75 cm, <10 per cent CaCO_3 and clay texture were found to be favorable. Mapping unit 1, 4, 6 and 7 in the micro-watershed are marginally suitable with severe limitations of coarse fragments, pH, CaCO_3 and depth for production of pearl millet. Remaining all other mapping units 2, 3 and 5 were moderately suitable moderate limitations erosion, drainage, texture and pH (Fig. 8). Similar results were obtained by Manojkumar (2011).

5.5.3.5 Bengal gram

Temperature, drainage, texture and rainfall are chief factors controlling bengal gram production. All mapping units were marginally suitable, except mapping unit 2, 3 and 5 (moderately suitable) for gram cultivation (Fig. 9) because they had moderate to severe limitations of climate, drainage, erosion, coarse fragments depth, pH and texture. Similar results were found by Meena *et al.* (2012b) in Banswara district in southern Rajasthan for chickpea cultivation. The study area was moderately suitable and marginally suitable for chickpea (*Cicer arietinum* L.) cultivation. Soil depth, wetness (drainage), erosion, texture and organic carbon are the major limitations for crop growth.

5.5.3.6 Pigeonpea

Rainfall, temperature, slope, depth, AWC, texture and base saturation of soils significantly influence the yield of pigeonpea. The areas represented by mapping unit no. 7 were potentially unsuitable for pigeonpea cultivation (Fig. 10) with very severe limitation of depth and remaining mapping units were marginally and moderately suitable with slight limitations of slope, EC, temperature and ESP whereas rainfall, erosion, drainage and texture are moderate but depth and pH are moderate to severe in limitations. Similar work was also carried out by Gabhane *et al.* (2006) in Maharashtra, Satyavathi and Suryanarayana Reddy (2004b) in soil of Telangana region of Andhra Pradesh and Kiran Reddy *et al.* (2014) in Nalgonda district Andhra Pradesh.

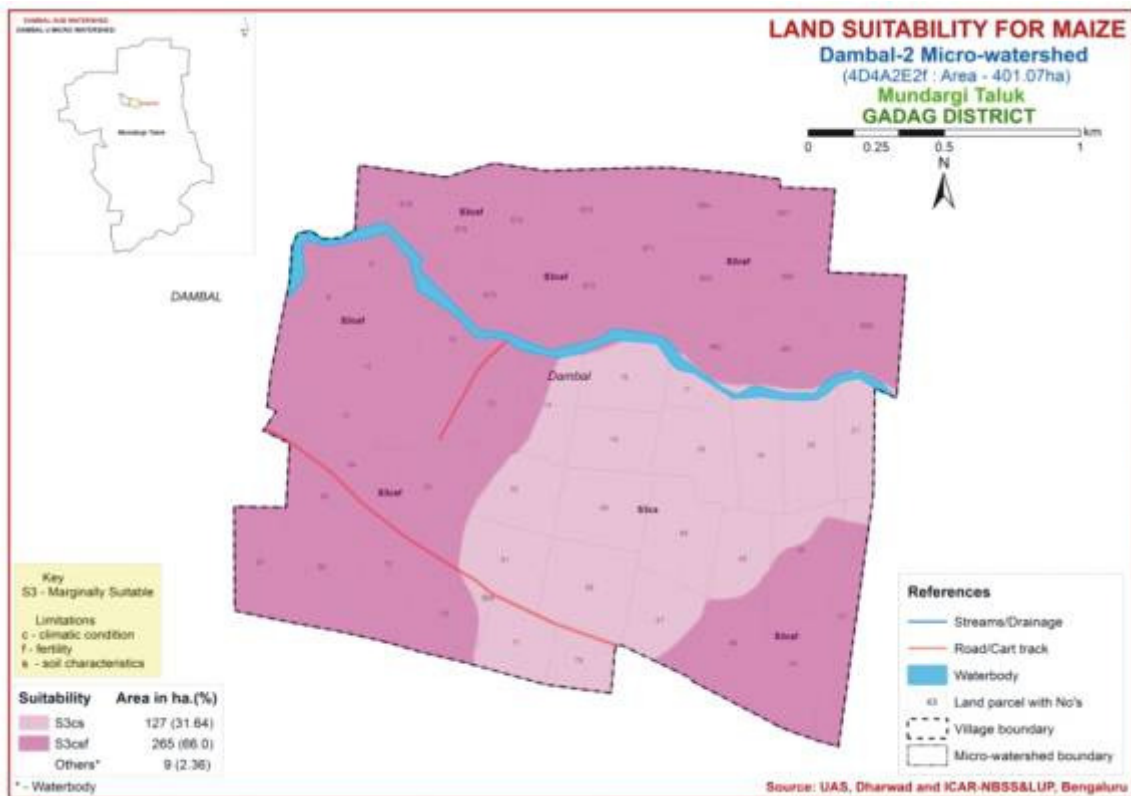


Fig. 6. Soil site suitability of Dabmal-2 micro-watershed for maize

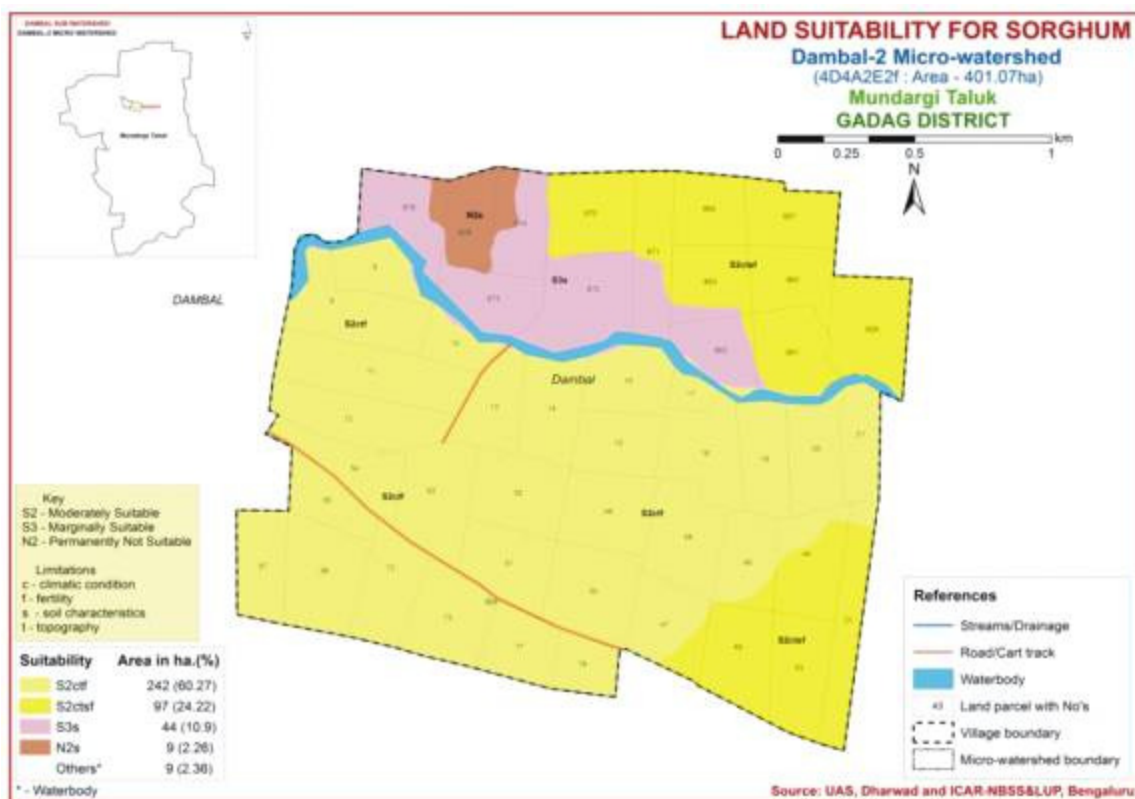


Fig. 7. Soil site suitability of Dabmal-2 micro-watershed for sorghum

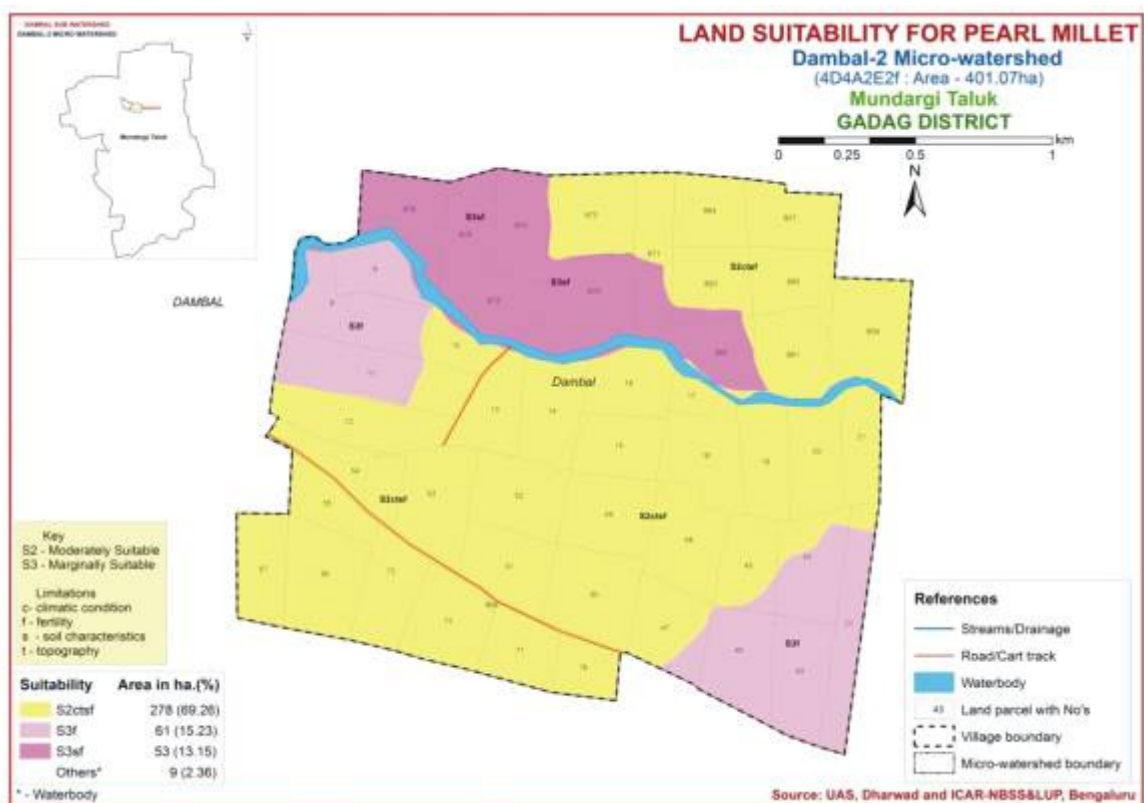


Fig. 8. Soil site suitability of Dabmal-2 micro-watershed for pearl-millet

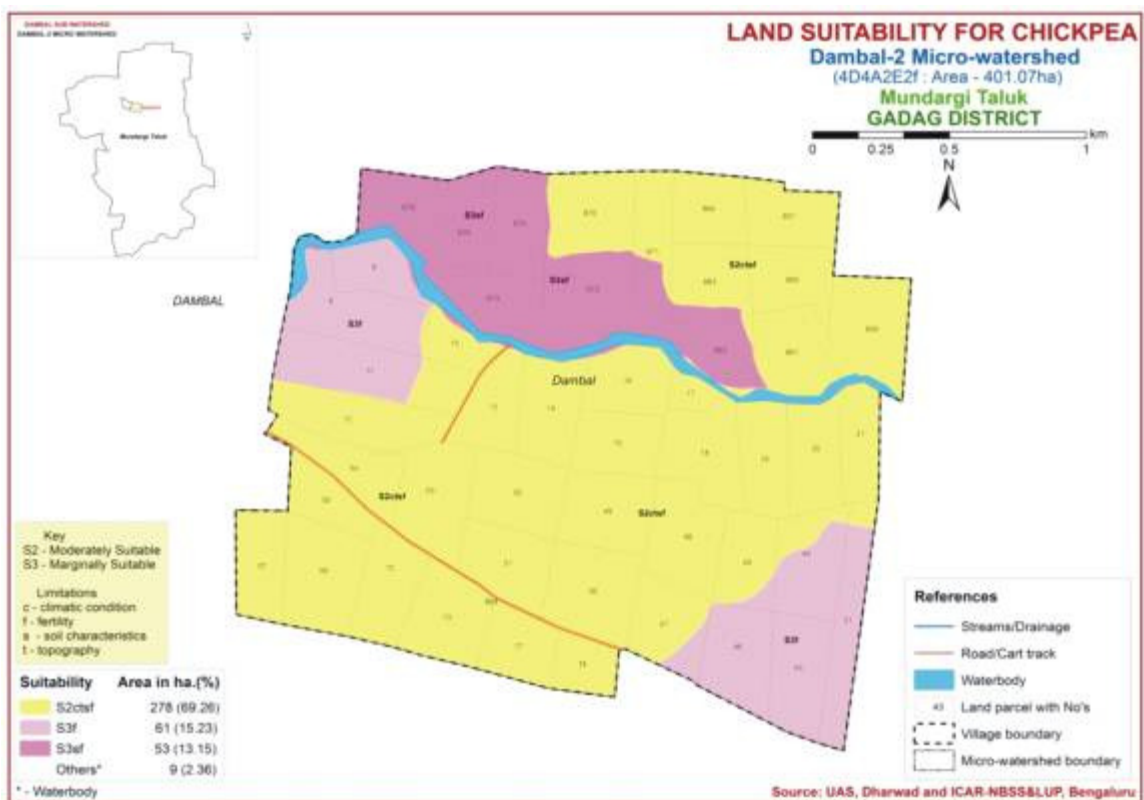


Fig. 9. Soil site suitability of Dabmal-2 micro-watershed for chickpea

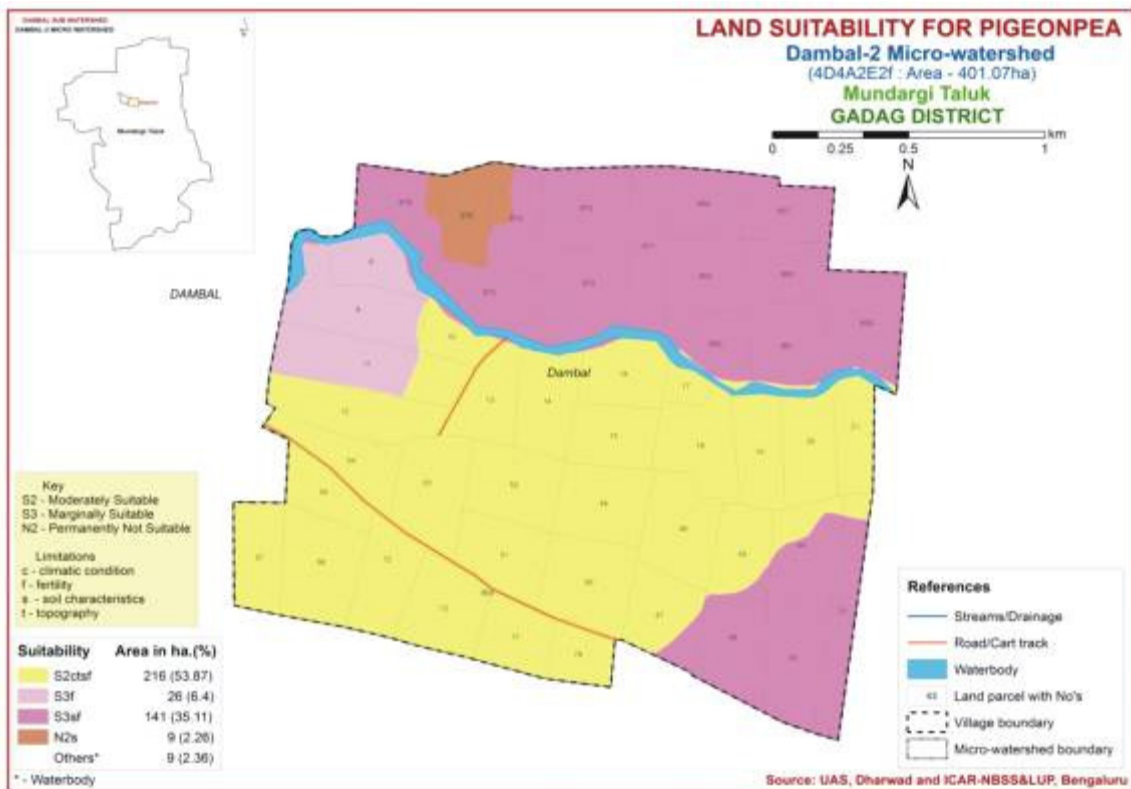


Fig. 10. Soil site suitability of Dabmal-2 micro-watershed for pigeonpea

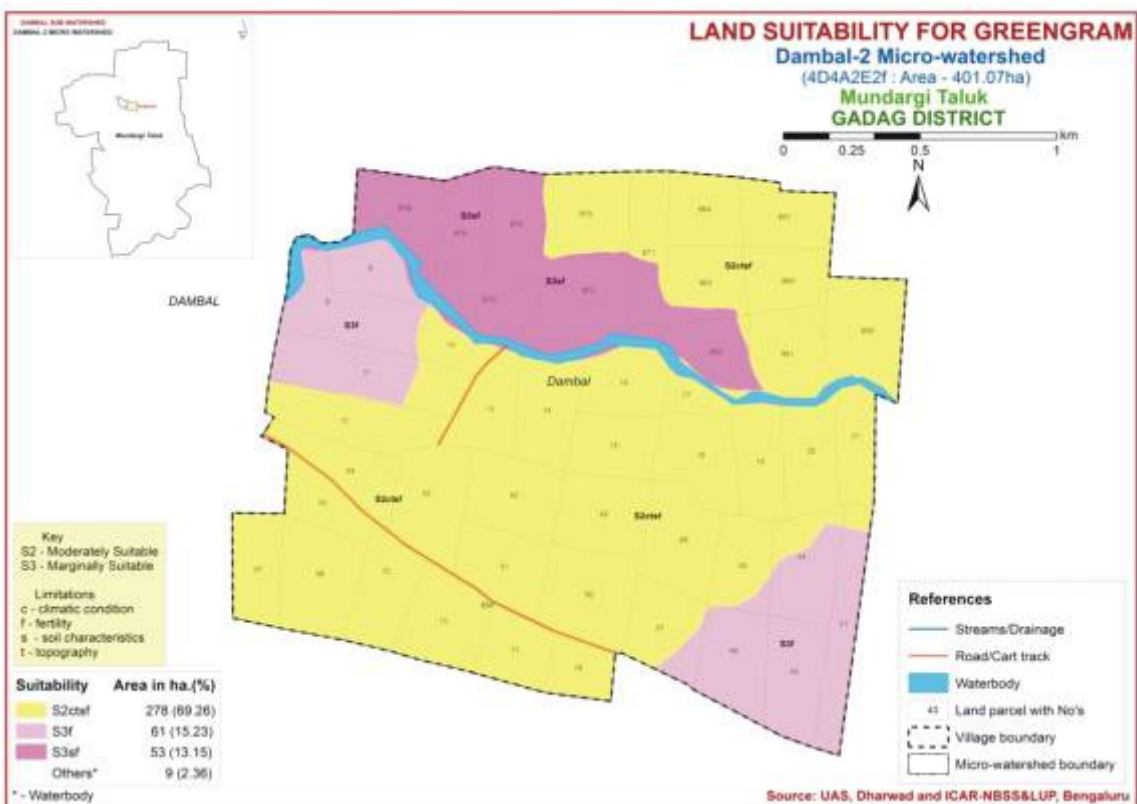


Fig. 11. Soil site suitability of Dabmal-2 micro-watershed for green gram

5.5.3.7 Green gram

Temperature, drainage, texture and rainfall are chief factors controlling green gram production. Considering this, all the mapping units were evaluated as moderately (S2) and marginally suitable (S3) and for green gram cultivation (Fig.11). Moderate to severe limitations of drainage, erosion, texture, pH and rainfall. Same result was observed by Malavath *et al.* (2013) from Chettind of Sivagangai district of Tamil Nadu.

5.5.3.8 Groundnut

The factors that influence groundnut yield are rainfall, CaCO₃, drainage, temperature, texture, depth, slope, pH and CEC. All the mapping units were marginally (S3) suitable for groundnut having marginal to severe limitations of coarse fragments, depth, texture and pH and none to slight limitations of land form characteristics (Fig. 12). Similar results were reported by Leelavathi (2007) in soils of Yerpedu Mandal of Chittoor district Andhra Pradesh and Selvaraj and Naidu (2013) in soils of Renigunta mandal of Andhra Pradesh. In general, soil texture, pH and organic carbon are the major limitations for crop growth in all the soils.

5.5.3.9 Soybean

The factors that influence the soybean yields are soil depth, available moisture content, CEC, clay, exchangeable cations, slope *etc.* Soybean needs about 20 to 32° C temperature for proper germination. A day temperature of 25°C or less results in delayed flowering. Prolonged period of cloudy weather tends to extend the vegetative phase at the expense of seed yield. All the mapping units were moderately (S2) to marginally (S3) suitable for soybean with moderate to severe limitations in respect of erosion, drainage, depth, texture, coarse fragments, ESP, organic carbon and pH (Fig. 13). Similar results were obtained by Pulakeshi (2010) in Manatagi village of Haveri district Karnataka.

5.5.3.10 Sunflower

The factors influencing sunflower yield are rainfall, temperature, slope, BS, CaCO₃, CEC, depth *etc.* The mapping units of the study area were moderately to permanently not suitable for sunflower cultivation due to limitations of depth, texture, pH, drainage and none to slight limitations of land form characteristics. Mapping units 6 and 7 are not suitable with severe limitation of depth and remaining mapping units 1, 4 and 5 are marginally suitable with severe limitation of pH and depth. Whereas mapping units 2 and 3 are moderately suitable with limitations of erosion, drainage, depth, texture, coarse fragments and pH (Fig. 14). Similar results were observed by Manojkumar Dabi (2011).

5.5.3.11 Sesamum

The mapping units of the study area were moderately to permanently not suitable for Sesamum cultivation due to limitations of temperature, depth, texture, pH, drainage and none to slight limitations of land form characteristics. Mapping units 6 and 7 are not suitable with severe limitation of coarse fragments and remaining mapping units 1 and 4 are marginally suitable with severe limitation of pH. Whereas mapping units 2, 3 and 5 are moderately suitable with limitations of erosion, drainage, depth, texture, coarse fragments and pH (Fig. 15). Kiran Reddy *et al.* (2014) from Nalgoda district of Andhra Pradesh was found same results.

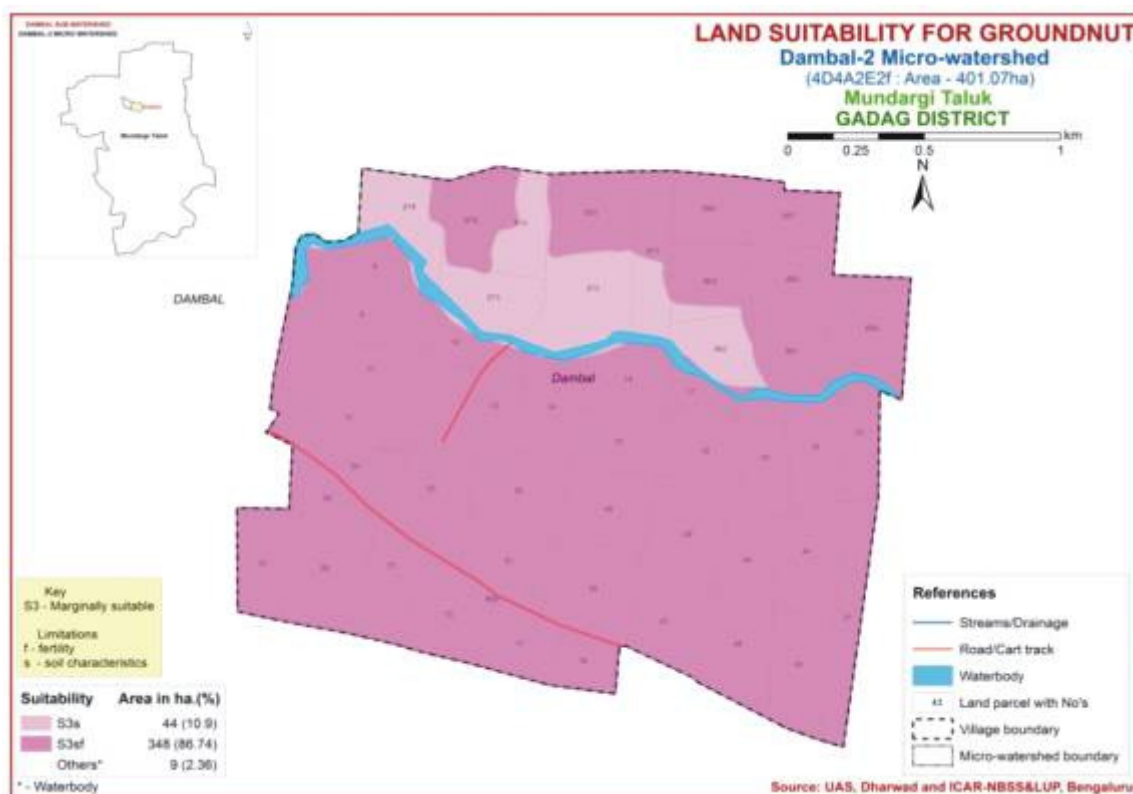


Fig. 12. Soil site suitability of Dabmal-2 micro-watershed for groundnut

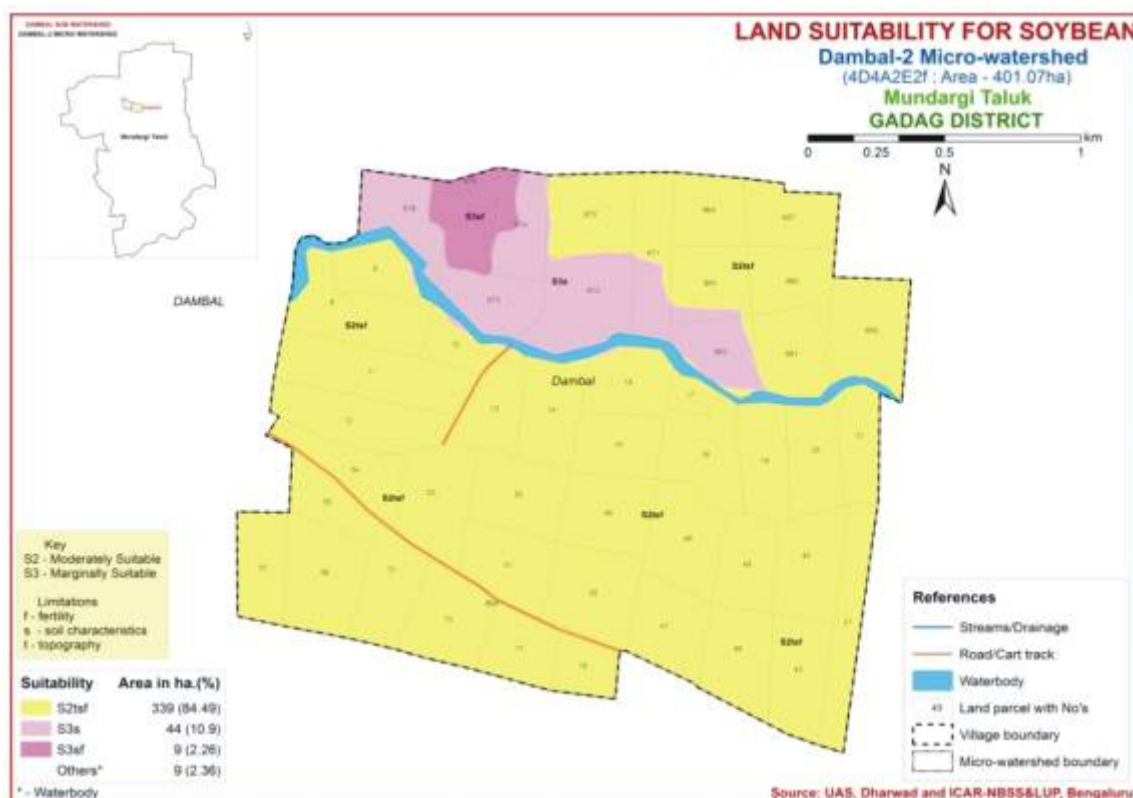


Fig. 13. Soil site suitability of Dabmal-2 micro-watershed for soybean

5.5.3.12 Cotton

The yield influencing factors on cotton are rainfall, soil depth and calcium carbonate. All mapping units except mapping units 2 and 3 were marginally suitable owing to severe limitations of organic matter and nutrient availability. Mapping unit 1, 4, 5 and 6, 7 was potentially and permanently not suitable owing to very severe limitation of depth and fertility respectively (Fig. 16). Similar work was also carried out by Gabhane *et al.* (2006).

5.5.3.13 Chilli

Rainfall, temperature, slope, depth, texture, sodicity and base saturation of soils significantly influence the yield of chilli. All the mapping units were marginally suitable for chilli cultivation with severe limitations of rainfall, texture, organic matter, coarse fragments, pH, rainfall and depth (Fig. 17). Similar results were observed by Manojkumar Dabi (2011) and Tumbal and Patil (2015).

5.5.3.14 Sugarcane

Land under all mapping units were marginally (1, 2, 3, 4 and 5) and not suitable (6 and 7) (Fig. 18) for sugarcane cultivation with severe limitation of temperature, depth pH, coarse fragments and fertility. Selvaraj *et al.* (2013) in Renigunta Mandal of Chittoor district was found same results.

5.5.3.15 Mango

Mango is well adapted to tropical and subtropical climate, thrives well upto 1500 M above mean sea level but commercially not economical beyond 600 M. Mapping unit 2 and 3 are marginally suitable with severe limitation of depth and pH. Remaining mapping units 1, 4, 5, 6 and 7 are not suitable for mango cultivation. (Fig.19). Similar results were reported by Denis *et al.* (2014).

5.5.3.16 Sapota

It is a hardy tree adapted to wide range of climatic conditions. Rainy or cloudy weather at any time of year is in no way harmful for setting of fruits. Mapping unit 1, 4 and 5 are marginally suitable (depth and pH limitations) and mapping unit 2 and 3 are moderately suitable. Remaining mapping units are permanently not suitable (Fig. 20) with very severe limitations of depth. Texture and pH moderate limitation whereas ESP, climate, drainage and topography were slight to moderate limitations for sapota cultivation. Similar results were reported by Denis *et al.* (2014) in Singhanhalli-Bogur micro-watershed of Dharwad district Karnataka.

5.5.3.17 Guava

Guava is successfully grown in tropical and subtropical climate. In areas having distinct winter season the yield tends to increase with quality. Annual rainfall of 100cm is sufficient during rainy season (July-September). Rains during harvest period deteriorate the fruit quality. Mapping unit 1, 2, 3, 4 and 5 are marginally suitable and remaining mapping units are permanently not suitable (Fig. 21) with severe to very severe limitations of depth, coarse fragments, pH, CaCO_3 , whereas ESP, climate, drainage and topography were slight limitations for guava cultivation. Similar results were reported by Manojkumar Dabi (2011) in Bastwad micro-watershed of Belgaum district, Karnataka.

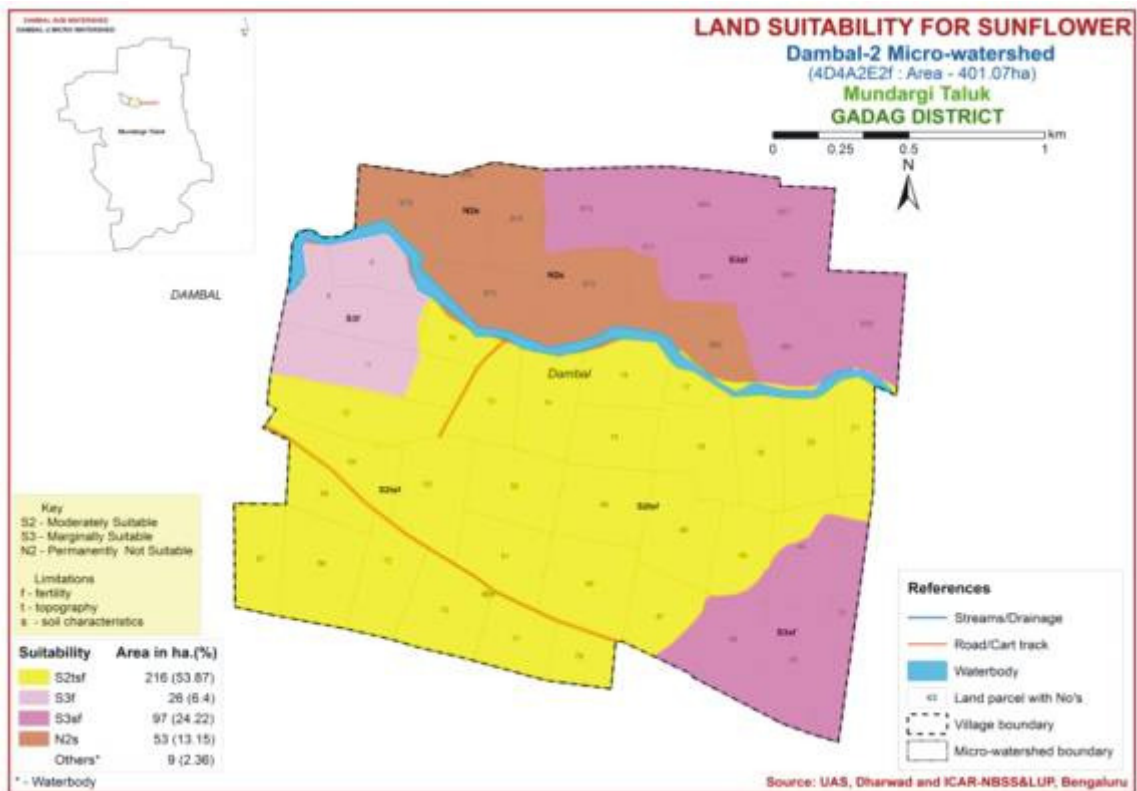


Fig. 14. Soil site suitability of Dabmal-2 micro-watershed for sunflower

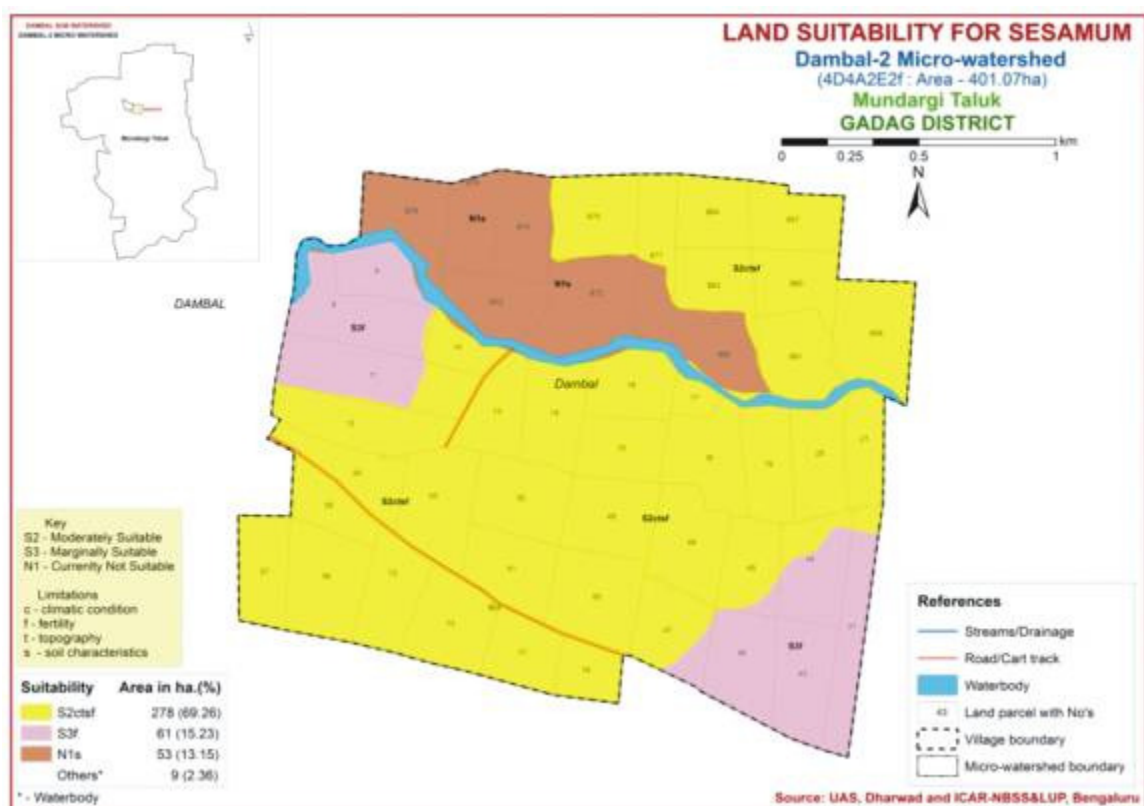


Fig. 15. Soil site suitability of Dabmal-2 micro-watershed for sesamum

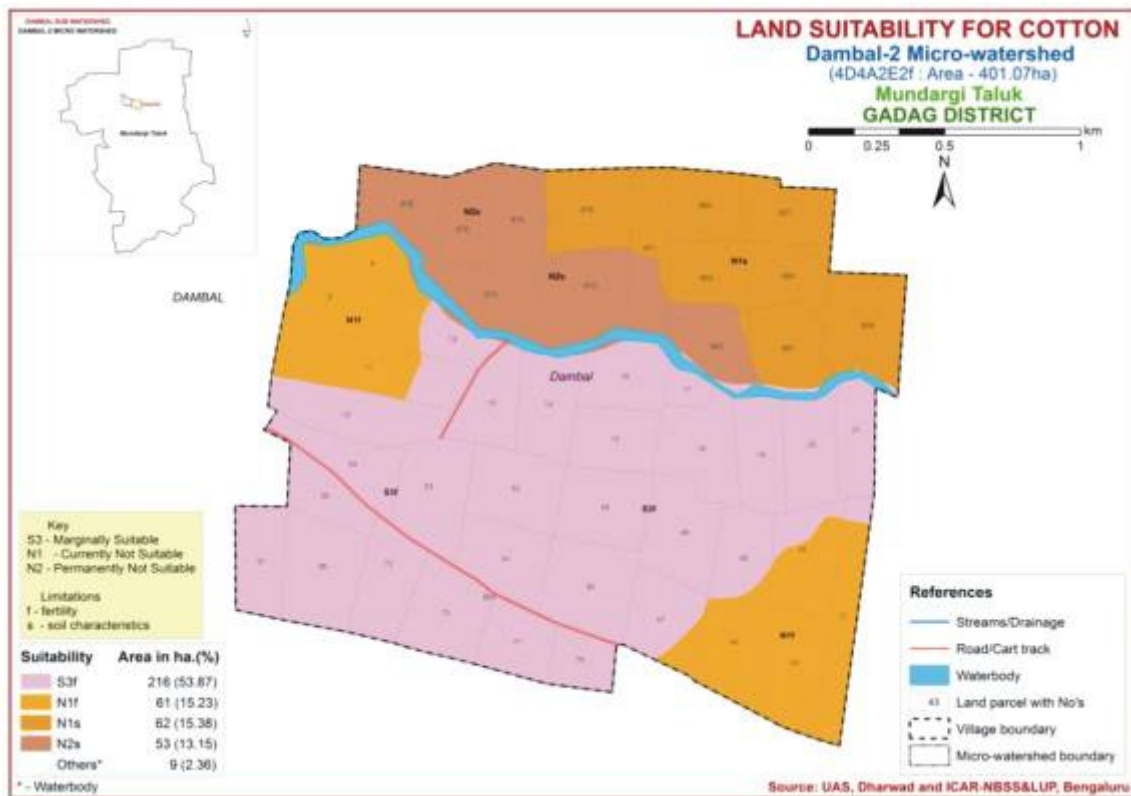


Fig. 16. Soil site suitability of Dabmal-2 micro-watershed for cotton

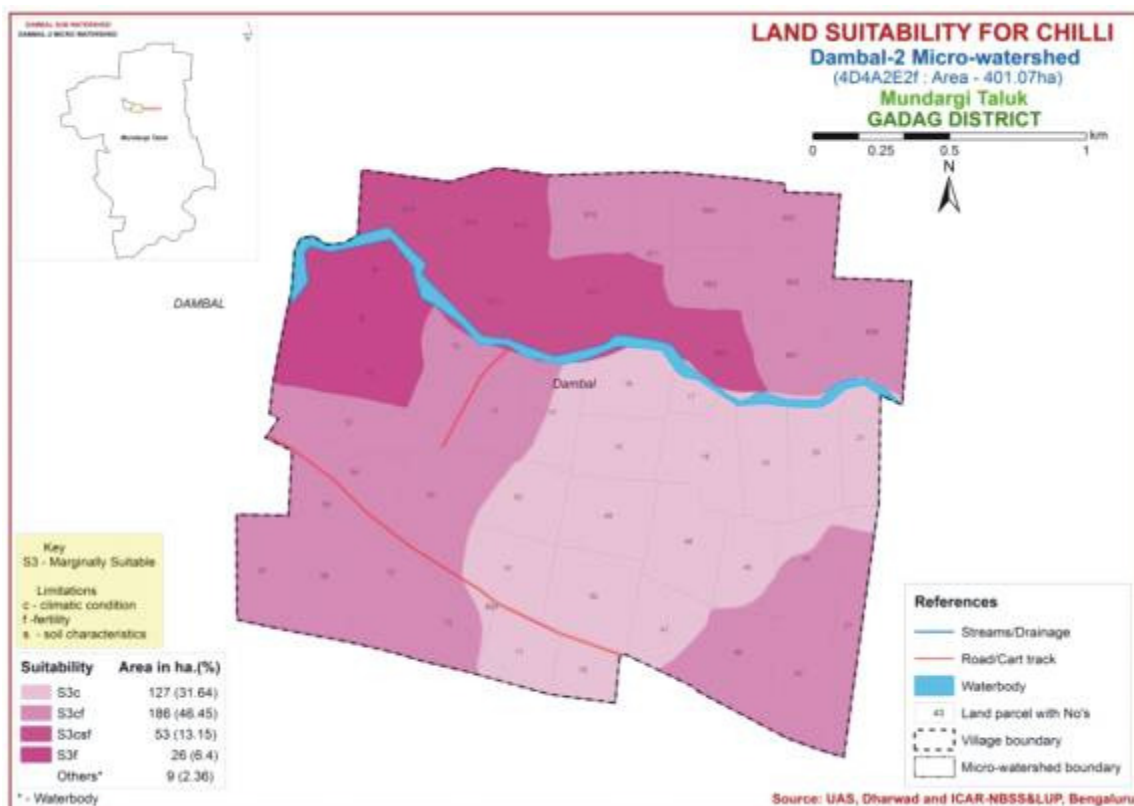


Fig. 17. Soil site suitability of Dabmal-2 micro-watershed for chilli

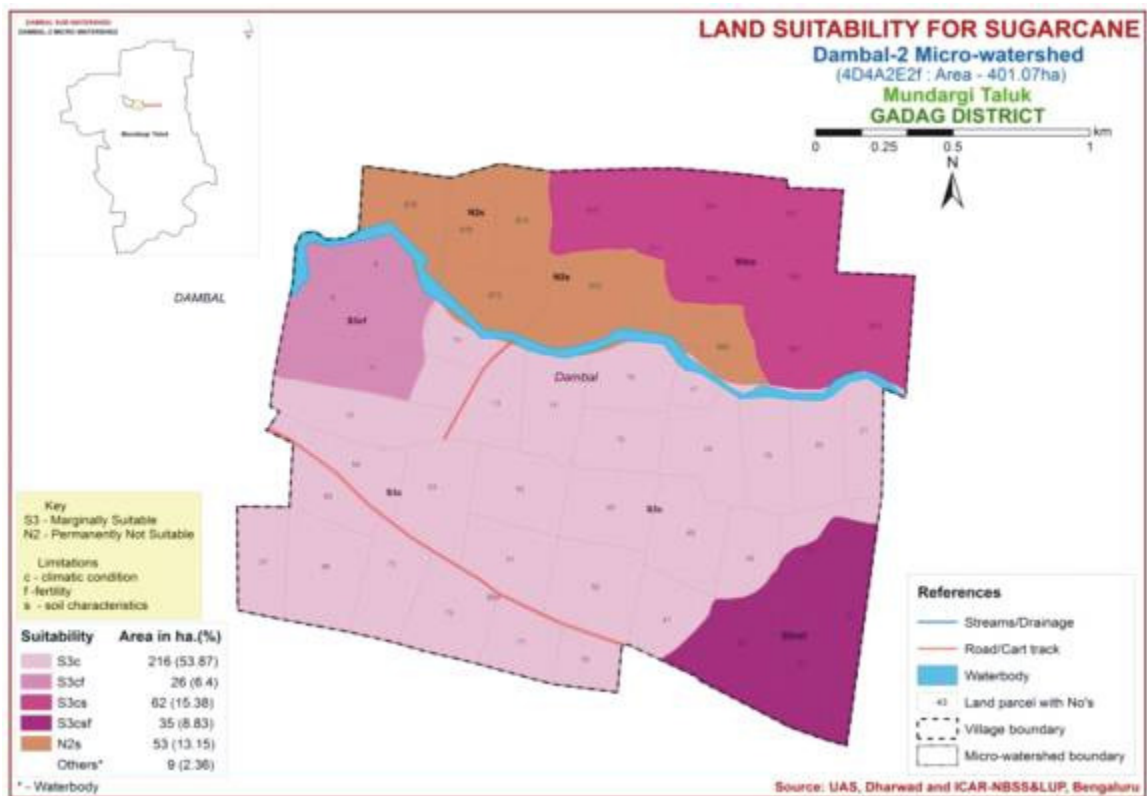


Fig. 18. Soil site suitability of Dabmal-2 micro-watershed for sugarcane

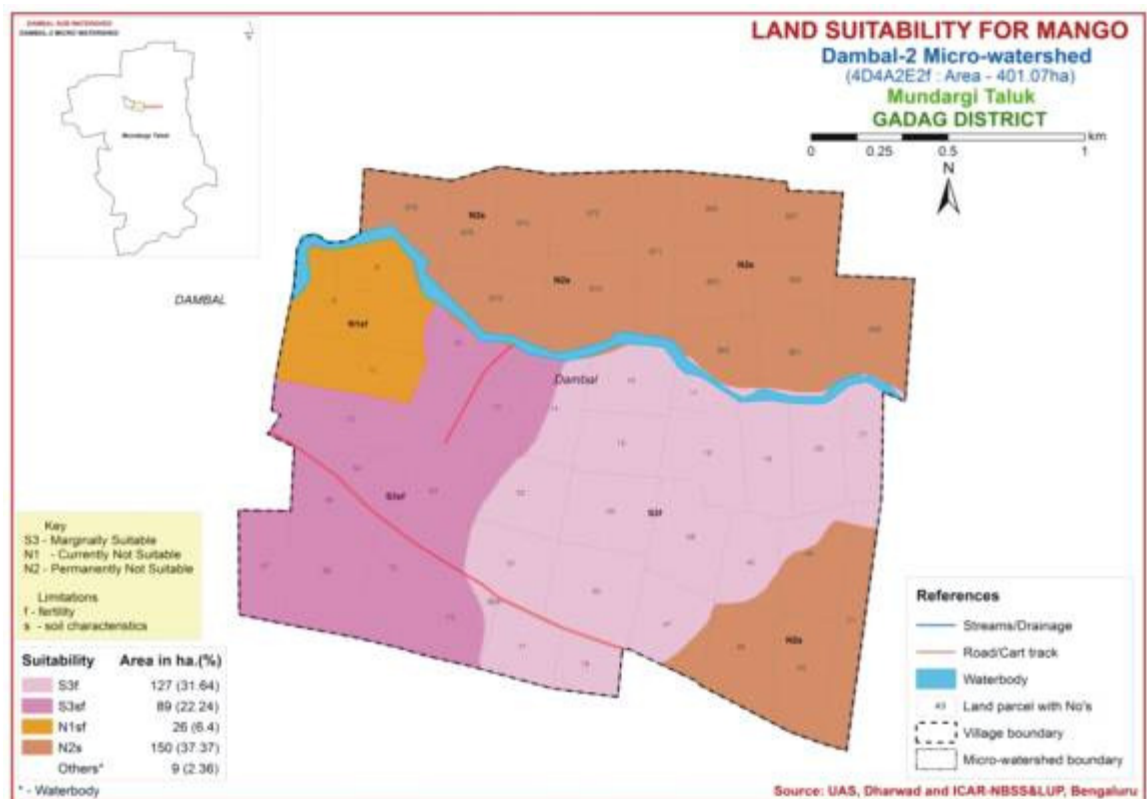


Fig. 19. Soil site suitability of Dabmal-2 micro-watershed for mango

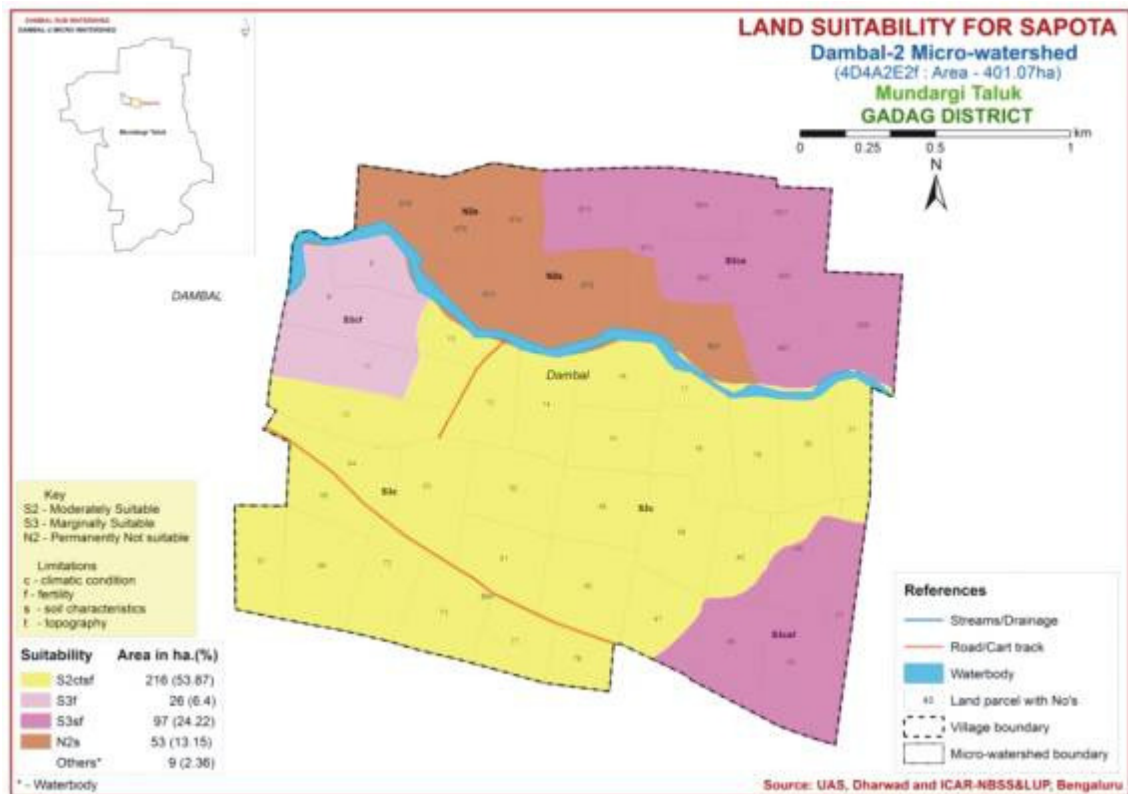


Fig. 20. Soil site suitability of Dabmal-2 micro-watershed for sapota

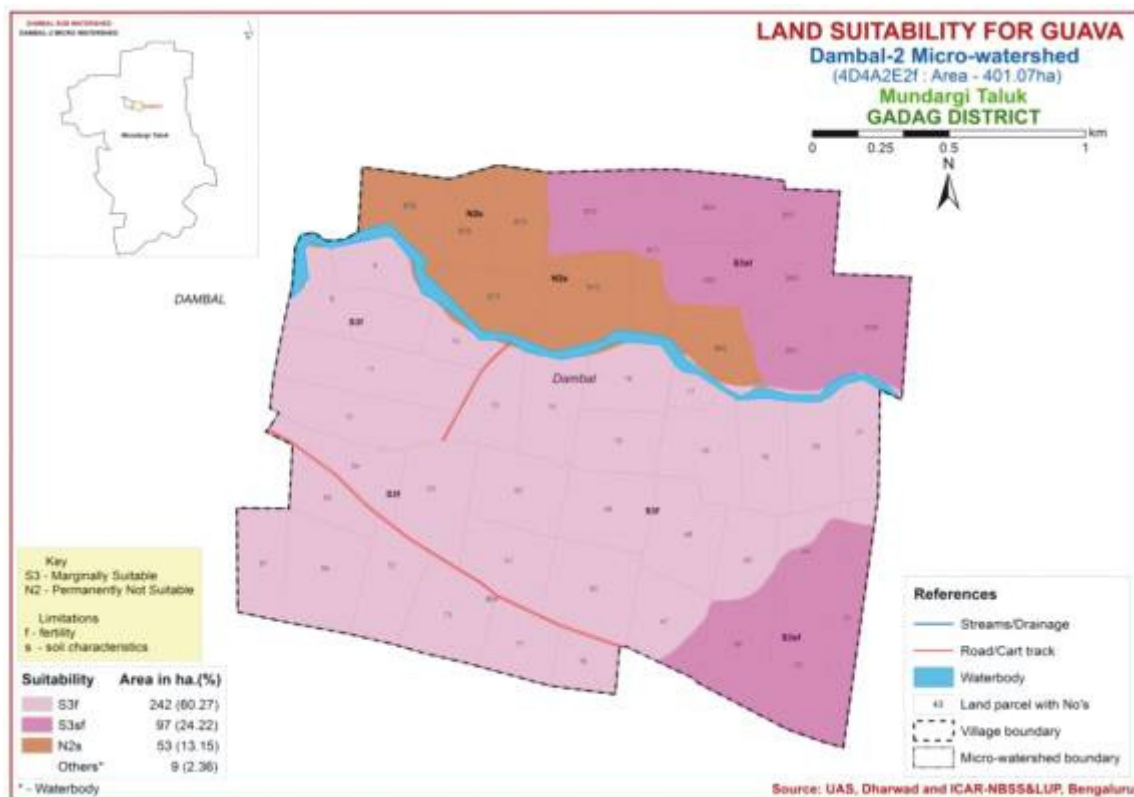


Fig. 21. Soil site suitability of Dabmal-2 micro-watershed for guava

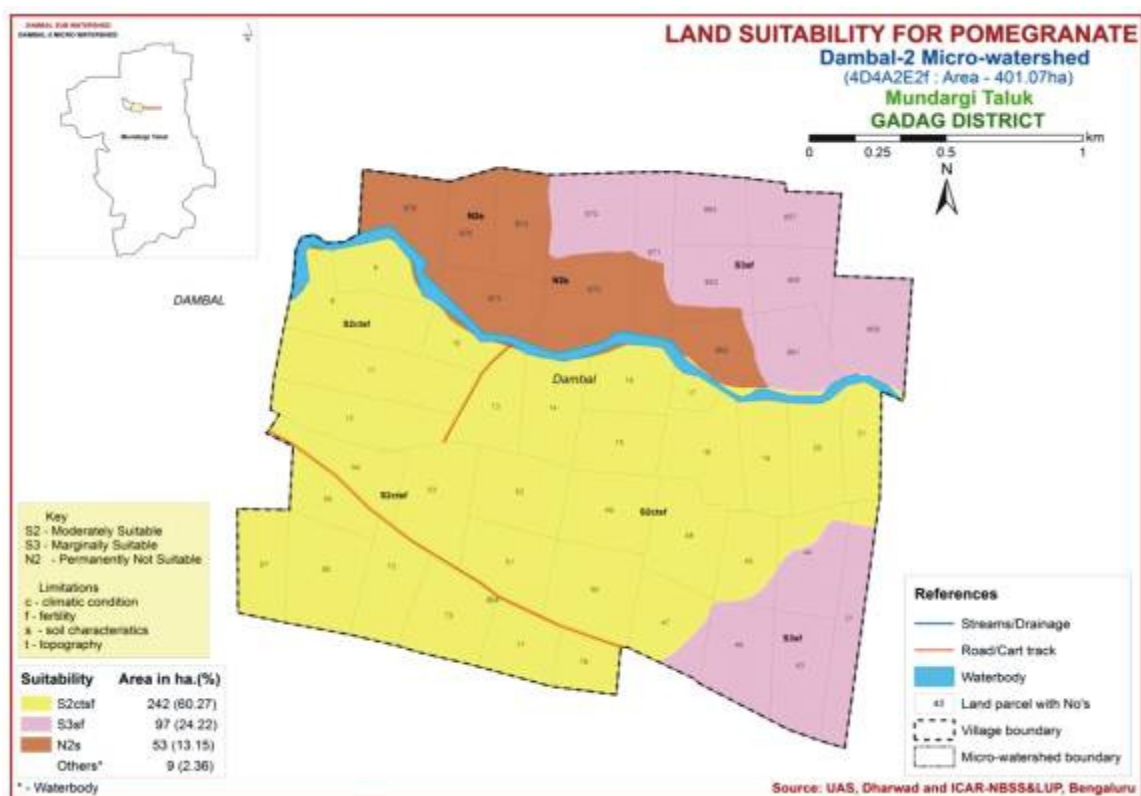


Fig. 22. Soil site suitability of Dabmal-2 micro-watershed for pomegranate

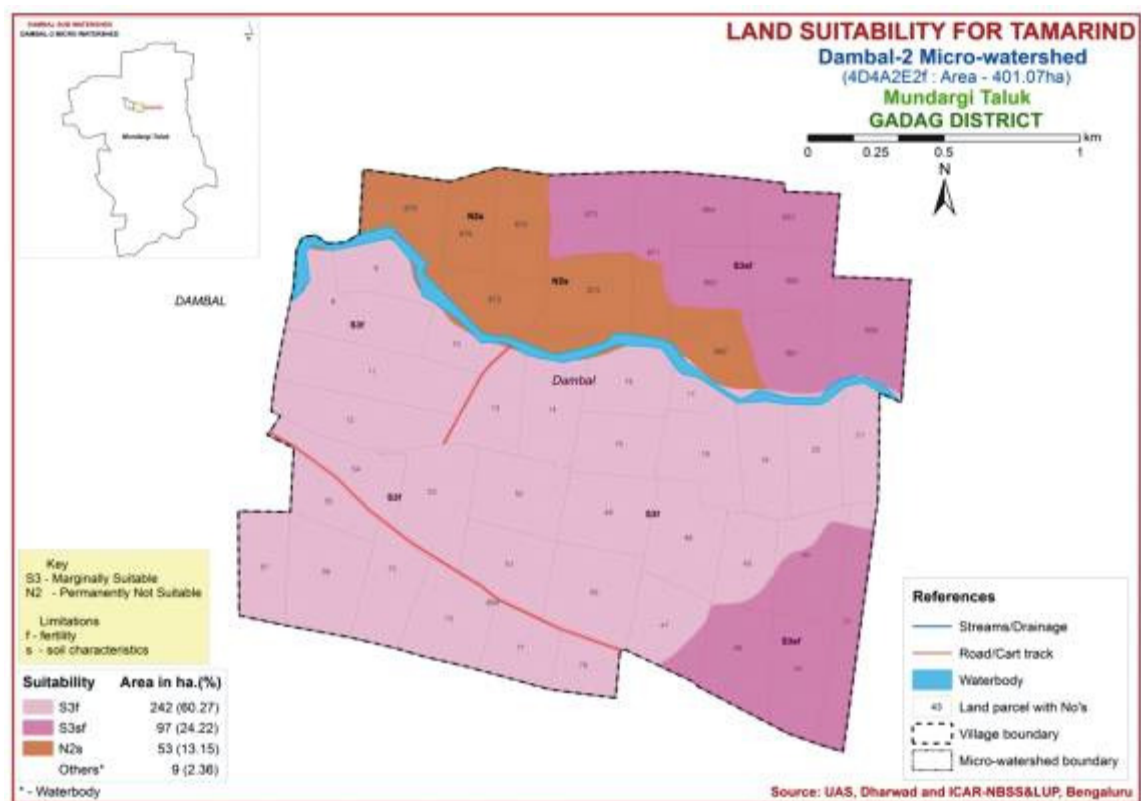


Fig. 23. Soil site suitability of Dabmal-2 micro-watershed for tamarind

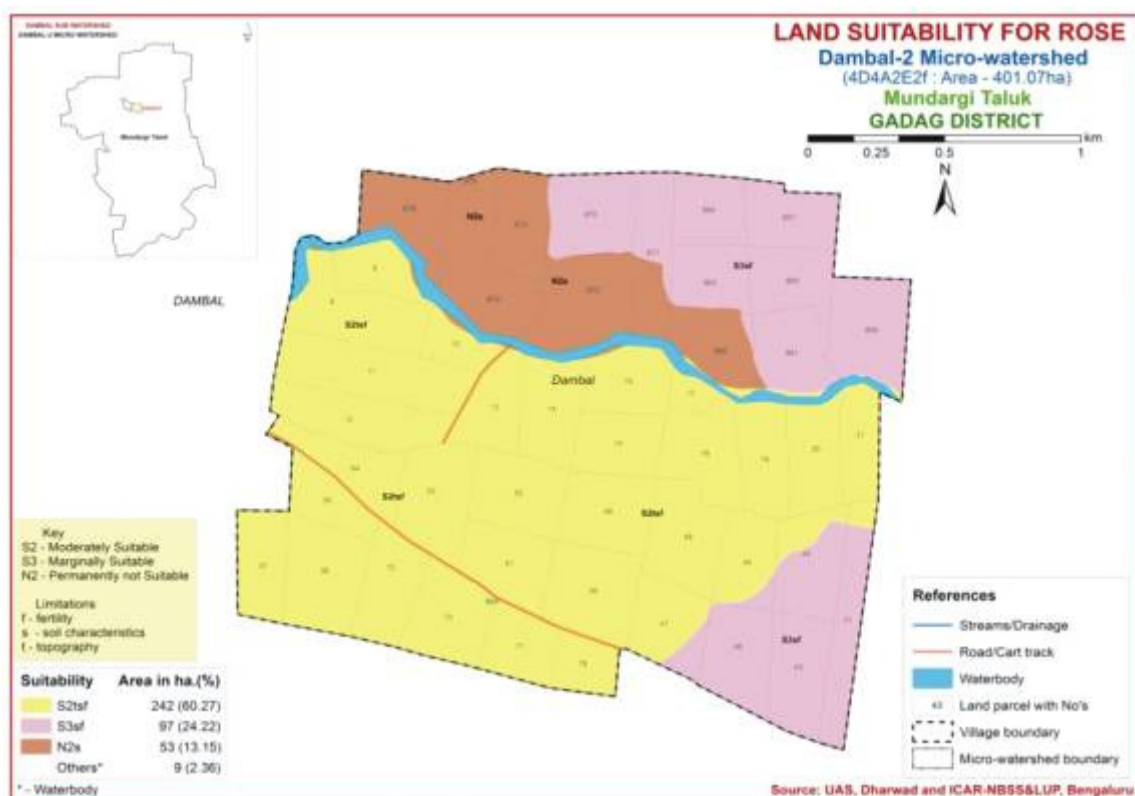


Fig. 24. Soil site suitability of Dabmal-2 micro-watershed for rose

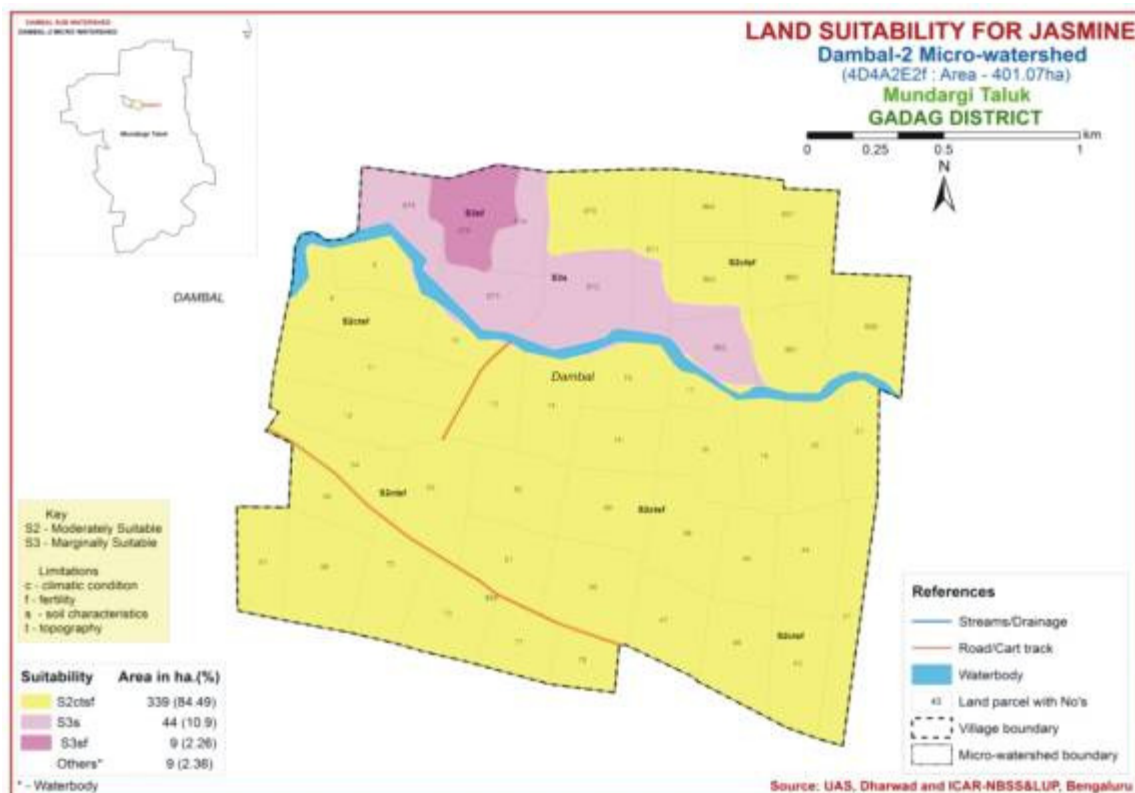


Fig. 25. Soil site suitability of Dabmal-2 micro-watershed for jasmine

5.5.3.18 Pomegranate

Pomegranate adapts to a wide range of climatic conditions. It grows well in plains as well as on hills upto an elevation of 2000 M above MSL. It is a hardy plant that can withstand drought. Soil mapping unit 6 and 7 are unsuitable for pomegranate cultivation (Fig. 22) owing very severe limitation of depth and remaining mapping units are moderately and marginally suitable with slight limitations of climate, drainage and topography. Moderate limitations are depth, texture and pH in study area for pomegranate cultivation. Nagendra (2015) in the soils of Shirol-West-1 micro-watershed of Karnataka.

5.5.3.19 Tamarind

Mapping unit 1, 2, 3, 4 and 5 were marginally suitable with severe limitations of pH and depth whereas mapping units 6 and 7 are permanently not suitable due to severe limitation of depth (Fig. 23). Malavath *et al.* (2013) from Chettind of Sivagangai district of Tamil Nadu.

5.5.3.20 Rose

Mapping unit 1, 2 and 3 was moderately suitable with slight limitations of slope, temperature, CEC, ESP and depth whereas moderate limitations of drainage, texture, pH and CaCO₃. Other mapping units (4 and 5) were marginally suitable with severe limitations of depth and pH. Remaining mapping units 6 and 7 were not suitable for rose cultivations (Fig. 24) with very severe limitation of depth. Similar results were obtained by Nagendra (2015) in the soils of Shirol-West-1 micro-watershed of Karnataka.

5.5.3.21 Jasmine

The mapping units of the study area were moderate to marginally suitable for jasmine cultivation. Mapping units 1, 2, 3, 4 and 5 were moderately suitable owing to slight limitations of slope and ESP. Remaining mapping units 6 and 7 are marginally suitable with severe limitation of depth and pH. Similar results were obtained by Manojkumar Dabi (2011) in the soils of Bastwad micro-watershed of Karnataka (Fig. 25).

Based on the land evaluation exercise carried out in the present study, following crops are listed in different suitable classes.

Mapping unit	Suitability classes			
	Highly suitable	Moderately suitable	Marginally suitable	Not suitable
Dmb-1-m-B-2	-	Sorghum, Wheat, Soybean, Pomegranate, Rose, Jasmine.	Maize, Pearl millet, Bengal gram, Pigeonepea, Green gram Groundnut, Sunflower, Sesamum, Chilli, Sugarcane, Sapota, Guava,Tamarind.	Cotton, Mango.

Dmb-2-m-B-2	-	Sorghum, Rose Wheat, Pearl millet, Bengal gram, Sapota, Pigeonepea, Greengram, Soybean, Sunflower, Sesamum, Pomegranate, Jasmine.	Maize, Groundnut, Cotton, Chilli, Mango, Guava, Sugarcane, Tamarind.	-
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Mapping unit	Suitability classes			
	Highly suitable	Moderately suitable	Marginally suitable	Not suitable
Dmb-3-m-B-2	-	Wheat, Sorghum, Pearl millet, Bengal gram, Pigeonepea, Green gram, Soybean, Sunflower, Sesamum, Sapota, Pomegranate, Rose, Jasmine.	Maize, Groundnut, Cotton, Chilli, Sugarcane, Mango, Guava, Tamarind.	-
Dmb-4-m-B-2	-	Wheat, Sorghum, Soybean, Jasmine.	Maize, Pearl millet, Bengal gram, Pigeonepea, Green gram, Groundnut, Sesamum, Sugarcane, Chilli, Sapota, Guava, Sunflower, Tamarind Pomegranate, Rose.	Cotton, Mango.
Dmb-5-m-B-2-g1	-	Wheat, Sorghum, Pearl millet, Bengal gram, Green	Maize, Pigeonepea, Groundnut, Chilli, Sugarcane, Sapota, Guava, Sunflower,	Cotton, Mango.

		gram, Soybean, Sesamum, Jasmine.	Tamarind, Pomegranate, Rose.	
Dmb-6-f-B-2-g2	-	-	Maize, Bengal gram, Green gram, Pigeonepea, Groundnut, Chilli, Wheat, Sorghum, Pearl millet, Soybean, Jasmine.	Sunflower, Sesamum, Cotton, sugarcane, Mango, Sapota, Guava, Tamarind, Rose, Pomegranate.
Dmb-7-h-B-2-g2	-	-	Maize, Pearl millet, Bengal gram, Green gram, Groundnut, Soybean, Chilli, Jasmine.	Sorghum, Wheat, Pigeonepea, Sapota, Sunflower, Sesamum, Sugarcane, Cotton, Mango, Guava, Pomegranate, Tamarind, Rose.

5.6 Fertility status

5.6.1 Soil reaction

The pH values of surface soil samples ranged from 7.06 to 9.27 their mean and standard deviation were 8.67 and 0.38, respectively. Most of the study area was under alkaline in soil reaction (Fig. 26). The probable reasons about their statuses have earlier been discussed in sections 5.3.1.

5.6.2 Electrical conductivity

The EC values of surface soil samples ranged from 0.10 to 0.73 dS m⁻¹, their mean and standard deviation values were 0.24 and 0.13, respectively. The study area was free from salinity (Fig. 27). The probable reasons about their statuses have earlier been discussed in sections 5.3.2

5.6.3 Organic carbon

All the soils of the study area fall under low to high category. But majority of Dambal-2 micro-watershed was low in organic carbon (Fig. 28). Low organic carbon in the soil is due to low input of FYM and crop residues as well as rapid rate of decomposition due to high temperature. The organic matter degradation and removal taken place at faster rate coupled with low vegetation cover thereby leaving less changes of accumulation of organic matter in the soil. Similar observations were also showed by Nayak *et al.* (2002) in soils of central research station, Bhubaneswar and also same results was made by Nagendra (2015).

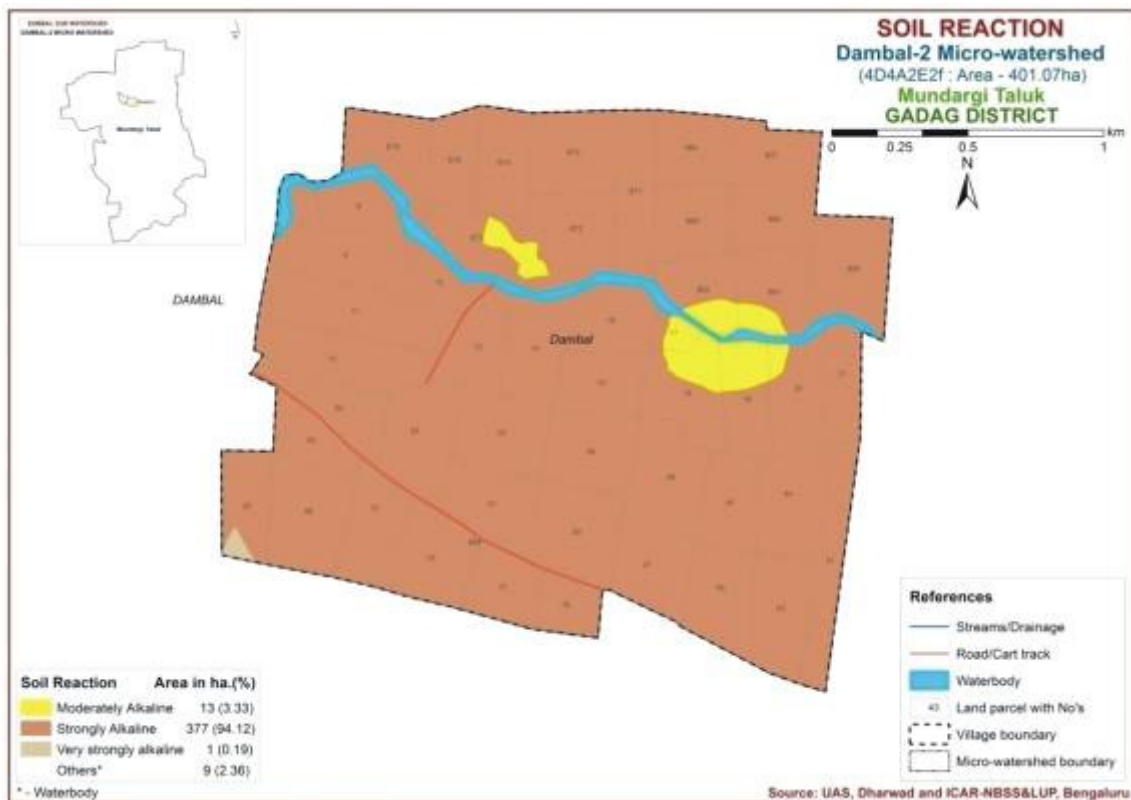


Fig. 27. Electrical conductivity of Dambal-2 micro-watershed

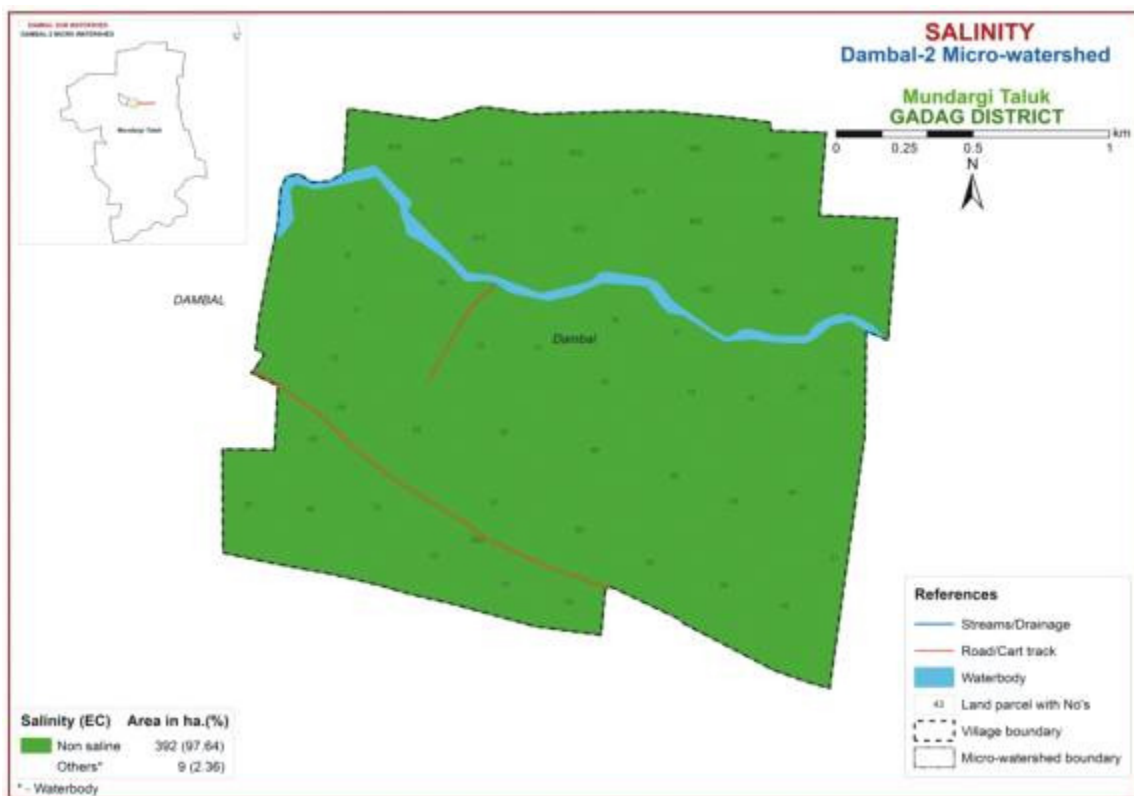


Fig. 28. Organic carbon status of Dambal-2 micro-watershed

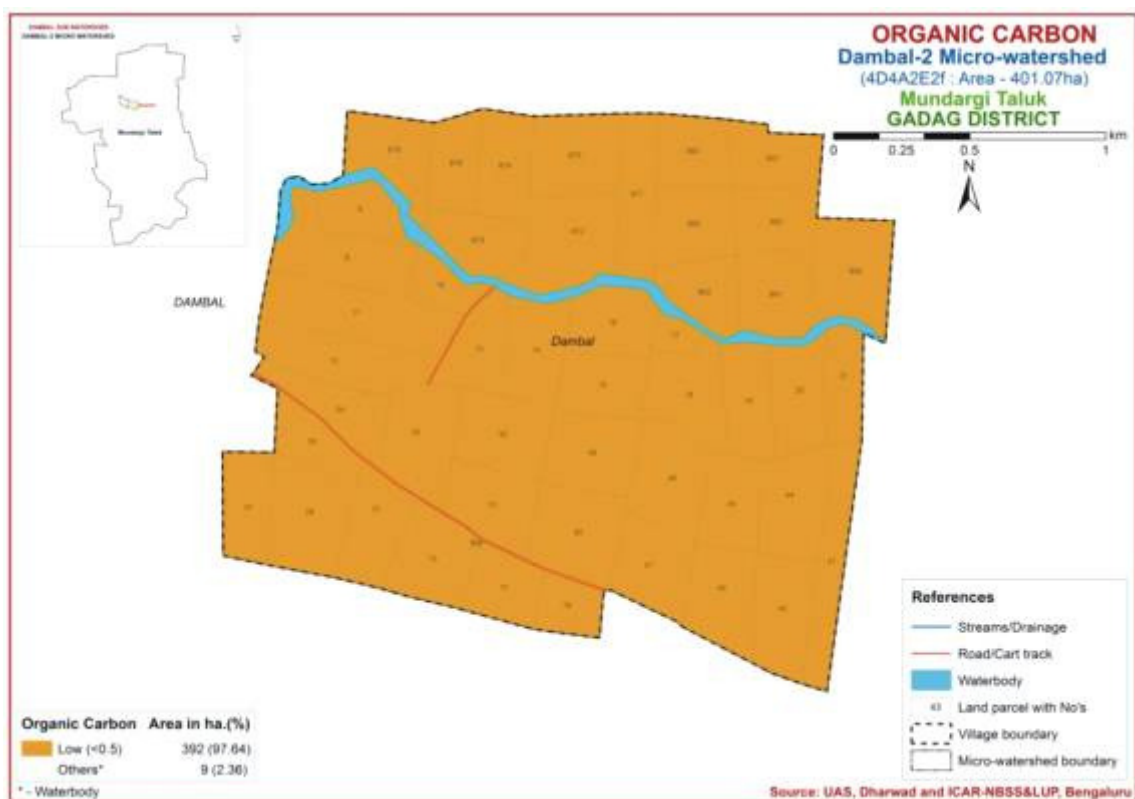


Fig. 29. Available nitrogen status of Dambal-2 micro-watershed

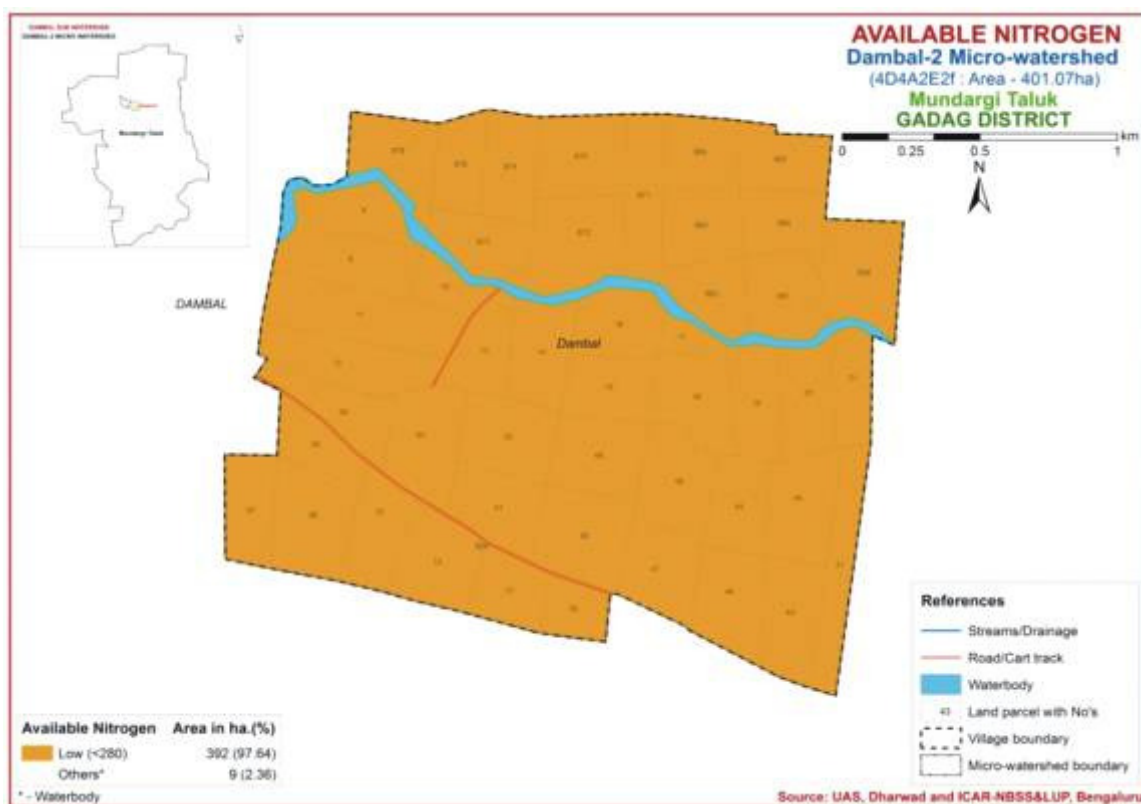


Fig. 30. Available phosphorus status of Dambal-2 micro-watershed

5.6.4 Available nitrogen

The available nitrogen content was low (Fig. 29) in the study area which might be due to low organic matter content in these soils. The variation in N content may be related to soil management, soil application of FYM and fertilizer to previous crop *etc.* (Ashok Kumar, 2000). The total nitrogen content in the soils is dependent on temperature, rainfall and altitude. Another possible reason may also be due to low organic matter content in these areas due to low rainfall and low vegetation facilitate faster degradation and removal of organic matter leading to nitrogen deficiency. Similar observation were made by Vara Prasad Rao *et al.* (2008) in typical pedons of Ramahcandrampuram Mandal in Chittoor district of Andhra Pradesh where the soils were low in available nitrogen. Sharma *et al.* (2008) studied spatial distribution of nitrogen (N) in Amritsar district of Punjab where the content of available N varied from 63 to 170 kg ha⁻¹ and Tumbal and Patil (2015) was also showed same results from Balapur micro-watershed, Koppal district Karnataka.

5.6.5 Available phosphorus

The available phosphorus content was medium (Fig. 30) in the entire watershed. Similarly, low to medium phosphorus (low; 24 per cent area, medium; 76 per cent area) was observed in Mantagani village of north Karnataka (Pulakeshi *et al.*, 2012), same results was observed by Nagendra (2015) in Shirol-West-1 micro-watershed of Gadag district, Karnataka.

5.6.6 Available potassium

The available potassium content in major portion of the study area was under medium and high category (Fig. 31) respectively. But majority of watershed area were high in available potassium content. Black soils show higher values due to predominance of K rich micaceous and feldspars minerals in parent material. Similar results were observed by Ravikumar (2006).

5.6.7 Available sulphur

The available sulphur content was low to medium in the study area (Fig. 32). Low level of available sulphur was recorded due to lack of sulphur addition and continuous removal of sulphur by crops and also the low amount of sulphur in surface samples was mainly because of acid reaction and low EC values. Black soils have gypsum ferrous nature of sulphur which is non-available (Balanagoudar, 1989). Ashok (2001) were found similar results in different agro-climatic zones of Karnataka.

5.6.8 Exchangeable calcium and magnesium

Total area of the study area was sufficient in exchangeable Ca and Mg status (Fig. 33 and 34). All the soils of the study area were high in exchangeable Ca and Mg contents. Ananthanarayana *et al.* (1986) reported higher exchangeable Ca and Mg contents in black soils than red soils. Availability of calcium and magnesium to the crops do not generally present problems in black soils, as these soils are calcareous in nature. The exchangeable Ca and Mg are attributed to the type and amount of clay, present in these soils. These results are in confirmation with the findings of Krishnamurthy (1993) and Dhananjaya (2000) reported the highest values of exchangeable calcium and magnesium were reported in surface and subsurface soils.



Fig. 30. Available phosphorus status of Dambal-2 micro-watershed



Fig. 31. Available potassium status of Dambal-2 micro-watershed

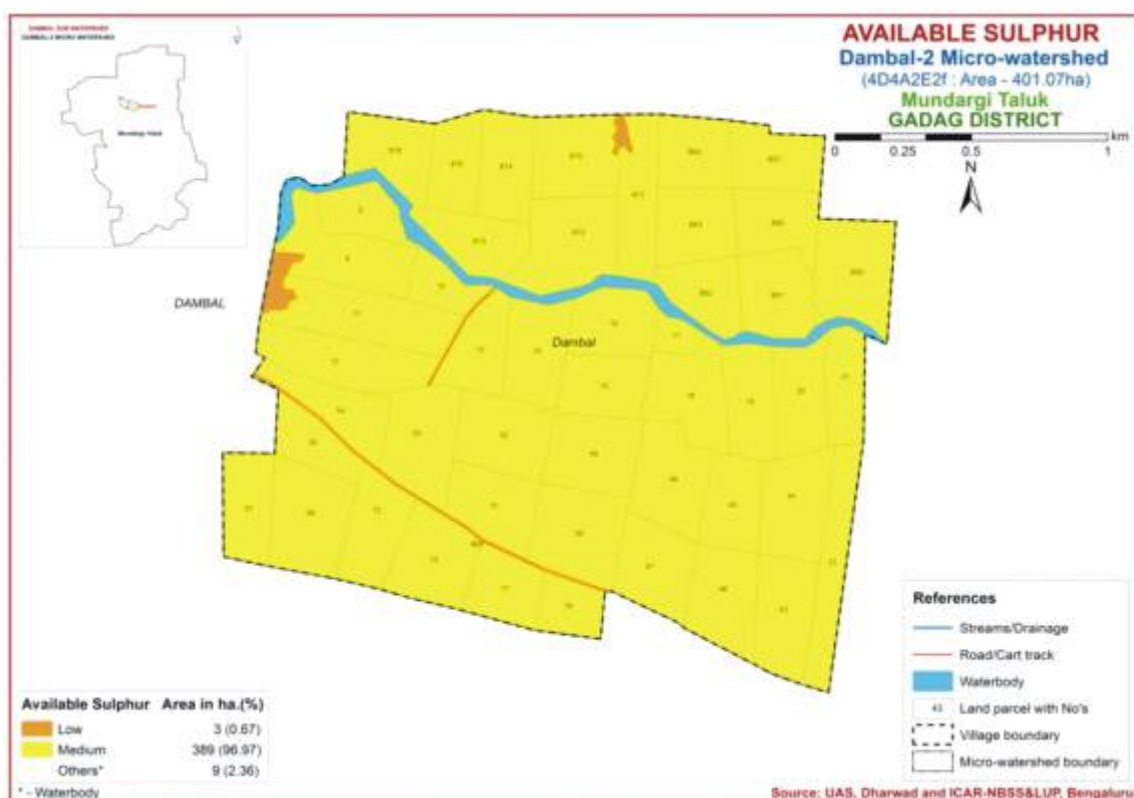


Fig. 32. Available sulphur status of Dambal-2 micro-watershed

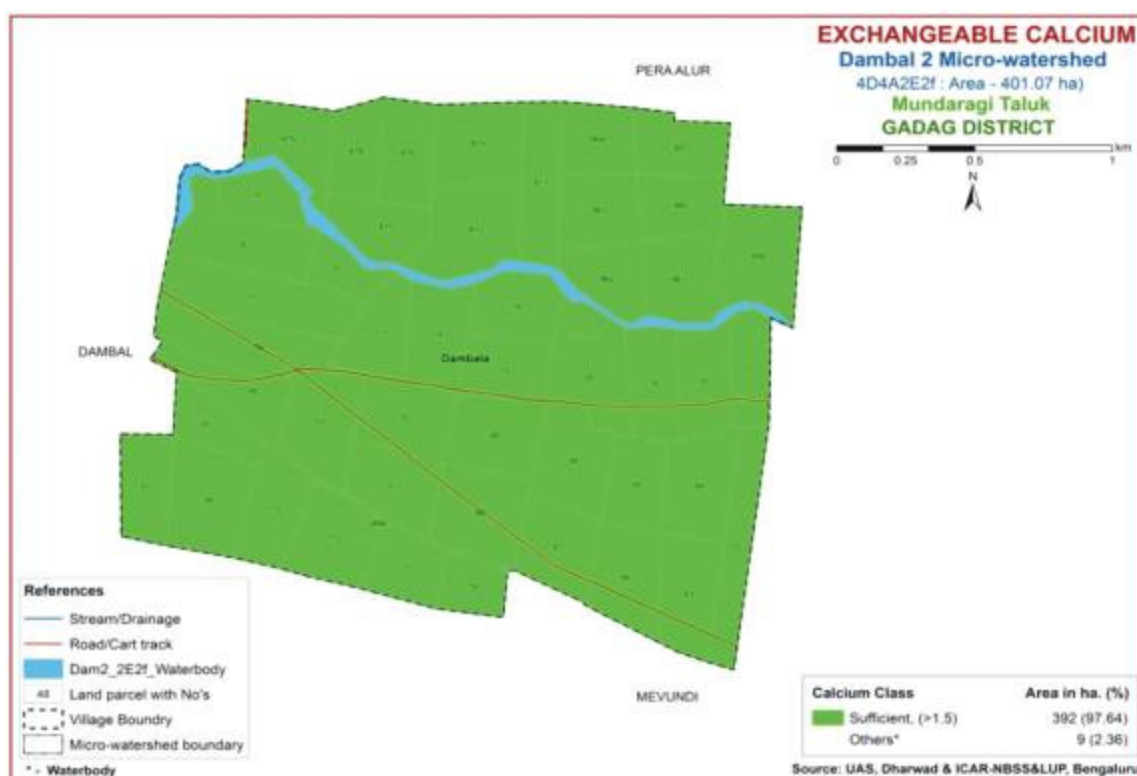


Fig. 33. Exchangeable calcium status of Dambal-2 micro-watershed

5.6.9 Available micronutrients

5.6.9.1 Available zinc

In black soil the available zinc was to be deficient in the entire study area (Fig. 35) except in about 134 ha. Since, the soils are alkaline and rich in CaCO_3 , zinc may be precipitated as hydroxides and carbonates under alkali pH range. Therefore, their solubility and mobility may be decreased resulting in reduced availability was also reported by Vijayshekar *et al.* (2000) and Ravikumar (2006) in Malaprabha right bank command area of Karnataka.

5.6.9.2 Available iron

In entire Dambal-2 micro-watershed area was deficient in Fe status. (Fig. 36). In black soils, low Fe content may be due to precipitation of Fe^{2+} by CaCO_3 and decrease the availability. Similar results were also observed by Ravikumar (2006). Similar results were noticed in Mantagani village of north Karnataka, Pulakeshi *et al.* (2012).

5.6.9.3 Available copper

In entire Dambal-2 micro-watershed area was sufficient in Cu status. (Fig.37). Raghupathi (1989) reported that available copper content in north Karnataka soils ranged from 0.4 to 1.2 ppm. Similar results were also observed by Satyavathi and Suryanarayana Reddy (2004a).

5.6.9.4 Available manganese

In black soils, the available manganese was found to be sufficient in study area (Fig. 38). Sufficient content of manganese content was observed in Upper Krishna Command Area by Yeresheemi *et al.* (1997). Similar findings were also reported by Vijayshekar *et al.* (2000).

5.6.9.5 Available boron

In Dambal-2 micro-watershed area was low to medium in B status. (Fig.39). Majority of area was low (74.5 per cent of TGA) to medium (23.14 per cent of TGA) in available boron category. This was due to low organic matter and alkaline to strongly in soil reaction. Same observation was showed by Kebedel and Hollington (2010) and Sarkar *et al.* (2008).

Practical utility of the results

- The thematic maps generated on suitability of crops for different mapping units will help to enhance the efficiency of natural resources and achieve higher crop productivity and production.
- The thematic maps generated on nutrients status of different mapping units will help to identify the constraints in plant nutrition. Suitable fertilizer recommendation can be made to overcome the nutrients constraints and enhance crop productivity.
- The land degradation database generated for different mapping units will be helpful to the planners / farmers to take up scientific soil and water conservation practices.
- Based on the constraints identified leading to low soil quality, recommendations on proper crop residue management and suitable tillage practices may be made.

Future line of work

1. Studies on genesis and characterization of soil minerals
2. Assessment of soil quality under different cropping systems
3. Studies on crop response to identified soil constraints

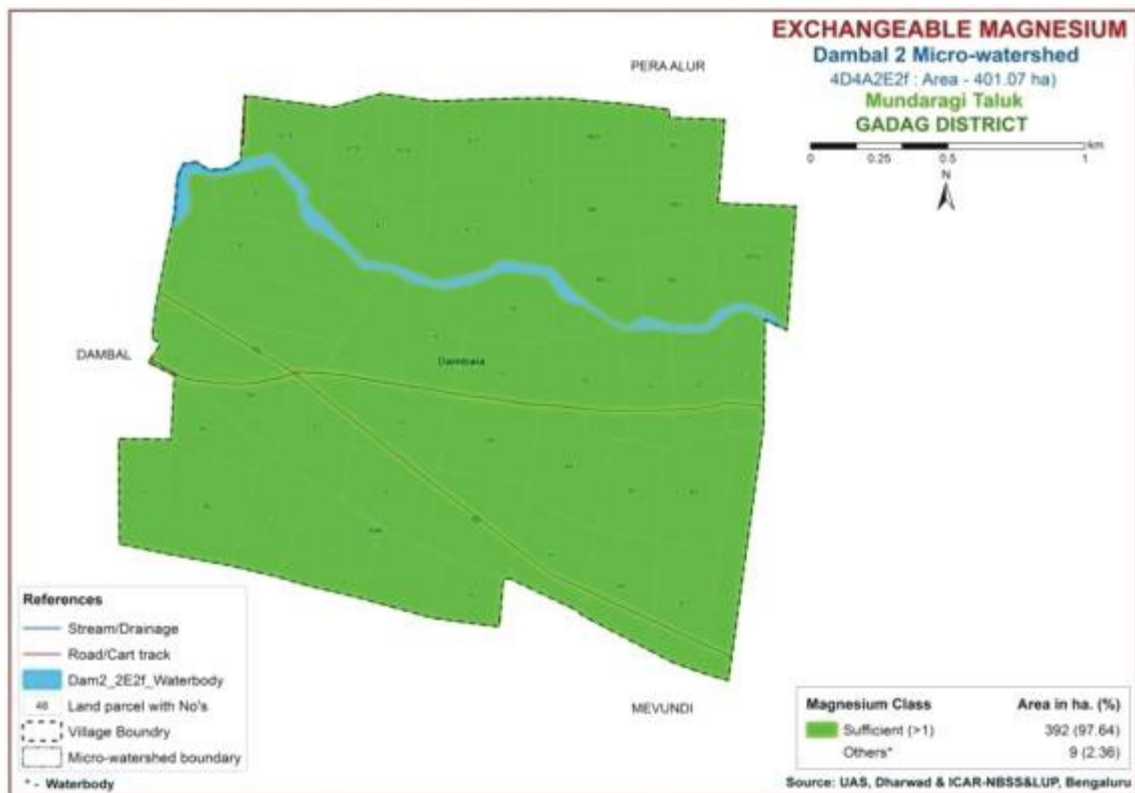


Fig. 34. Exchangeable magnesium status of Dambal-2 micro-watershed

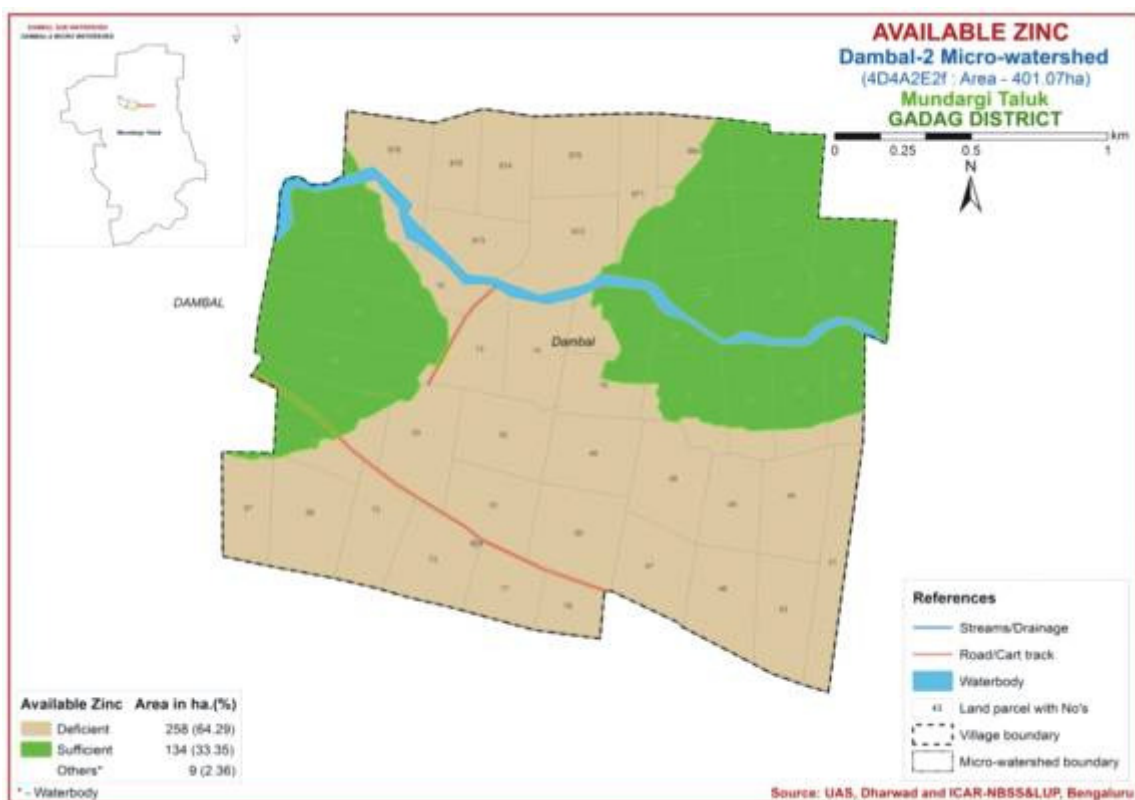


Fig. 35. Available zinc status of Dambal-2 micro-watershed

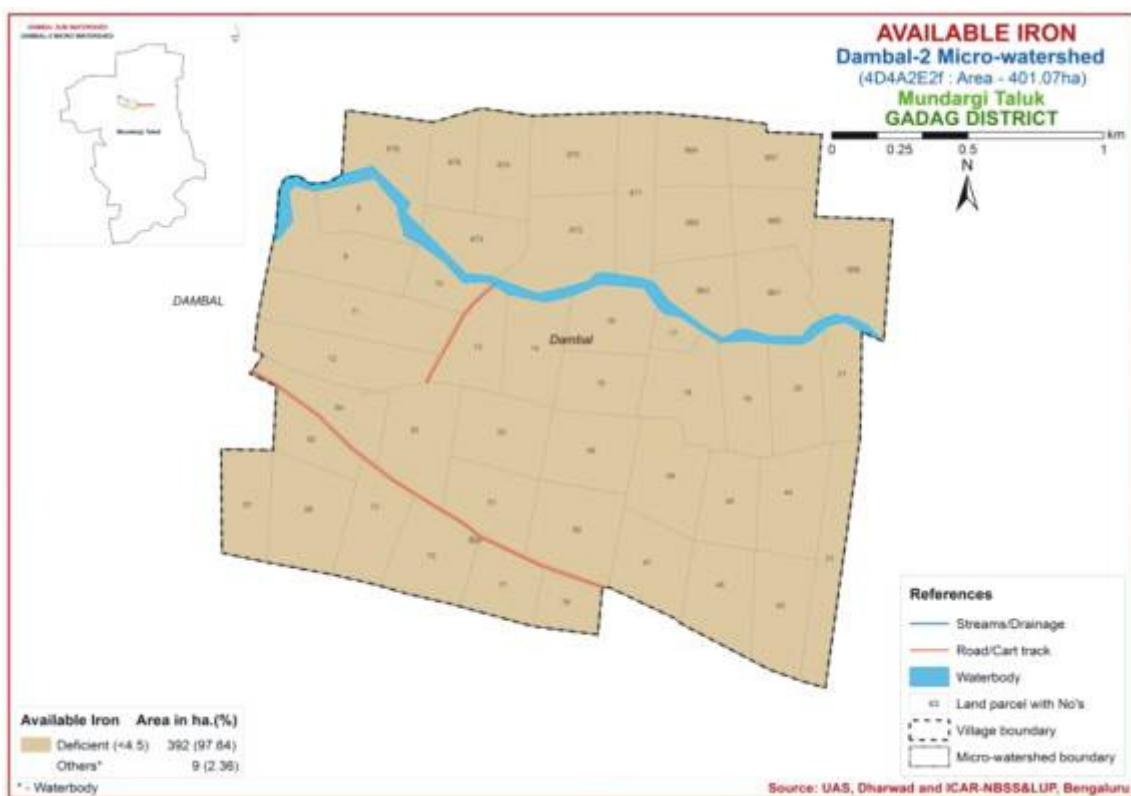


Fig. 36. Available iron status of Dambal-2 micro-watershed



Fig. 37. Available copper status of Dambal-2 micro-watershed



Fig. 38. Available manganese status of Dambal-2 micro-watershed

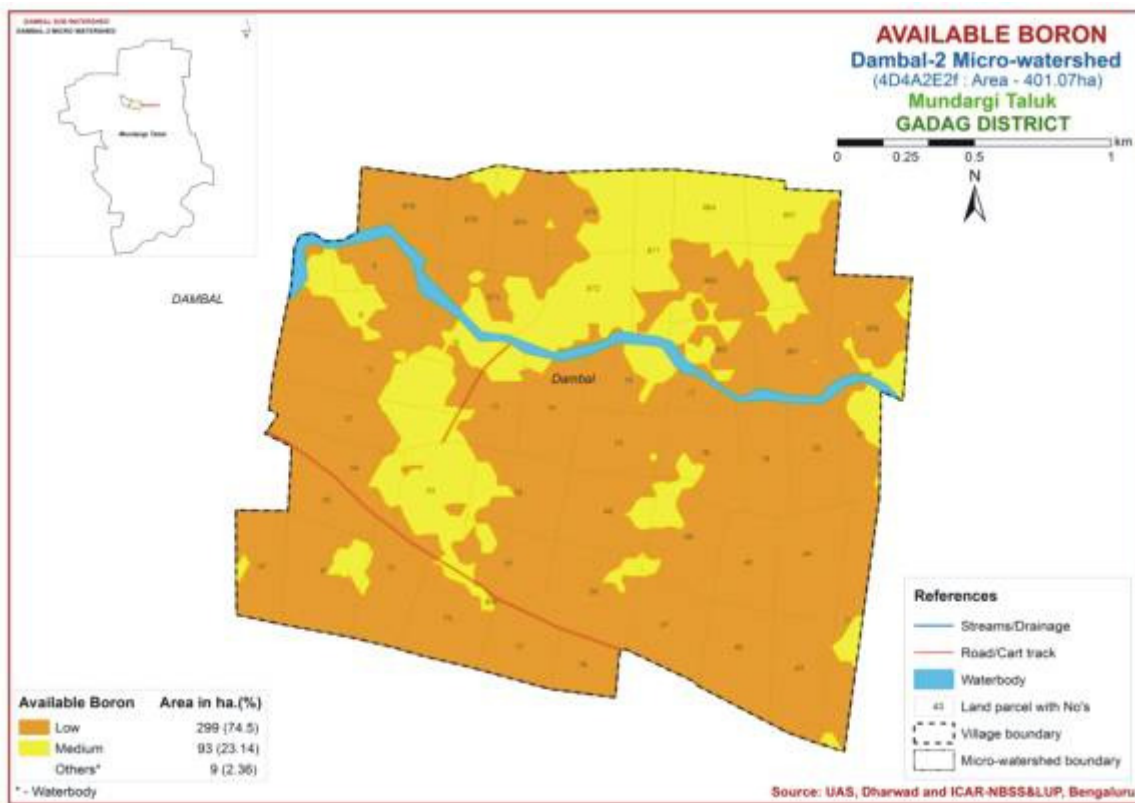


Fig. 39. Available boron status of Dambal-2 micro-watershed

6. SUMMARY AND CONCLUSIONS

A study was undertaken to characterize and classify the soils of a Dambal-2 micro-watershed in agro-climatic zone-3 of Karnataka in order to assess their land capability, irrigability and suitability for various crops and also to assess soil fertility constraints of the area.

An exhaustive field survey was carried out to know the type and distribution of soil for its mapping. Eleven profiles in the micro-watershed area were studied for their morphological, physical and chemical properties and classified upto family level and identified seven series (Dmb). The identified series are mapped into 7 mapping units of phases of soil series. Each mapping unit was evaluated for land capability. Soil site suitability for some important crops was also evaluated in the micro-watershed. Sixty-five surface samples were drawn at 250 meter grid interval from the farmers' fields and analyzed for their fertility status. The findings of the investigation are summarized below.

Depth of the soils ranged from very shallow to very deep. There was gradation in colour from very dark grayish brown to very dark grey in all soils. Except pedons (8, 9 and 11) shown dark brown to very dark brown. The structure was predominantly sub-angular blocky in all pedons. The consistency was slightly hard to hard when dry and friable to firm when moist. Very sticky and very plastic consistency was observed in almost all pedons when wet.

Soils of Dambal-2 were clay in texture except pedon 11 viz., sandy clay loam in texture and distribution pattern of clay content increased upto last depth. The distribution of silt and sand content did not follow definite trend in the pedons under the study. The maximum water holding capacity of all profiles shown increase in water holding capacity with depth, due to increase in clay content. The bulk density increased with depth due to rapid decomposition, mineralization and presence of low organic matter.

The pH of the profiles was neutral to strongly alkaline in nature. The pH increased with increasing depths in most of the pedons. However, electrical conductivity indicates non-saline nature of soils and did not show any specific relationship with depth. The organic carbon content was low to high, but majority area were low OC, decreasing trends with depth were observed in all soil pedons.

Lime concretions were observed in the pedons 2, 4 and 10 except in pedons (1, 3, 5, 6, 7, 8, 9 and 11) lime concretions were absent. Among exchangeable cations, calcium and magnesium were dominant cations followed by sodium and potassium in all the pedons. The cation exchange capacity values were high and followed the distribution pattern of clay content in all pedons.

The family level classification of these soils according to revisions of US Soil Taxonomy revealed that pedons under study belonged to orders *Inceptisols* and *Entisols*.

The overall classification of selected pedons are given below:

Pedon No.	Soil classification
1, 2, 4, 5, 6,7, 8 and 10	Fine, mixed, super active, isohyperthermic, <i>Typic Haplustepts</i> .
3 and 9	Clayey, mixed, super active, isohyperthermic, <i>Lithic Ustorthents</i> .
11	Fine-loamy, mixed, super active, isohyperthermic, <i>Lithic Ustorthents</i> .

Seven soil series were identified in the study area and were mapped into seven different mapping units as phases of soil series. Land capability classification was carried out for the study area based on the inherent soil characteristics, external land features and environmental factors. In the land capability map, the different classes namely IIItsf and VIIsf were differentiated and mapped.

Based on the soil suitability criteria, the mapping units were evaluated for growing 21 major crops of the area. The suitability evaluation revealed that more than 50 per cent of the area was suitable for pearl millet (S2, 69.26 per cent TGA) and sorghum (S2, 84.49 per cent TGA), wheat (S2, 84.49 per cent TGA), while maize was least suitable (S3, 97.64 per cent TGA). Among pulse crops majority crops are moderately suitable, soybean (S2, 84.49 per cent TGA) and chickpea (S2, 69.29 per cent TGA), green gram (S2, 69.26 per cent TGA) and pigeon pea (S2, 53.87 per cent TGA). Among oilseed crops, sunflower (S2, 53.87 per cent TGA) and sesame (S2, 69.26 per cent TGA) were moderately suitable, while groundnut (S3, 97.64 per cent TGA) was marginally suitable. Among commercial crops like sugarcane, cotton and chilli were marginally suitable. Among horticultural crops pomegranate (S2, 60.27 per cent TGA) and sapota (S2, 53.87 per cent TGA) was moderately suitable, while mango, guava and tamarind were least suitable. Among floricultural crops like jasmine (S2, 84.49 per cent TGA) and rose (S2, 60.27 per cent TGA) were moderately suitable for cultivation.

The soil samples collected at 250 meter grid interval, 0-30 cm depth from farmers' field in the study area were analyzed for pH, EC, OC, available nitrogen, phosphorus, potassium, calcium, magnesium, sulphur and micronutrients. The pH of soil samples ranged from 7.06 to 9.27 indicating neutral to strongly alkaline in reaction and soils are free from salinity or non saline in nature. Soil organic matter content was low to high in these soils. Available nitrogen was low, available phosphorus and sulphur were low to medium, whereas available potassium was medium to high in these soils and exchangeable calcium and magnesium were sufficient. Regarding available micronutrients, zinc except (33.35 per cent TGA) and iron were deficient in these soils but copper and manganese was sufficient. Whereas, three-fourth of the area was low in available boron and remaining area was medium in these soils.

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Appendix I: Long-term average monthly meteorological data (2001-2014) of Dambal-2 micro-watershed in Gadag district

Month	Rainfall (mm) (2001-2013)	Rainfall (mm) (2014)	Maximum temperature (°C) (2013-14)	Minimum temperature (°C) (2013-14)	Relative humidity (%) (2013-14)
January	2.0	0.0	30.8	14.8	48
February	1.0	0.0	31.0	18.9	49
March	6.0	18.8	36.4	20.0	57
April	38.0	38.9	38.2	22.1	44
May	79.0	83.3	37.5	21.0	43
June	89.0	99.5	33.4	22.3	61
July	73.0	92.1	33.2	19.9	71
August	82.0	203.8	29.8	20.1	69
September	129.0	96.1	30.1	20.6	68
October	139.0	96.7	29.8	18.9	57
November	34.0	28.3	30.0	16.6	60
December	8.0	17.3	28.0	15.0	54
Total	671	774.8	32.85	19.18	56.75

Appendix II: Geographical locations of surface soil samples

Sl. No.	Latitude	Longitude	Elevation (m)	Sl. No.	Latitude	Longitude	Elevation (m)
01	15.284	75.791	577.80	37	15.293	75.793	582.10
02	15.284	75.793	579.45	38	15.292	75.796	582.12
03	15.283	75.800	571.17	39	15.293	75.798	575.38
04	15.282	75.803	570.51	40	15.293	75.800	569.46
05	15.282	75.803	575.12	41	15.293	75.802	573.50
06	15.287	75.780	590.89	42	15.296	75.784	584.08
07	15.285	75.785	588.11	43	15.295	75.786	578.47
08	15.285	75.787	585.77	44	15.295	75.788	578.21
09	15.286	75.790	583.10	45	15.295	75.791	583.62
10	15.286	75.793	577.37	46	15.296	75.793	571.11
11	15.286	75.795	578.07	47	15.295	75.796	569.54
12	15.286	75.798	579.11	48	15.296	75.798	569.58
13	15.286	75.800	580.17	49	15.295	75.800	569.46
14	15.285	75.802	573.90	50	15.295	75.802	567.42
15	15.291	75.781	589.33	51	15.298	75.784	577.98
16	15.289	75.782	585.99	52	15.298	75.786	581.01
17	15.288	75.788	578.42	53	15.297	75.788	574.82
18	15.289	75.790	576.15	54	15.297	75.790	579.34
19	15.288	75.793	573.78	55	15.297	75.792	583.84
20	15.288	75.795	571.95	56	15.297	75.795	577.18

Contd....

Sl. No.	Latitude	Longitude	Elevation (m)	Sl. No.	Latitude	Longitude	Elevation (m)
21	15.289	75.798	573.39	57	15.297	75.797	580.52
22	15.288	75.801	570.10	58	15.297	75.800	578.87
23	15.288	75.802	573.68	59	15.300	75.784	583.31
24	15.291	75.783	590.01	60	15.300	75.787	584.02
25	15.291	75.785	588.87	61	15.300	75.791	587.21
26	15.291	75.788	574.88	62	15.300	75.793	581.80
27	15.291	75.791	574.64	63	15.301	75.795	584.60
28	15.291	75.793	581.23	64	15.300	75.798	579.96
29	15.291	75.796	578.06	65	15.300	75.800	575.60
30	15.291	75.798	580.73				
31	15.290	75.800	577.30				
32	15.291	75.802	575.00				
33	15.293	75.784	590.10				
34	15.293	75.785	581.08				
35	15.293	75.788	581.99				
36	15.292	75.784	582.44				

Appendix III: Criteria of land capability classification

Land Characteristics	Class-I	Class-II	Class-III	Class-IV	Class-V	Class-VI	Class-VII	Class-VIII
Topography(t)								
Slope (%)	0-1	1-3	3-8	8-15	Up to 3	15-35	35-50	>50
Erosion	Nil	Slight	Moderate	Severe	Nil	Nil	V. severe	
Wetness (w)								
Flooding	Nil (F0)	Nil (F0) (F0/F1)	Nil to slight (F1/F2)	Slight to mod. (F3)	Moderate to severe (F0/F3)	Nil to severe, (F0/F4)	Nil to V. severe	-
Drainage (l)	Well	Mod. well	Imperfect	Poor	V. poor	Excessive	Excessive	Excessive
Physical soil condition (s)								
Surface Texture	Loam	sil & cl	sl & c	scl	s, c (m)	ls, cl	ls, s, c	ls, c, c
Soil depth (cm)	>150	150-100	100-50	50-25	-	25-10	25-10	<10
Surface stoniness (%)	<1	1-3	3-5	5-8	8-15	15-40	40-75	>75
Sub-surface Coarse. Frg.(%)	<15	<15	15-35	35-50	50-75	50-75	50-75	>75
Fertility (f)								
CEC cmol (p⁺) kg⁻¹	40-16	16-12	16-12	-	-	-	-	-
BS (%)	80+	80+	80-50	50-35	50-35	35-15	<15	-
OC (0-15cm) (%)	>1	0.75-1.0	0.5-0.75	<0.5	<0.5	-	-	-
Salinity EC (dS/m)	<1	2-4	2-4	4-8	8-15	15-35	35-50	>50

Appendix IV: Criteria of land irrigability classification

Land irrigability classes						
Land characteristics	S1 (suitable)		S2 (moderate)	S3 (marginal)	N1 (not-suitable)	N2 (not suitable)
	Class-I	Class-1	Class-2	Class-3	Class-4	Class-5
Topography (t)						
Slope (%)	<1	1-3	3-5	5-10	10-15	>25
Erosion	Nil	Slight	Moderate	Severe	v. severe	Very severe
Wetness(w)						
Drainage	Well	Mod. well	Imperfect	Poor	V. poor	Excessive
Drainage outlets	Suitable outlets available			Suitable outlets not available		
Physical soil condition (s)						
Surface texture	Sandy loam to clay loam	Loamy sand , clay	Sand, clay	Sand, clay	Any texture	Any texture
Effective Soil depth (cm)	>90	45-90	22.5-45	7.5-22.5	<7.5	<7.5
Rock out crops (m) apart	40	20	15	5	<5	
Sub-surface Coarse. Frg.(%)	<5	5-15	15-35	35-65	>65	>65
Chemical parameters (f)						
EC	0-4	4-8	8-16	16-30	>30	>30
ESP (%)	0-5	5-15	15-25	25-45	>45	>45
CaCO ₃ (%)	0-5	5-15	15-30	30-50	>50	

Appendix V: Soil-site suitability criteria (crop requirements) for wheat

Soil site characteristics			Rating			
		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Climatic regime	Mean temperature in growing season	°C	20-25	26-28 18-19	29-34 14-17	<14 >34
Land quality	Land characteristics					
Moisture availability	Length of growing period	Days	>150	120-150	90-120	<90
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained to moderately well drained	Imperfectly drained	Poorly drained	Very poorly drained; excessively drained
Nutrient availability	Texture	Class	l, cl, sil, scl	sc, sic, c, ls, sicl, sl	C ⁺ (45-60%)	S, c ⁺⁺ (>60%)
	pH	1:2.5	6.5-7.5	7.6-8.5; 5.5-6.4	8.6-10; 4.5-5.4	<4.5; >10
	OC	%	0.6-0.7	0.5-0.6	0.3-0.5	<0.3
Rooting conditions	Effective soil depth	cm	65-100	65-50	50-25	<25
	Stonnines	%	<15	15-35	>35	
Soil toxicity	Salinity (EC saturation extract)	dS m ⁻¹	<4.0	4.0-6.0	>6.0	
	Sodicity (ESP)	%	<15	15-30	30-40	>40
Erosion hazard	Slope	%	<3	3-<5	5-10	>10

Source; Naidu *et al.* (2006)

Appendix VI: Soil-site suitability criteria (crop requirements) for maize

Soil site characteristics		Rating				
		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Climatic regime	Mean temperature in growing season	°C	21-32	33-38 15-20	39-40 <15	
	Total rainfall	mm	900-100	750-900	500-750	<500
Land quality	Land characteristics					
Moisture availability	Length of growing period	Days	>100	100-80	60-80	
Oxygen availability to roots	Soil drainage	Class	Well drained	Mod. To imperfectly	Poorly/Excessively	V. poorly
Nutrient availability	Texture	Class	l, cl, scl, sil	Sl, sicl, sic (c(n-s))	C (s-s), ls	
	pH	1:2.5	5.5-7.5	7.6-8.5 5.0-5.4	8.6-9.0 <5.0	
	CEC	c mol (p ⁺) kg ⁻¹	>20	15-20	10-15	
	OC	%	High	Medium	Low	
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Stoniness	%	Non gravelly	15-35	35-50	>50
Soil toxicity	Salinity (EC saturation extract)	dS m ⁻¹	Non saline	1.0-2.0	2.0-4.0	
	Sodicity (ESP)	%	Non sodic	10-15	>15	
Erosion hazard	Slope	%	<3	3.5	5-8	

Source; Naidu *et al.* (2006)

Appendix VII: Soil-site suitability criteria (crop requirements) for sorghum

Soil site characteristics		Rating				
		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Climatic regime	Mean temp. in growing season	°C	26-30	31-34 24-25	35-40 20-23	>40 <20
	Mean max. temp. in growing season	°C	31-33	33-35	>35	-
	Mean min. temp. in growing season	°C	20-18	18-15	<15	-
	Mean RH in growing season	%	50-70	50-40	<40	-
	Total rainfall	mm	650-850 >850	650-550	450-550	<450
	Rainfall in growing season	mm	500-700	400-500	300-400	<300
Land quality	Land characteristics					
Moisture availability	Length of growing period	Days	120-150	120-90	<90	-
	AWC	mm/m	150-200	100-150	50-100	<50
Oxygen availability to roots	Soil drainage	Class	Well to moderate	Imperfect	Poor and excessive	Very poor
	Water logging in growing season	Days	2-3	3-4	4-5	>5
Nutrient availability	Texture	Class	c, cl, sicl, sc	l, sil, sic	sl, ls	s, fragmental skeletal
	pH	1:2.5	6.0-8.0	5.5-5.9 8.1-8.5	<5.5 8.6-9.0	>9.0
	CEC	c mol (p ⁺) kg ⁻¹	30-20	20-10	<10	
	BS	%	80-50	50-35	<35	
	CaCO ₃ in root zone	%	5-10	10-25	>25	
	OC	%	0.50-0.75	0.50-0.20	<0.20	
Rooting conditions	Effective soil depth	cm	100-75	50-75	30-60	>30
	Stonnes	%	5-15	15-30	30-60	>60
	Coarse fragments	Vol%	5-15	15-40	40-75	>75
Soil toxicity	Salinity (EC saturation extract)	dS m ⁻¹	2-4	4-8	8-10	>10
	Sodicity (ESP)	%	5-8	8-10	10-15	>15
Erosion hazard	Slope	%	2-3	3-8	8-15	>15

Source; Naidu *et al.* (2006)

Appendix VIII: Soil-site suitability criteria (crop requirements) for pearl millet

Soil site characteristics			Rating			
		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Climatic regime	Mean temperature in growing season	°C	28-32	33-38 24-27	39-40 20-23	<20
	Total rainfall	mm	500-750	400-500	200-400	<200
Land quality	Land characteristics					
Moisture availability	Length of growing period	Days	>90	70-<90	50-<70	
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately well drained	Imperfectly drained; poorly drained	
Nutrient availability	Texture	Class	sl, l, scl, sil, cl	ls, c, sicl, sc, c<45	c>45% (SS), s	
	pH	1:2.5	6.0-8.0	5.0-5.9; 8.1-8.5	4.5-4.9; 8.6-9.5	
	CaCO ₃ in root zone	%	<5	5-10	10-25	>25
	OC	%	0.50-0.75	0.50-0.20	<0.20	
Rooting conditions	Effective soil depth	cm	>75	51-75	25-50	
	Stoniness	%	<15	15-35	>35-50	>50
	Coarse fragments	Vol %				
Soil toxicity	Salinity (EC saturation extract)	dS m ⁻¹	<1.0	1.0-2.0	2.0-4.0	
	Sodicity (ESP)	%	<15	15-20	20-35	
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Source; Naidu *et al.* (2006)

Appendix IX: Soil-site suitability criteria (crop requirements) for chickpea

Soil site characteristics		Unit	Rating			
			Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Climatic regime	Mean temperature in growing season	°C	20-25	15-19	5-15 26-30	>30 <5
	Total rainfall	mm	800-1000	600-800	400-600	<400
Land quality	Land characteristics					
Moisture availability	Length of growing period for short duration varieties	Days	>100	90-100	70-90	<70
	Length of growing period for long duration varieties	Days	>150	120-150	90-120	<90
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately well drained; imperfectly drained	Poorly drained; excessively drained	Very poorly drained
Nutrient availability	Texture	Class	I, sil, cl, scl	Sic, sicl, c	SI, c>60%	
	pH	1:2.5	6.0-7.5	7.6-8.0; 5.5-5.7	8.1-9.0; 4.55.4	>9.0
Rooting conditions	Effective soil depth	cm	>75	51-75	25-50	<25
	Coarse fragments	Vol %	<15	15-35	>35	
Soil toxicity	Salinity (EC saturation extract)	dS m ⁻¹	<1.0	1.0-2.0	>2.0	
	Sodicity (ESP)	%	<10	10-15	>15	
Erosion hazard	Slope	%	<3	3-5	5-10	

Source; Naidu *et al.* (2006)

Appendix X: Soil-site suitability criteria (crop requirements) for pigeonpea

Soil site characteristics			Rating			
		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Climatic regime	Mean temperature in growing season	°C	25-28	22-24	20-21	<20
	Total rainfall	mm	800-1000	600-800	400-600	<400
Land quality	Land characteristics					
Moisture availability	Length of growing period for short duration	Days	>120	100-120	80-100	<80
	Length of growing period for long duration	Days	>180	150-180	120-150	<120
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately well drained; imperfectly drained	Poorly drained; excessively drained	Very poorly drained
Nutrient availability	Texture	Class	sl, sil, cl, scl,	Sic, sicl, c	ls	
	pH	1:2.5	6.0-7.5	7.6-8.0; 5.5-5.9	8.1-9.0; 4.5-5.4	>9.0
Rooting conditions	Effective soil depth	cm	>100	85-100	40-85	<40
	Stoniness	%				
	Coarse fragments	Vol %	<20	20-35	>35	
Soil toxicity	Salinity (EC saturation extract)	dS m ⁻¹	<1.0	1.0-2.0	>2.0	
	Sodicity (ESP)	%	<10	10-15	>15	
Erosion hazard	Slope	%	<3	3-5	5-10	

Source; Naidu *et al.* (2006)

Appendix XI : Soil site suitability criteria (crop requirements) for green gram

Site characteristics	Suitability Rating			
	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Climate (c)				
MARF (mm)	800-1000	600-800	400-600	<400
MAT (°C)	20-25	15-19	5-15	<30
Landform (t)				
Ero.hazard (% slope)	<3	3-5	5-10	>10
Wetness (w)				
Soil drainage	Well	moderate to Imperfect	Poor & excessive	Very poor
Physical characters (s)				
Effective soil Depth (cm)	>75	51-75	25-50	<25
Texture	l, sil, cl, scl	sic, sicl, c	sl, c>60%	-
Coarse. Frg. (%)	<15	15-35	>35	-
Chemical nature (f)				
pH (1:2.5)	6-7.5	7.6-8, 5.5-5.7	8.1-9, 4.5-5.4	>9
ECe (dS/m)	<1	1-2	>2	-
ESP	5-8	8-10	10-15	>15

Source; Naidu *et al.* (2006)

Appendix XII: Soil-site suitability criteria (crop requirements) for groundnut

Soil site characteristics			Rating			
		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Climatic regime	Mean temperature in growing season	°C	24-30	22-23 31-33	20-21 34-40	<20 >40
	Total rainfall	mm	700-1000	500-700	350-500	<350
Land quality	Land characteristics					
Moisture availability	Length of growing period					
	Bunch varieties	Days	100-125	90-105	75-90	
	Spreading varieties	Days	120-135	105-120	90-105	
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately well drained	Imperfectly drained	Poorly drained
Nutrient availability	Texture-surface	Class	ls, sl	cl, sicl, scl	c, sic	
	Texturesubsurface		sil, l, scl, cl, sicl	sc, sic, c	s, is, sl, c>60	
	pH	1:2.5	6.0-8.0	8.1-8.5; 5.-5.9	>8.5; <5.5	
	CaCO ₃ in root zone	%	High	Medium	Low	
Rooting conditions	Effective soil depth	cm	>75	51-75	25-50	<25
	Crusting		None	Slight	Moderate	
	Coarse fragments	Vol %	<35	35-40	>50	
Soil toxicity	Salinity (EC saturation extract)	dS m ⁻¹	<2.0	2.0-4.0	4.0-8.0	>8.0
	Sodicity (ESP)	%	Non-sodic	5-10	>10	
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Source; Naidu *et al.* (2006)

Appendix XIII: Soil-site suitability criteria (crop requirements) for soybean

Soil site characteristics			Rating			
		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Climatic regime	Mean temperature in growing season	°C	25-28	29-32	33-36	>36
	Mean RH in growing season	%	70-75	60-65	50-60	<50
	Total rainfall	mm	600-750	500-600	400-500	<400
Land quality	Land characteristics					
Moisture availability	Length of growing period	Days	>120	100-120	85-100	<85
	AWC	mm/m	>200	150-200	15-50	
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately well drained	Poorly drained to imperfectly drained	
Nutrient availability	Texture	Class	cl, scl, l, sil	Sl, c, sic, sicl	c+ (ss), ls	s
	pH	1:2.5	6.5-7.5	7.6-8.5 6.4-6.0	>8.5	
	OC	%	Medium	High	Low	
Rooting conditions	Effective soil depth	cm	>75	50-75	50-25	<25
	Stoniness	%	>15	15-25	25-35	
	Coarse fragments	Vol %				
Soil toxicity	Salinity (EC saturation extract)	dS m ⁻¹	<1.0	1-2	2 to 4	>4
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	<3	3.5	5-8	>8

Source; Naidu *et al.* (2006)

Appendix XIV: Soil-site suitability criteria (crop requirements) for sunflower

Soil site characteristics			Rating			
		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Climatic regime	Mean temperature in growing season	°C	24-30	31-34 20-23	35-38 16-19	>38 <16
	Total rainfall	mm	600-700	500-600	400-500	<400
Land quality	Land characteristics					
Moisture availability	Length of growing period	Days	>90	80-90	70-80	<70
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately well drained	Imperfectly drained	Poorly drained
Nutrient availability	Texture	Class	l, cl, sil, sc	scl, sic, c	c>60%, sl	ls, s
	pH	1:2.5	6.5-8.0	8.1-8.5; 5.5-6.4	8.6-9.0; 4.55.4	>9.0; <4.5
Rooting conditions	Effective soil depth	cm	>100	76-100	50-75	<50
	Coarse fragments	Vol %	<15	15-35	>35	
Soil toxicity	Salinity (EC saturation extract)	dS m ⁻¹	<1.0	1.0-2.0	2.0-4.0	>4.0
	Sodicity (ESP)	%	<10	10-15	>15	
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Source; Naidu *et al.* (2006)

Appendix XV: Soil site suitability criteria (crop requirements) for sesame

Site characteristics	Suitability Rating			
	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Climate (c)				
MARF (mm)	500-600	400-500	300-400	<300
MAT (°C)	30-34	29-25, 35-38	20-24, 39-40	<20, >40
Landform (t)				
Ero. hazard (% slope)	<3	3-5	5-8	>8
Wetness (w)				
Soil drainage	Well	Moderate	Poorly to imperfect	Very Poorly drained
Physical characters (s)				
Effective soil Depth (cm)	>75	50-75	50-25	<25
Texture	scl, l, sil, cl, sl	sicl, sc, c	ls, c (s-s)	s
Coarse. Frg. (%)	<15	15-25	25-35	>35
Chemical nature (f)				
pH (1:2.5)	5.5-7.5	7.6-8, 5-5.4	8.1-9, 4.9-4.5	>9, <4.5
ECe (dS/m)	<1	1-2	2-4	>4
OC %	High	Medium	Low	-
ESP	<5	5-10	10-15	>15

Source; Naidu *et al.* (2006)

Appendix XVI: Soil-site suitability criteria (crop requirements) for cotton

Soil site characteristics		Unit	Rating			
			Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Climatic regime	Mean temp. in growing season	°C	20-30	31-35	<19 >35	-
	Mean max. temp. in growing season	°C	-	-	>36	-
	Mean min. temp. in growing season	°C	-	-	<19	-
	Mean RH in growing season	%	60-90	-	<50	-
	Total rainfall	mm	700-1000	500-700 1000-1250	<500 >1250	-
	Rainfall in growing season	mm	600-950	450-600	<450	-
Land quality	Land characteristics					
Moisture availability	Length of growing period	Days	180-240	120-180	<120	-
	AWC	mm/m	200-250	125-200	50-125	<50
Oxygen availability to roots	Soil drainage	Class	Well to moderately well	Imperfectly drained	Poor, some what excessive	Stagnant/ excessive
	Water logging in growing season	Days	1-2	2-3	3-5	>5
Nutrient availability	Texture	Class	sic, c	sicl, cl	si, sil, sc, scl, l	sl, cm, s, ls
	pH	1:2.5	6.5-7.5	7.6-8.0	8.1-9.0	>9.0; <6.5
	CEC	c mol (p ⁺) kg ⁻¹	>55	50-55	30-50	<30
	BS	%	>80	50-80	35-50	<35
	CaCO ₃ in root zone	%	<3	3-5	5-10	10-20
	OC	%	>1.00	0.75-1.00	0.50-0.75	<0.50
Rooting conditions	Effective soil depth	cm	100-150	60-100	30-60	<30
	Stonnines	%	<15	15-25	25-50	50-75
	Coarse fragments	Vol%	<5	5-10	10-15	15-35
Soil toxicity	Salinity (EC saturation extract)	dS m ⁻¹	2-4	4-8	8-12	>12
	Sodicity (ESP)	%	5-10	10-20	20-30	>30
Erosion hazard	Slope	%	1-2	2-3	3-5	>5

Source; Naidu *et al.* (2006)

Appendix XVII: Soil-site suitability criteria (crop requirements) for chilli

Soil site characteristics			Rating			
		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Climatic regime	Mean temperature in growing season	°C	25-32	33-35 20-24	36-38 <20	>38
	Total rainfall	mm	750-900	900-1200	500-600 >1200	-
Land quality	Land characteristics					
Moisture availability	Length of growing period	Days	>150	120-150	90-120	<90
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately to imperfectly drained	Poorly drained; excessively	Very poorly drained
Nutrient availability	Texture	Class	l, scl, cl, sil	Sl, sc, sic, c(m/K)	c(ss), ls, s	
	pH	1:2.5	6-7	7.1-8.0	8.1-9.0; 5.05.9	>9
	OC	%	>0.75	0.5-0.75	<0.5	
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Coarse fragments	Vol %	<15	>15-35	>35	
Soil toxicity	Salinity (EC saturation extract)	dS m ⁻¹	Non saline	1-2	2-4	<4
	Sodicity (ESP)	%	Non sodic	5-10	10-15	
Erosion hazard	Slope	%	<3	3-5	5-10	

Source; Naidu *et al.* (2006)

Appendix XVIII: Soil site suitability criteria (crop requirements) for sugarcane

Site characteristics	Suitability Rating			
	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Climate (c)				
MAT (°C)	30-34	35-38, 26-29	25-20, 39-40	<20, >40
Landform (t)				
Ero.hazard (% slope)	<3	3-5	5-8	>8
Wetness (w)				
Soil drainage	Well	moderate to Imperfect	Poor	Very poor/ excessive
Physical characters (s)				
Effective soil Depth (cm)	>100	75-100	75-50	<50
Texture	l, cl, sil, sicl, sc, scl	c(m/k), sl	c+(ss)	-
Coarse. Frg. (%)	<15	15-35	35-50	>50
Chemical nature (f)				
pH (1:2.5)	7-8	6-6.9, 8.1-9	4-5.9, 9.1-9.5	<4, >9.5
ECe (dS/m)	<2	2-4	4-9	>9
CEC Cmol (+) kg ⁻¹	>20	10-20	5-10	<5
ESP	<10	10-15	15-25	>25

Source; Naidu *et al.* (2006)

Appendix XIX: Soil-site suitability criteria (crop requirements) for mango

Soil site characteristics			Rating			
		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Climatic regime	Mean temp. in growing season	°C	28-32	24-27 33-35	36-40	20-24
	Mean min. temp. in growing season	°C	10-15	15-22	>22	
Land quality	Land characteristics					
Moisture availability	Length of growing period	Days	>180	150-180	120-15	<120
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately to imperfectly	Poorly	Very poorly
	Depth of water table	m	>3	2.50-3.00	2.50-1.50	<15.0
Nutrient availability	Texture	Class	sc, l, sil, cl	sl, sc, sic, sic, l, c (m/k)	c (s<60%)	c(s>60%), s, ls
	pH	1:2.5	5.5-7.5	7.6-8.5 5.0-5.4	8.6-9.0 4.0-4.9	>9.0 <4.0
	CaCO ₃ in root zone	%	Non calcareous	<5	5-10	>10
	OC	%	High	Medium	Low	
Rooting conditions	Effective soil depth	cm	>200	125-200	75-125	>75
	Presence of gravel in subsoil	%	Non gravelly	<15	15-35	>35
	Presence of hard pans in subsoil	cm	>250	150-250	100-150	<100
Soil toxicity	Salinity (EC saturation extract)	dS m ⁻¹	Non saline	<2.0	2.0-3.0	>3.0
	Sodicity (ESP)	%	Non sodic	<10	10-15	>15
Erosion hazard	Slope	%	<3	3-5	5-10	

Source; Naidu *et al.* (2006)

Appendix XXI: Soil-site suitability criteria (crop requirements) for guava

Soil site characteristics			Rating			
		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Climatic regime	Mean temp. in growing season	°C	28-32	33-36 24-27	37-42 20-23	
Land quality	Land characteristics					
Moisture availability	Length of growing period	Days	>150	120-150	90-120	,90
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately to imperfectly	Poorly	Very poorly
Nutrient availability	Texture	Class	Scl, l, cl, sil	Sl, sicl, sic, sc, c (m/k)	C (<60)	C (>60) s, ls
	pH	1:2.5	6.0-7.5	7.6-8.0 5.0-5.9	8.1-8.5 4.5-4.9	>8.5 <4.5
	CaCO ₃ in root zone	%	Non calcareous	<10	10-15	>15
	Available nutrient status (NPK)	Fertility rating class	High	Medium	Low	
Rooting conditions	Effective soil depth	cm	>100	75-100	50-75	<50
	Presence of gravel	%	Non gravelly	<15	15-35	<35
	Coarse fragments	Vol %				
Soil toxicity	Salinity (EC saturation extract)	dS m ⁻¹	<2.0	2.0-4.0	4.0-6.0	>6.0
	Sodicity (ESP)	%	Non sodic	10-15	15-25	>25
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Source; Naidu *et al.* (2006)

Appendix XXII: Soil-site suitability criteria (crop requirements) for pomegranate

Soil site characteristics			Rating			
		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Climatic regime	Mean temp. in growing season	°C	30-34	35-38 25-29	39-40 15-24	
Land quality	Land characteristics					
Moisture availability	Length of growing period	Days	>150	120-150	90-120	<90
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately well drained	Poorly drained	V. poorly drained
Nutrient availability	Texture	Class	scl, l, sil, cl	c, sic, sicl	cl, s, ls	
	pH	1:2.5	5.5-7.5	7.6-8.5	8.6-9.0	
Rooting conditions	Effective soil depth	cm	>100	75-100	50-75	<50
	Presence of gravel	%	Non gravelly	15-35	>35	
Soil toxicity	Salinity (EC saturation extract)	dS m ⁻¹	Non saline	<9	>9	<50
Erosion hazard	Slope	%	<3	3-5	5-10	

Source; Naidu *et al.* (2006)

Appendix XXIII: Soil site suitability criteria (crop requirements) for tamarind

Site characteristics	Suitability Rating			
	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Climate (c)				
MAT (°C)	28-32	24-27, 33-36	37-42, 20-23	-
Landform (t)				
Ero.hazard (% slope)	<3	3-5	5-10	>10
Wetness (w)				
Soil drainage	Well	Moderate to Imperfect	Poor	Very poor
Physical characters (s)				
Effective soil Depth (cm)	>100	75-100	50-75	<50
Texture	scl, l, cl, sil	sl, sicl, sic, sc, c(m/k)	c (<60%)	c (>60%)
Coarse. Frg. (%)	Non gravelly	<15	15-35	>35
Chemical nature (f)				
pH (1:2.5)	6-0.75	7.6-8, 5-5.9	8.1-8.5, 4.5-4.9	>8.5, <4.5
ECe (dS/m)	<2	2-4	4-6	>6
OC %	High	Medium	Low	-
CaCO ₃ (%)	Non calcarious	<10	10-15	>15
ESP	Non sodic	10-15	15-25	>25

Source; Naidu *et al.* (2006)

Appendix XXIV: Soil-site suitability criteria (crop requirements) for rose

	Soil site characteristics		Rating			
		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Climatic regime	Mean temp. in growing season	°C	25-30	31-32 20-24	32-36 15-19	
Land quality	Land characteristics					
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderate	Imperfect	Poor
Nutrient availability	Texture	Class	sl, l, scl, cl, sil	sic, sicl, sc, c (m/k)	c (ss)	s, sl
	pH	1:2.5	6.0-7.5	67.6-8.5 5.0-5.9	<5 >8.5	
	CEC	c mol (P ⁺)kg ⁻¹	>15	10-15	<10	
	CaCO ₃ in root zone	%	Non-calcareous	Slightly calcareous	Strong calcareous	
Rooting conditions	Effective soil depth	cm	>100	75-100	50-75	<50
	Coarse fragments	%	<15	15-35	>35	
Soil toxicity	Salinity (EC saturation extract)	dS m ⁻¹	Non-saline	Slight	Strongly	
	Sodicity (ESP)	%	Non-sodic	Slight	Strongly	
Erosion hazard	Slope	%	1-5	5-10	10-20	>20

Source; Naidu *et al.* (2006)

Appendix XXV: Soil-site suitability criteria (crop requirements) for jasmine

	Soil site characteristics		Rating			
		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Climatic regime	Mean temp. in growing season	°C	18-23	17-15 24-35	35-40 10-14	
Land quality	Land characteristics					
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderate	Imperfect	Poor
Nutrient availability	Texture	Class	sl, l, scl, cl, sil	sicl, sc, sic, c(m/k)	c (ss)	ls, s
	pH	1:2.5	6.0-7.5	5.5-5.9 7.6-8.5	<5 >8.5	
	CEC	c mol (P ⁺) kg ⁻¹	>25	10-15	<10	
	CaCO ₃ in root zone	%	Non calcareous	Slightly calcareous	Strong calcareous	
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Coarse fragments	%	<15	15-35	>35	
Soil toxicity	Salinity (EC saturation extract)	dS m ⁻¹	Non-saline	Slight	Strongly	
	Sodicity (ESP)	%	Non-sodic	Slight	Strongly	
Erosion hazard	Slope	%	1-3	3-5	5-10	>10

Source; Naidu *et al.* (2006)

LAND RESOURCE INVENTORY IN THE DAMBAL-II MICRO-WATERSHED OF GADAG DISTRICT USING REMOTE SENSING AND GIS TECHNIQUES

SURESH BIRANI

2016

DR. S. S. GUNDLUR
MAJOR ADVISOR

ABSTRACT

A study was undertaken to characterize, classify and map the soil resources of Dambal-II micro-watershed in northern dry zone (zone-3) of Karnataka in order to assess their land capability, irrigability and suitability for crops and also to assess soil fertility constraints. Soil survey was carried by using IRS P6, LISS-IV image and cadastral map. Based on soil heterogeneity, eleven soil profiles were studied for the morphological, physical and chemical properties and classified using soil taxonomy as *Inceptisols* and *Entisols*.

Seven series were identified and mapped into seven mapping units by GIS technique. The identified land capability sub-classes namely; III_{tsf} and VI_{sf} have been mapped. Soil suitability evaluation for irrigation showed that soils were moderately suitable to the extent of 84.49 per cent of total geographical area (TGA), marginally suitable (13.15 % TGA) and not suitable (2.36 % TGA) for surface irrigation. The study area was moderately (S2) and marginally suitable (S3) for crops like wheat, sorghum, pearl millet, soybean, bengal gram, green gram, pigeon pea, sunflower, sesame, pomegranate, sapota, jasmine and rose. Whereas, maize, groundnut, sugarcane, chilli, cotton, mango, tamarind and guava were marginally suitable (S3).

Sixty five surface soil samples were drawn from the study area and analysed for their fertility status and mapped by GIS technique. The soil pH was neutral to strongly alkaline in reaction and free from salinity. Soil organic matter content was low. Available nitrogen was low, available phosphorus and sulphur were low to medium, whereas available potassium was medium to high in these soils and exchangeable calcium and magnesium were sufficient. Regarding available micronutrients, zinc (except 33.35 % TGA) and iron were deficient in these soils but copper and manganese were sufficient. Whereas, three-fourth of the area was low in available boron and remaining area was medium in these soils.