

**CHARACTERIZATION AND CLASSIFICATION OF
SOILS OF A MICROWATERSHED ON BASALT
PARENT ROCK IN NORTHERN TRANSITION ZONE OF
KARNATAKA**

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1. INTRODUCTION

Soil, one of the most heterogeneous objects on the Earth, has always been regarded as natural resource. May be no layman can notice its importance but it has an enormous importance for our lives.

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.

Soils provide food, fodder and fuel for meeting the basic needs of humans and animals. With the growth in human and animal population, demand for food has been increased. Moreover, the maximum carrying capacity of the soils is finite and limits the production process. It is influenced by intrinsic characteristics of soils, agro-ecological setting, land use and management.

This demands systematic appraisal of our soil resources with respect to their extent, distribution, characteristic, behaviour and use-potential which is very crucial for developing an effective land use system for augmenting agricultural production on sustainable basis.

The sustainable development of a region needs not only protection and reclamation of natural resources particularly soil and land, but also a scientific basis for the management in harmony with environment. These resources should be managed in a sustainable manner so that the changes proposed to meet the needs of development are brought out without diminishing the potential for their future use (Kanwar, 1994).

In general, soils are being degraded at a rate faster than their natural degeneration due to poor management, excessive exploitation and faulty land use. It has now become imperative to preclude them from further degradation as there is a concomitant decline in soil quality to produce healthy crops in turn, to support healthy mankind.

In the recent past, concept of watershed based holistic development has emerged as one of the potential approaches in rainfed areas, which has led to higher productivity and sustainability in agricultural production. Different measures are adopted and executed carefully in different soils according to their capability. Hence, a detailed study for characterization and classification of soils is needed to extend the concept of watershed approach successfully. A study has been undertaken in Bastwad microwatershed of Belgaum district for characterization and classification of soil resources for sustainable land use planning.

The selected area of Bastwad micro-watershed covers an area of 450.74 ha. It comprises of both red and black 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 chemical and physical properties of soils helps in better crop planning.

For the sustainable use of the natural resources, a detailed charter of land resources encompassing its potential and constraints becomes pre-requisite for planning. The site specificity of agricultural research and technology is largely measured from differences in two environmental variables, soil and climate. At present, most systems of land evaluation are interpretative classifications. A general evaluation based on limitations of land characteristics is best illustrated in the USDA land capability classification. The classification automatically points out the feasibility of production and limitations of the climate and soil for each crop and type of agriculture.

Land use planning evaluates land and alternative land use patterns for the purpose of selecting the best choice for land usage. 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 influences the area.

Keeping these considerations in view, an investigation was undertaken with the following objectives.

- i. To characterize, classify and map the soil resources of a micro-watershed on basalt parent rock in northern transition zone of Karnataka
- ii. To evaluate the micro-watershed for land capability, irrigability and soil-site suitability for crops.
- iii. To map nutrient status by GIS techniques and identification of soil fertility constraints of the micro-watershed.

2. REVIEW OF LITERATURE

The rational utilization, improvement and conservation of soil resources are not possible without thorough understanding of their physico-chemical properties, geographical distribution and classification. Although the soils of much of the arid and semi-arid regions are superficially similar in appearance, careful study reveals a great diversity. Studies carried out, both within and outside India, on red and black soils are not exhaustive and there is a need for detailed investigation. Based on the available information the literature is reviewed under the following headings and their sub-headings.

2.1 Soil survey for land evaluation and land use planning

2.2 Pedon characteristics

2.3 Soil classification

2.4 Land evaluation

2.5 Surface soil properties and nutrient status

2.1 SOIL SURVEY FOR LAND EVALUATION AND LAND USE PLANNING

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

Soil Survey Staff (1951) distinguished detailed basic soil survey, reconnaissance soil survey and exploratory soil surveys based on the extent of effort made in the field to draw soil boundaries. Kind of surveys will be according to the purpose or objective of the survey and the level of information required for making decisions on land use planning.

A soil map with its memoir forms a tool from which the user can have information about the soil conditions at any site without having to go there. An important general concept in soil resource inventory is that of site specificity (Forbes *et al.*, 1983). Objective and purpose of soil survey should specify the evaluation level of soil survey. Land use objectives for which soil resource inventories are used differ widely in both kind and level of generalization (Cline, 1981). Soil surveys have several objectives. It should be designed carefully so as to encompass immediate needs and future purpose as well (Swindale, 1977).

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 are grouped under Sodic Haplusterts.

Sahu *et al.* (2001) studied morphological features of four Vertisol pedons in the Western Zone of Orissa and characterized and classified them. The soils are very deep, colour ranges from black to grayish brown in different horizons, cracks of 2 to 3 cm wide extend beyond 1 m. Slickensides, wedge shaped aggregates, iron, manganese and calcretes are observed in the subsurface horizons of the soils. The soils were imperfectly drained, slightly acid to moderately alkaline and the pH value increased with depth. The soils are base rich and high in CEC: clay ratio (0.65 to 0.75) and classified as Typic Chromic Haplusterts.

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.

Bhatta *et al.* (2005) conducted a detailed soil survey in Budhabudhiani Irrigation Project in Nayagarh district of Orissa. Four soil series were identified. Ostia soil (Typic Haplustept) is the dominant one and occupies 54 per cent of the area surveyed followed by Rabera soil (Typic Paleustalf) which occupies 30 per cent of the area. Arada soil (Typic Ustorthent) and Petapalli soil (Aquic Ustifluent), both placed under soil order Entisols, occupy 9 per cent and 7 per cent area, respectively.

Four typical pedons representing major landforms of Kiar-Nagali microwatershed, developed from sedimentary rocks, comprising ferromagnesian shale and dolomites/dolomitic limestone and occurring at different elevations under varying land uses were studied by Tripathi *et al.* (2006) for their morphological characteristics and physico-chemical properties and suitability for locally preferred crops. As per Storie's Index the soil productivity potential of the microwatershed area varies from non-agricultural to good. Nagali-I soils were found to be unfit for cultivation. Nagali-II and Kundla soils had good productivity potential.

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. There was gradation in colour from reddish in the higher topographic position to yellowish colour in the lower topographic position. There was an accumulation of clay in low hills and mid lands were with A-Bt-BC horizon sequence. Soil temperature and moisture regimes in the area are 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 Ustifluents

Sankar *et al.* (2010) made a detailed soil survey (1:5000 scale) of Kutturavupatti village (537 ha) in Sivagangai district of Tamil Nadu was conducted during 2005-06 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 GIS 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.

2.2 PEDON CHARACTERISTICS

Diwakar and Singh (1994) reported 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) studied that 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 per m³. Water retention at 33 kPa 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 Dystrachrepts.

2.2.1 Morphological Properties

2.2.1.1 Slope: A factor influencing soil properties

Aspect or topography is regarded as an independent factor of soil formation as it embodies an immense power to alter and even nullify the effects of other factors *viz.* parent material, climate, time and organism. Thus it has become important to discuss its effect on nature and properties of soils which is being justified with the following reviews of literature.

The soils located on gently sloping topography exhibited yellowish brown (10 YR 5/6) to dark red (2.5 YR3/6) while the soils found on nearly leveled topography showed light yellowish brown (10 YR 6/4) to very dark grayish brown (10 YR 3/2) in Sivagiri microwatershed of Chittoor district in Andhra Pradesh. This variation in the soil colour was a function of chemical and mineralogical composition, topographic position, and textural makeup and moisture regimes of the soils (Thangasamy *et al.*, 2005).

An attempt has been made to study the landform and soils of Ringnabodi watershed of Nagpur district in sub-humid tropics of central India for their characterization and classification by Maji *et al.* (2005). The analysis of satellite data and field investigation reveal summit crest, escarpments, isolated mounds, denuded plateau, foot slopes, upper piedmont, lower piedmont and narrow valley floor as dominant landforms. The slope varies from level to nearly level (0.1 per cent) to steeply sloping (30-50 per cent) land. With changing topographic position, the depth of soil changed from 33 to 140 cm and the coarse fragments decreased from 61 to 2 per cent. The soils developed on topographically higher elevation have dark brown (7.5 YR hue) and those developed on lower elevation have dark brown to very dark gray and very dark grayish brown (10 YR hue) colour. Soils at higher elevation have clay loam texture, whereas, the low-lying areas have clayey textural class. Higher available water holding capacity (AWC 199 mm) is found in low lying area and low to medium (AWC 68 mm) is noticed in the soils developed on higher elevation. The reaction (pH) of the soils is slightly acidic (6.0 to 6.5) in nature on summit crest, escarpment and isolated mounds and remaining soils from denuded plateau to narrow valley floor are slightly alkaline (7.7-8.3). Increasing trend of electrical conductivity (EC) with depth is noticed and it ranges from 0.06 to 25 dS m⁻¹. The cation exchange capacity (CEC) of the soils of the area varies from 25.6 to 57.1 cmol (p⁺) kg⁻¹. Clay, CaCO₃ and base saturation increases with decreasing elevation and slope. Lithic Ustorthents on summit crest and escarpment, Typic Haplusterts on upper and lower piedmonts and Vertic Haplustepts on narrow valley floor are the major soils observed.

Gebrekidan and Mishra (2005) studied soils in three toposequences of Amensis sub-catchment of Hirna watershed that were characterized and classified. Soils in the steep slopes were shallow whereas, they became deep along the topographic lows

The quantitative evaluation of the annual (productivity index) and potential (index of potentiality) productivity of soils in three distinct toposequences in Amensis sub-catchment of Hirna watershed was carried out following parametric method by Gerbrekidan *et al.* (2005). The soils occurring in the mountainous steep sloppy landscape were grouped as extremely poor to poor whereas, the soils of the alley/basin were grouped as good in their productivity index.

In order to understand the effect of aspect and altitude on the soil properties, a detailed investigation was carried out in the soils of Tehri Garhwal and Uttarakhand by Verma *et al.* (2008). Six pedons, representing north and south slope aspects at three attitudes on steep slopes were selected for the present study. Soil developed on northern slopes are darker in colour due to organic horizons on mineral soil surface containing high amounts of clay having low bulk density, high water holding capacity, high cation exchange capacity and organic carbon content than pedons of southern slopes. Vegetation played a dominant role in the soil profile development of the pedons of northern slopes. The soils developed on northern aspects were taxonomically found to be Mollisols and those on southern aspects were Inceptisols.

2.2.1.2 Soil colour

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

Sarkar *et al.* (2001) stated that the soils of upper slopes in toposequence of Chhotanagpur plateau were yellowish red (5YR 4/6) in colour in the surface layer and dark red (2.5YR4/6) in the lower layers while the soils in lower slope of the toposequence were light brownish gray to light gray in surface horizon and gray in the lower layers.

Sarkar *et al.* (2002) stated that the colour in the surface horizons of soils developed from shale parent material varied from very dark brown (10YR 2/2) to dark yellowish brown (10 YR 3/4) while the sub-surface 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).

The soils of Ramachandrapuram Mandal in Chittoor district of Andhra Pradesh were moderately deep to very deep in depth, light yellowish brown to dark red in colour (Vara Prasad Rao *et al.*, 2008)

2.2.1.3 Texture

Soil texture may be defined as the relative proportion of the various 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 as a basic property of a soil.

Reddy *et al.* (1993) studied morphological and physico-chemical properties of red soils (Alfisols) occurring under irrigated and unirrigated conditions and observed that the texture of soils ranged from sandy loam on the surface to sandy clay loam in the sub soil. Colour of the Bt horizon in all irrigated soils was reddish brown where as in unirrigated soils; it was dark reddish brown.

Sharma *et al.* (1996) observed while characterizing soils in a toposequence over basaltic terrain of southern Rajasthan that the soils at elevated topography were shallow to moderately shallow depth, clayey to loamy skeletal texture and yellowish brown, while at lower topography soils were deep to very deep, fine to fine loamy texture and grayish colour.

2.2.1.4 Structure

Roy and Barade (1962) reported that, in general, presence of sub angular blocky to angular blocky structure is commonly noticed in soils of India.

A review of soil survey reports on the black soils of Tungabhadra project area revealed that the various soil series described by them consisted of granular blocky in Ap horizon which grades to sub angular blocky to angular blocky with slickensides on their faces in some cases (Murthy *et al.*, 1972).

Distinct horizons are not discernible in black soils due to argilli-pedoturbation which disturbs the soil horizons and impeded the process of propedanisotropic factor developing the anisotropic properties within the soil (Bhattacharjee *et al.*, 1974).

The structure of soils in Kathiawar watershed of Gujarat varied from fine, weak and sub-angular blocky to medium to coarse, moderate to strong and sub-angular blocky to angular blocky (Sharma *et al.*, 2001). The structure of the soil of lower Palar-Manimuthar watershed in Tamil Nadu varied from weak to strong, fine to coarse and granular to sub-angular blocky (Arun Kumar *et al.*, 2002). Kadao *et al.*, (2003) stated that Inceptisols in Wardha district of Maharashtra showed sub-angular blocky structure. Entisols of Chandauli district in Uttar Pradesh exhibited dominantly fine, weak and granular whereas, that of Inceptisols was sub-angular blocky which was a reflection of their sandy loam to sandy clay loam texture (Singh and Agrawal, 2003).

The Inceptisols and Entisols of Southern Rajasthan had sub-angular blocky structure. Furthermore, the structure becomes massive in substratum of slightly and moderately saline layer, indicating lack of development or destruction of soil structure due to prevailing moist conditions in the soils (Sharma *et al.*, 2004).

In a shrink-swell soil of Central India, the structure is sub-angular blocky in the A-horizon and angular blocky in the B-horizon (Pal *et al.*, 2006).

Tripathi *et al.* (2009) investigated six representative pedons of Banganala watershed of Kymore plateau and Satpura hills in Rewa district, Madhya Pradesh. Sub angular and angular blocky were the dominant structures.

2.2.1.5 Consistence

It is a term used in describing 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 moulded.

Mishra and Ghosh (1995) noticed that, due to negligible or very small amount of expanding clay minerals in soils derived from mica-rich parent material, the consistence was not very sticky and plastic.

Singh and Mishra (1996) reported that the consistence of soils in higher topographic positions was non-sticky and non-plastic whereas, the soils in lower topographic positions exhibited very sticky and very plastic consistence.

According to Sharma and Anil Kumar (2003) the dry consistence in sandy loam to loamy soils varied from soft to hard whereas, loamy sand to silty clay loam soils, was loose to extremely hard in Maul Khad catchment of Himachal Pradesh.

The 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 (Sharma *et al.*, 2004).

Thangasamy *et al.* (2005) observed that the consistence of the soils in Sivagiri microwatershed of Chittoor district in Andhra Pradesh was loose to very hard (dry), loose to very firm (moist) and non-sticky and non-plastic to very sticky and very plastic (wet).

2.2.2 Physical Properties

2.2.2.1 Particle Size Distribution

According to Verma *et al.* (2001) 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 sub-surface (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 lateritized basalt and hence produced higher amount of clay (Patil and Jagdish Prasad, 2004).

Sub-surface 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 microwatershed 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 Bulk Density and Maximum Water Holding Capacity

Rajeev Srivastava *et al.* (1998) studied the water retention characteristics of five swell-shrink soils of Chandrapur district, Maharashtra. The study showed that water retentivity at 33 kPa and 1500 kPa tension was significantly and positively correlated with clay, silt + clay, CEC and $\text{exch. Ca} + \text{Mg}$ and negatively correlated with sand content. The effect of organic carbon content on water retentivity, both at 33 kPa and 1500 kPa tension, was found non-significant due to low and similar content of organic carbon in these soils. The multiple regression equations were also developed to predict water retentivity using clay content and CEC values.

The bulk density ranged from 1.40 to 1.80 Mg m^{-3} in Inceptisols and 1.40 to 1.60 Mg m^{-3} in Alfisols of granitic terrain in Jabalpur district of Madhya Pradesh (Gupta *et al.*, 1999). Ramprakash and Seshagiri Rao (2002) stated that the bulk density values of red soils were higher (1.45-1.63 Mg m^{-3}) than black soils (1.30-1.57 Mg m^{-3}).

Marathe *et al.* (2003) reported that the bulk density values varied from 1.46 to 1.74 Mg m^{-3} and the bulk density also increased with increasing depth in mandarin orchards of Nagpur.

The bulk density in the soils of Maul Khad catchment of Himachal Pradesh varied from 1.38 to 1.62 Mg m^{-3} in surface and 1.35 to 1.72 Mg m^{-3} in sub-surface horizons. The bulk density tended to increase with depth. The variation in bulk density was attributed to variation in organic matter, texture etc. (Sharma and Anil Kumar, 2003) while the study by Swarnam *et al.*, 2004 revealed 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 increase in bulk density with depth was attributed to lower organic matter, more compaction and less aggregation in rice soils of Eastern region of Varanasi (Singh and Agrawal, 2005).

The bulk density of the soils in Sivagiri microwatershed 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 was 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).

2.2.3 Chemical Properties

2.2.3.1 Soil reaction (pH)

The pH varied from slightly acidic (5.83) to moderately alkaline (8.47) in the soils of Sivagiri microwatershed 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 pH varied from slightly acidic to alkaline with a range of 6.11 to 8.57 in the soils of Shikohpur watershed of Gurgaon district, Haryana. The increase in soil reaction (both H_2O and KCl) down the slope could be due to leaching of bases from higher topography and getting accumulated in lower elevations and also high concentration of CaCO_3 in the lower areas. Further, the KCl-pH values were lower than the water pH values and the difference between KCl-pH and H_2O -pH values with large negative value (more than -0.5) indicated a high negative surface charge density in these soils (Sitanggang *et al.*, 2006).

Soil pH varied from 7.1 to 8.6 with an average of 7.8 and the relatively high pH of the soils might be due to the presence of high degree of base saturation in soils of Tonk district of Rajasthan (Meena *et al.*, 2006).

Vara Prasad Rao *et al.* (2008) studied typical pedons representing major landforms of Ramahcandrapuram Mandal in Chittoor district of Andhra Pradesh. The soils were slightly acidic to moderately alkaline in reaction. Triptahi *et al.* (2009) studied six representative pedons of Banganala watershed of Kymore plateau and Satpura hills in Rewa district, Madhya Pradesh. The soils were calcareous and neutral to mildly alkaline in soil reaction.

2.2.3.2 Electrical conductivity (EC)

The low EC (0.08 to 0.4 dS m⁻¹) in soils of Trans-Yamuna plains indicated the low amount of soluble salts. The EC of Vertisols and Inceptisols developed from different parent materials were normal with very low (<1 dS m⁻¹) salt content (Chinchmalatpure *et al.*, 1998).

According to Pillai and Natarajan (2004) the electrical conductivity of the soils of Garakahalli watershed ranged from 0.02 to 0.2 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 draining water.

The Inceptisols and Entisols of Shahibi basin in Haryana and Delhi were non-saline with electrolyte concentration ranging from 0.18–0.95 dS m⁻¹ (Swarnam *et al.*, (2004). The Entisols and Inceptisols of Shikohpur watershed of Gurgaon district, Haryana were non-saline with electrolyte concentration ranging from 1.05 to 1.40 dS m⁻¹ in surface layers and 1.00 to 1.50 dS m⁻¹ in sub-surface layers (Sitanggang *et al.*, 2006).

The soils in Sivagiri microwatershed of Chittoor district in Andhra Pradesh showed very low electrical conductivity values ranging from 0.02 to 0.36 dS m⁻¹, suggesting the presence of very low amount of soluble salts (Thangasamy *et al.*, 2005).

The forest soils of North Karnataka were non-saline with EC values ranging from 0.01 to 0.07 dS m⁻¹ (Shamsudheen *et al.*, 2005).

2.2.3.3 Organic carbon

Sarkar *et al.* (2002) reported that the organic carbon content in the surface soils of Loktak catchment area in Manipur ranged from 24.7 to 45.4 g kg⁻¹ and decreased with depth.

The organic carbon in surface horizons of banana growing soils in Wardha district of Maharashtra was more (5.5 to 8.7 g kg⁻¹) and it decreased in sub-surface soils to a minimum of 1.4 g kg⁻¹ (Kadao *et al.*, 2003). Pacharne *et al.* (1996) noticed that the organic carbon content of ferruginous soils were low to medium (2.40 to 8.60 g kg⁻¹) whereas, black soils had low organic carbon (1.6 to 4.9 g kg⁻¹) in Saptadhara watershed of Nagpur district, Maharashtra. The organic carbon in soils of uplands showed a regular decrease with depth while the soils in inter-hill valleys exhibited an irregular trend with depth. The organic carbon was high in the grassland soils on summits and convex plateau tops when compared to the soils on side-slopes and narrow valleys of Meghalaya (Bhaskar *et al.*, 2004).

The organic carbon content in soils of Chandragiri mandal of Chittoor district, Andhra Pradesh varied from 0.6 to 6.3 g kg⁻¹ (plains), 0.8 to 4.1 g kg⁻¹ (uplands) and 3.7 to 6.6 g kg⁻¹ (hill slope). Irrespective of landforms, the organic carbon decreased with depth (Basavaraju *et al.*, 2005). The organic carbon content decreased with the depth in soils of Sivgiri microwatershed in Chittoor district of Andhra Pradesh. This could be due to the addition of plant residues and farm yard manure to surface horizons than in the lower horizons (Thangasamy *et al.*, 2005). Vara Prasad Rao *et al.* (2008) studied typical pedons representing major landforms of Ramahcandrapuram Mandal in Chittoor district of Andhra Pradesh. The soils were low to medium in organic carbon.

The organic carbon content was invariably high in surface horizons and exhibited a declining trend with depth in forest soils as compared to cultivated soils (Sanjeev *et al.*, 2005).

2.2.3.4 Free calcium carbonate (CaCO₃)

When the process of evaporation is rapid, as in case of arid and semi-arid parts of the world, there occurs a concentration of carbonates and bicarbonates, as a result of which calcium and magnesium get precipitated as their carbonates and bicarbonates and are rendered less soluble.

This trend causes an apparent enhancement in soil sodium concentration and results in development of sodic soils. Such a trend of sodium, occurring as its carbonates and bicarbonates, accounting for more than 60 per cent of salts, was noticed in Cauvery basin of Karnataka by Ambadas Rao (1969).

Desai (1942) reported that in general red soils were devoid of free CaCO_3 whereas, associated black soils were in general rich in free CaCO_3 . In some cases, however, free CaCO_3 was present in small quantity in red soils due to the semi-arid climatic condition.

The per cent calcium carbonate in North Gujarat soils increased with depth and the values were 0, 1.8, 6.7 and 20.5 at 0-25, 25-50, 50-75 and 75-100 cm depth, respectively (Barade and Gowaikar, 1965).

The adjoining soils of Uttar Pradesh have shown increase in calcium carbonate with depth and the values were 0.2 and 22.0 per cent at surface and 1 m depth, respectively (Sehgal *et al.*, 1968).

Sankar *et al.* (2010) studied soils of Kutturavupatti village (537 ha) in Sivagangai district of Tamil Nadu. The soils of Sivagangai series had more than 70 per cent gravel content and more than 10 per cent free CaCO_3 .

2.2.3.5 Cation exchange capacity and base saturation

Suresh Kumar *et al.* (2001) found that the CEC of soils in residual hills, denudational hills and pediments was low (11.70 to 16.37 cmol (p+) kg^{-1} soil) whereas, the soils of shallow and moderately buried pediments and valley fills had moderately high CEC (15.10 to 28.20 cmol (p+) kg^{-1} soil).

Swarnam *et al.* (2004) stated that the CEC of the soils of Shahibi basin in Haryana and Delhi varied from 3.20 to 10.20 cmol (p+) kg^{-1} soil and decreased with depth. Low CEC of these soils could be attributed to low content of clay and organic carbon.

Sharma *et al.* (2004) stated that the CEC in the soils of Neogal watershed in North-West Himalayas ranged from 4.9 to 14.3 cmol (p+) kg^{-1} soil. The difference in CEC between the soils was due to the varied type / content of soil colloids and soil pH values. The CEC of the Garkahalli watershed soils was found to be low to medium. Maximum CEC was observed in the horizons where illuviation of clay from surface to sub-surface horizon had taken place (Pillai and Natarajan, 2004).

CEC of the soils in Dindori district of Madhya Pradesh with smectitic mineralogy was higher (72.0 cmol (p+) kg^{-1}) as compared to the soils with mixed mineralogy (28.9 cmol (p+) kg^{-1}) (Patil and Jagdish Prasad, 2004).

The CEC values were higher in horizons containing high clay and/or high organic carbon content. Low values of CEC (9.0 to 11.5 cmol (p+) kg^{-1}) may be ascribed to the predominance of low CEC minerals, especially illite, in outer Himalayas (Sanjeev *et al.*, 2005). The CEC of the soils in Sivagiri microwatershed of Chittoor district in Andhra Pradesh ranged from 1.50 to 45.14 cmol (p+) kg^{-1} soil which corresponds to their clay content in the respective horizons (Thangasamy *et al.*, 2005).

Singh and Agarwal (2005) reported that the CEC values of rice soils of eastern region of Varanasi were low to medium and consistent with clay fractions dominated by the illite and kaolinite minerals. The dominant basic cation was Ca^{++} which influenced the development of the soils.

The cation exchange capacity of soils varied from 51.16 to 62.98 cmol (p+) kg^{-1} and the soils which had lower amount of clay content had lowest CEC values in a microwatershed of Vidharbha region in Maharashtra (Gabhane *et al.*, 2006). The CEC varied from 23.00 to 59.00 cmol (p+) kg^{-1} soil with a tendency to decrease with depth but it was found closely associated with clay ($r = +0.72$) and clay plus organic carbon ($r = +0.73$) in grape growing soils in Nasik district of Maharashtra (Balpande *et al.*, 2007). Also, Sarkar *et al.* (2001) studied the soils of lower outlier of Chhotanagpur plateau and noticed 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 49.00 to 77.00 per cent.

Sharma *et al.* (2001) stated that the soils of Kathiawar region of Gujarat had high base saturation with dominance of Ca^{2+} followed by Mg^{2+} on the exchange complex. The exchangeable calcium ranged from 0.1 to 8.8 cmol (p+) kg^{-1} soil while exchangeable magnesium varied between 0.5 and 6.5 cmol (p+) kg^{-1} soil in Entisols (Typic Ustipsamments) and Inceptisols (Typic Haplustepts) of Nellore district in Andhra Pradesh (Venkatesu *et al.*, 2002). Ca^{2+} 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). Triptahi *et al.* (2009) studied six representative pedons of Banganala watershed of Kymore plateau and Satpura hills in Rewa district, Madhya Pradesh. In soils, cation exchange capacity and Ca^{++} and Mg^{++} ions were high in horizons having high clay.

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. Among different cations, Ca^{2+} dominated the exchange complex followed by Mg^{2+} , K^+ and Na^+ (Sharma and Anil Kumar, 2003).

According to Pillai and Natarajan (2004) the base saturation of soils was medium to high due to the low to medium amount of rainfall in Garakahalli watershed of Bangalore rural district.

The base saturation in soils of Sivagiri microwatershed in Chittoor district of Andhra Pradesh varied from 31 to 92 per cent and exchangeable bases were in the order of $\text{Ca}^{2+} > \text{Mg}^{2+} > \text{Na}^+ > \text{K}^+$ (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 and also showed tendency to increase with depth and followed the distribution pattern of pH (Sitanggang *et al.*, 2006).

2.3 SOIL CLASSIFICATION

The soil is a natural object having many variations and randomness. This makes it very comprehensive and complex. Thus soil may not be easy to classify. The multitude of characteristics involved in the variant makes the grouping difficult. The soil is a typical example wherein number of variants influencing its origin is large. Therefore, in order to understand differences, similarities and relationships among different members, it is necessary that these are grouped in some orderly manner.

Classification is the grouping of objectives in some orderly and logical manner into compartments. It is based on the properties of objects for the purpose of studying, identifying and grouping them. The properties are selected in accordance with the purpose of classification. They are termed as differentiating characteristics and serve to differentiate one class from all others.

A new system of soil classification was presented by soil survey staff of USDA in the year 1975. According to recent edition of Keys to Soil Taxonomy (Soil Survey Staff, 2006) soils are classified into twelve orders based on their properties. Each order is further divided into suborders, great groups, subgroups, families and series.

The soils of Karnataka belong to 7 orders, 12 suborders, 27 great groups, 47 subgroups and 96 soil families. Of the total area of Karnataka, 27 per cent is covered by Alfisols, 25 per cent by Inceptisols, 16 per cent by Entisols, 15 per cent by Vertisols, 8 per cent by Ultisols, 5 per cent by Aridisols and 1 per cent by Mollisols (Shivaprasad *et al.*, 1998).

The red and lateritic soils of Bangalore district (Karnataka state) were classified as Kandic Paleustalfs and Kandic Rhodustalfs by Reddy *et al.* (1993).

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 are classified as Halic Haplusterts while other soils were grouped under Sodic Haplusterts.

Sahu *et al.* (2001) studied morphological features of four Vertisols pedons in the Western Zone of Orissa and characterized and classified them. The soils are very deep, colour ranges from black to grayish brown in different horizons, crack of 2 to 3 cm wide extends beyond 1 m, slickensides, wedge shaped aggregates, iron, manganese and calcretes were observed in the subsurface horizons of the soils. The soils were imperfectly drained, slightly acid to moderately alkaline and the pH value increased with depth. The soils are base rich and high in CEC: clay ratio (0.65 to 0.75) and classified as Typic/Chromic Haplusterts.

Ramprakash and Seshagiri Rao (2002) classified the soils of Krishna district of Andhra Pradesh into Vertic Haplustepts, Lithic Haplustepts and Typic Haplusterts. 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 cultivated soils in low hill zone of Neogal watershed were classified into Entisols and Inceptisols while those of mid hills zone belong to Entisols, Inceptisols and Alfisols (Sharma *et al.*, 2004).

Sharma *et al.* (2004) 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 pedo-environment (Sitanggang *et al.*, 2006).

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) sub-surface 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) sub-surface 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 Ustifluent. However, pedons 6 and 7 located on hill slope did not show any diagnostic horizon and were classified as Typic Ustorthents.

2.4 LAND EVALUATION

2.4.1 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.

The soils were classified into different land capability classes and sub-classes based on their limitations and potentials. The soils of Shiwalik hills were classified under IVt, VI t and VII t land capability sub-classes whereas, the soils of upper pediment plains qualified for sub-classes III t, II w and II e (Patel *et al.*, 2001).

According to Sarkar *et al.* (2002) the high hill soils such as Humic Dystrudepts and Humic Hapludults were placed in the land capability sub-class Vles due to very steep slope, very severe erosion, low moisture holding capacity and high soil acidity while the medium hill soils (Typic Haplohumults) were classified under land capability sub-class IVes due to moderately steep slope, severe erosion, low moisture holding capacity, gravelly or concretionary subsoil and high soil acidity. Further, the foot hill soils (Typic Palehumults) and gently sloping plain soils (Aquic Haplohumults) were classified into capability sub-classes IIes and IIsw, respectively due to their limitations.

Esther Shekinah *et al.* (2004) classified the soils of Shahpur block in Uttaranchal into six land capability classes viz., II, III, IV, VI, VII and VIII base on their limitations in physiography and soil properties.

Krishnan *et al.* (2004) studied the soils of Lakshadweep islands and stated that 15 per cent of the lands can be classified as fairly good lands with soil limitations (IVs), 15 per cent of lands with soil and drainage limitations (IVsw) and 13 per cent of lands as lands suitable only for forestry, grazing and recreation (VIs).

The soils of Chandragiri Mandal in Chittoor district of Andhra Pradesh have been classified into three land capability sub-classes i.e., II_s, III_{lw}, III_{es}, III_{se} and IV_s (Basava Raju *et al.*, 2005). The soils of Sivagiri microwatershed in Chittoor district of Andhra Pradesh have been classified into three land capability sub-classes i.e. II_s, III_{es}, III_{lw} and IV_s (Thangasamy *et al.*, 2005).

Thangasamy *et al.* (2005) assessed the suitability of soils of Shivagiri microwatershed 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 Sivagiri microwatershed have been classified into three land capability sub-classes for better management of lands. The soils of Typic Haplustepts and Aquic Ustorthents of Sivagiri microwatershed were placed in the land capability class II_s, whereas, the soils of Typic Ustifluvents, Typic Rhodustalfs and Typic Haplustalfs were kept in III_{es}, a soil of Vertic Haplustepts alone was placed in III_{lw} and Typic Ustipsamments was placed in IV_s.

Characterization and evaluation of land resources in Khapri village of Nagpur district of Maharashtra were carried out by Shweta *et al.* (2010). These soils were grouped into II_s, III_s, IV_s and Ives capability sub classes with poor to extremely poor soil productivity.

2.4.2 Soil-site suitability for irrigation

As a case study, Kanadi village of Dadra and Nagar Haveli was 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 was moderately suitable for irrigation with limitations of topography, erosion and compactness in surface soil layers. About 1.3 per cent area was with severe limitations and about 0.7 per cent area was of marginal land with deficiency of depth. Based on the parametric method 35 per cent area was not suitable for irrigation whereas, 45.0 and 51.5 per cent area were moderately and marginally suitable, respectively (Challa *et al.*, 2000).

2.4.3 Soil-site suitability for crops

The most recent evaluation procedure has been introduced since the mid seventies by FAO. 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 hereby 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 structure of the classification is based on the FAO framework for land evaluation. The classification includes four categories: orders, classes, sub classes 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.

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 Haplustalts) 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 (S1) whereas, Vertic Haplustepts and Typic Haplustepts were moderately suitable (S2) for growing paddy. Further, Plinthustalfs, Udic Haplustalfs, Typic Haplustalfs and Typic Rhodustalfs were marginally suitable (S3), Lithic Haplustepts and Typic Ustorthents were not suitable temporarily (N1) and Lithic Ustorthents was not suitable permanently (N2) for growing paddy in Chhattisgarh.

The soils of Neogal Watershed in North-West Himalayas are moderately suitable (S2) and marginally suitable (S3) for growing paddy crop (Sharma *et al.*, 2004). Soil characteristics such as fine- texture, improper drainage, presence of lime and soluble salts in shrink swell soils and gravelly sub-soils and low fertility in lateritic soils are major constraints in sugarcane growing soils of Karnataka, limiting the cane production (Naidu, 2002).

According to Satyavathi and Suryanarayan Reddy (2004), the soils of Telangana region in Andhra Pradesh were evaluated for crop suitability and reported that Typic Haplustalfs and Typic Rhodustalfs were moderately suitable (S2), Vertic Haplustepts, Typic Haplusterts and Chromic Haplustalfs were marginally suitable (S3) and Typic Ustipsamments were not suitable (N1) for growing groundnut crop.

The soil suitability evaluation revealed that the soils of a microwatershed in Vidarbha region of Maharashtra such as Typic Haplusterts and Vertic Haplustepts were found to be moderately suitable (S2) for growing cotton, sorghum and pigeonpea (Gabhane *et al.*, 2006).

Major landforms of Kiar-Nagali microwatershed, developed from sedimentary rocks, comprising ferromagnesian shale and dolomites/dolomitic limestone and occurring at different elevations under varying land uses were studied by Tripathi *et al.* (2006). They studied morphological characteristics and physico-chemical properties and suitability for locally preferred crops. As per Storie's Index the soil productivity potential of the microwatershed area varies from non-agricultural to good. Nagali-I soils were found to be unfit for cultivation. Nagali-II and Kundla soils had good productivity potential. The land capability classes ranged from II to VIII. The agricultural land belongs to class II and III. The lands had limitations of slope and texture. Kundla and Nagali-II soils were highly suitable for commercial vegetable crops *viz.*, pea and tomato and marginally suitable for growing wheat and maize. The growing of pastures/forest trees/medicinal plants will be more effective and remunerative on Nagali-I soils.

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 and Typic Ustifluvents were moderately suitable (S2) for growing groundnut and sugarcane. Ultic Haplustalfs and Typic Haplustepts were marginally suitable (S3) for growing rice crop, while Ultic Haplustalfs, Typic Ustipsamments, Typic Haplustepts and Typic Ustifluvents were permanently not suitable (N2) for growing paddy.

In a study by Shweta *et al.* (2010), characterization and evaluation of land resources in Khapri village of Nagpur district of Maharashtra were carried out. The soil suitability analysis indicated that very shallow soils are marginally to not suitable and very deep soils of valley plain are moderately suitable for growing cotton, sorghum and soybean. Suitable conservation measures and interventions have been suggested to improve the productivity of these soils.

2.5 SURFACE SOIL PROPERTIES AND NUTRIENT STATUS

2.5.1 Soil properties

2.5.1.1 Soil reaction (pH)

The pH of saline soils was less than 8.5 and that of sodic soils was always more than 8.5. It usually lies between 8.5 and 10.0 (USSL Staff, 1954). However, in saline-sodic soils, the pH depends upon the amount of salts present in them.

Sivasankaran *et al.* (1993) observed that the pH of red soils varied from 3.9 to 7.0 in Western Ghat of Karnataka and remarked that rainfall was the major factor contributed to the increase in acidity in these soils. Shivaprasad *et al.* (1998) while characterizing the soils of Karnataka observed that soils derived from granitic-gneiss material were found to be slightly acidic to near neutral in reaction.

2.5.1.2 Electrical conductivity (EC)

The electrical conductivity of North Gujarat soils increased with depth and the values were 0.19, 1.21, 1.80, 2.10 and 3.00 dS m⁻¹ at 0-20, 20-40, 40-60 and 60-100 cm depth (Barade and Gowaikar, 1965).

Working on red and black soils in Andhra Pradesh, Krishnamoorthy and Govinda Rajan (1977) observed that in red soils electrical conductivity values ranged from less than 0.15 to 0.25 dS m⁻¹ and showed increasing trend with depth. Gundlur (1991) concluded that the electrical conductivity was found to increase with depth in Vertisols in both the irrigated and unirrigated conditions.

2.5.1.3 Organic carbon

While, the organic matter content of arid and semi-arid regions is low under virgin conditions, it commonly increased with the application of irrigation water and cultivation, especially when crop management is good. And this organic matter, apart from being a source of nutrient to plants, also has a favourable effect on soil physical properties (USSL Staff, 1954).

Krishnamurthy and Govinda Rajan (1977) working with black and red soils of Andhra Pradesh noticed higher organic matter in second horizon which later decreased in red soils while in black soils accumulation of organic matter was noticed in fourth horizon due to the downward movement of it along with clay. .

2.5.2 Soil fertility status

2.5.2.1 Nutrient mapping

Ravikumar (2006) characterized and classified the soil resources of 48A Distributary of Malaprabha Right Bank Command for sustainable land use planning and to assess the productivity of the soils. The mapping of available nutrient status by GIS technique indicated that majority of the area was low to medium with respect to available N, P and S. The entire study area was high in K. Among the micronutrients, the majority area was deficient in iron and zinc, whereas, manganese and copper status was low to sufficient. The crop cutting experiment revealed that the yields of the crops were in general low as soils were deficient in N, P, S, Zn and Fe.

Dhanya *et al.* (2009) undertook a study to map the nutrient status of Mirjan village under the coastal agroecosystem of Karnataka. The soil analysis showed the deficiency of N, P, K and Zn in the study area. From the soil fertility maps it was observed that in the study area 247.3 ha low (69.5 per cent of the study area), 86.50 ha medium and 22.14 ha high in available nitrogen. An area of 249.3 ha was low (70.0 per cent of the study area), 88.40 ha was medium and 18.32 ha was high in available phosphorous. In the case of potassium, 159.15 ha was low (44.7 per cent of the study area), 131.71 ha medium and 65.39 per cent ha high in available potassium. Zn deficiency was observed in 201.21 ha (56.5 per cent of the study area).

Binita *et al.* (2009) conducted an investigation on soil fertility status of portion of Ghatprabha left bank canal (GLBC) command area to evaluate the status of major nutrients as affected by the different physiographic units. Two hundred and forty samples were collected at random in GLBC command area representing all physiographic positions in the landscape and major crops grown. The fertility maps were prepared for the area using ArcView 3.1 and spatial analyst using spline function for interpolation. The nutrient status was discussed in relation with physiographic position and cropping pattern. Due to intensive irrigated agriculture practice in the command area, the nutrient status did not follow any distinct trend with respect to physiographic units and crops grown. Based on the overall assessment, the nutrient status in these soils was optimum.

Soils of Bhanapur microwatershed in northern dry zone of Karnataka was studied by Srikant *et al.* (2008), for available nutrient status and mapped by GIS technique. Twenty five surface soil samples from black soils and seventy five surface soil samples from red soils in Bhanapur microwatershed were collected and assessed for the available major nutrient status. The results revealed that the majority of the area (580.42 ha) in the watershed was low in available nitrogen, available phosphorus was medium in major part of the watershed (555.25 ha), but it was low in 26.71 ha, the available potassium content in major portion of the study area was medium and high category in 365.65 and 150.31 ha, respectively. Available sulphur status was low (417.32 ha) to medium (164.64 ha).

In an investigation by Sharma *et al.* (2008), spatial distribution of nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) was studied at flag leaf stage of wheat (*Triticum aestivum* L.) by collecting random geo-referenced surface (0-0.15 m) soil samples from 645 sites representing different soils using global positioning system (GPS) and mapped on 1:50,000 scale in Amritsar district of North-West Punjab.

2.5.2.2 Available N, P and K

In Karnataka, about 10.3 per cent of soils fall under low category, 35.8 per cent under medium and 53.9 per cent under high category of available nitrogen status (Shivaprasad *et al.*, 1998)

While characterizing and classifying soils of an irrigated river flood plain in the eastern coastal region. Sahu and Mishra (1997) reported that available phosphorus content varied between 12.76 to 14.00 kg per ha and available potassium content varied from 171.00 to 211.66 kg per ha and both materials were in medium level.

The data on the available phosphorus status in the soils of Karnataka showed that about 83 per cent of the soils are low in phosphorus and 17 per cent area is under medium category (Shivaprasad *et al.*, 1998).

The available K is medium to high in most of the soils of the Karnataka except in lateritic soils of coastal plains and Western Ghats and in shallow red and black soils (Shivaprasad *et al.*, 1998).

According to Vara Prasad Rao *et al.* (2008), in typical pedons representing major landforms of Ramahcandrampuram Mandal in Chittoor district of Andhra Pradesh, the soils were low in available nitrogen, low to medium in available phosphorus, and medium to high in available potassium.

Sharma *et al.* (2008) studied spatial distribution of nitrogen (N), phosphorus (P), potassium (K) at Amritsar district of Punjab. The content of available N varied 63 to 170 kg ha⁻¹, available P from 9.4 to 84.9 kg ha⁻¹, available K from 84 to 700 kg ha⁻¹.

2.5.2.3 Available Sulphur and Micronutrients

In the red, black and associated soils of Giddalur Mandal of Andhra Pradesh, the available sulphur content was sufficient (5.00 to 21.20 mg kg⁻¹) in surface soils (Gurumurthy *et al.*, 1996).

Sharma and Gangwar (1997) observed that the total sulphur content in Inceptisols of Moradabad district in Uttar Pradesh ranged from 167 to 917 mg kg⁻¹soil and also noticed negative correlation between total sulphur and pH and also between total sulphur and electrical conductivity.

Ashok (2001) examined 12 soil series representing black, red and coastal soils from different agro-climatic zones of Karnataka and 12 surface soil samples from each series are analyzed for sulphur status and distribution of different form of sulphur, relationship between sulphur and various soil properties. The CaCl_2 -extracted sulphur content in black, red and coastal soils ranged between 5.08 to 59.95 ppm, 8.66 to 27.15 ppm and 7.26 to 20.32 ppm, respectively.

Katyal and Sharma (1991) reported that available zinc varied from 0.12 and 2.80 mg per kg soil in Indian soils. It was nearly one hundredth of the total zinc in Indian soils.

Satyavathi and Suryanarayana Reddy (2004) studied fifty four soil samples from ten pedons of Telangana region, Andhra Pradesh for vertical distribution of DTPA-extractable Zn, Cu, Fe and Mn and their relationship with some soil properties. Soil pH, calcium carbonate, organic carbon and particle size fractions had strong influence on the distribution of these micronutrients. The content of micronutrient increased with the increase in organic carbon and decreased with increase in pH and CaCO_3 . There was no definite trend for the distribution of these micronutrients with respect to depth. As per critical limit prescribed for Zn and Fe, 44 and 20 per cent of the soils could be rated as deficient in available zinc and iron, respectively. Copper and manganese were found to be adequate.

Thangasamy *et al.* (2005) studied the physico-chemical characteristics of soils in Sivagiri microwatershed of Chittoor district in Andhra Pradesh. The soils were high in sulphur whereas, deficient in Fe, deficient to sufficient in available Zn and sufficient in available Cu and Mn.

Red soils fall under sufficient (114.23 ha) and excess (407.25 ha) category for the Fe status. In black soils (60.27 ha) it was found to be deficient which might be due to precipitation of Fe^{2+} by CaCO_3 in soil and decrease the availability. Similar results were also observed by Ravikumar (2006).

A study was undertaken by Ravikumar *et al.* (2006) to identify micronutrient constraints of 48 A distributory of Malaprabha right bank command of Karnataka for site-specific recommendations. The mapping of available micronutrient status by GIS technique indicated that the majority of the area was deficient in iron (0.18 to 3.51 mg/kg) and zinc (0.01 to 0.37 mg/kg), whereas, manganese (0.014 to 11.38 mg/kg) and copper (0.016 to 6.78 mg/kg) status was low to deficient.

The soils of Ramahcandrapuram Mandal in Chittoor district of Andhra Pradesh were deficient in DTPA-extractable zinc and iron while these were sufficient in DTPA-extractable copper and manganese (Vara Prasad Rao *et al.*, 2008).

Sharma *et al.* (2008) studied spatial distribution of nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) at Amritsar district of Punjab. The content of available S ranged from 24.6 to 60.0 kg ha^{-1} .

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 (cf. Fig. 1)

The selected study area, the Bastwad Microwatershed (WS-code: 4D7D6L2c) lies on the NH-4, about 63 km away from the UAS, Dharwad and approximately 10 km from the city of Belgaum (Karnataka). Bastwad microwatershed covers Bastwad and Halaga villages in Belgaum taluka. The adjacent black and red soils are seen in this area with the red soils being limited to hill-tops which are also a feature of the microwatershed. The study area belongs to Northern Transition Zone of Karnataka. Here, slope and soil texture both are the limiting factors for crop production that in turn are determined by soil type; red or black. So, characterization of the area is crucial for better agricultural production.

3.2 LOCATION OF THE STUDY AREA

The selected Bastwad microwatershed belongs to Belgaum district. Bastwad Microwatershed is located between; 15°49'55.03"N; 15°47'55.28"N latitudes and 74°35'1.08" E; 74°31'49.03" E longitudes.

3.3 RELIEF AND DRAINAGE (cf. Plate 1, 2 and 3)

The average elevation of this area is 785.74 m above the mean sea level. The relief is normally having nearly level to very gently sloping in the domain of black soils (valley area) but hill-tops possess high degree of slope.

3.4 GEOLOGY

The basalt covers the Bastwad microwatershed area. The predominant minerals noticed in the area are oligoclase and orthoclase feldspar and besides these minerals, some of the dark coloured minerals occur.

3.5 CLIMATE (cf. Table 1)

The climate of the area is of semi-arid type. The summer season starts from third week of February and continuous up to the May, winter commences from first or second week of November and continuous up to the middle of February or sometimes up to the end of February. Monsoon starts from June and continues up to end of October..

3.6 NATURAL VEGETATION AND LAND USE

Peepal (*Ficus religiosa*), Kikar (*Prosopis cineraria*), Subabul (*Lucaena leucocephala*) and Neem (*Azadirachta indica*) are the predominant trees found in the study area. The economy of the area revolves around agriculture. The important cereal and oilseed crops of the area are rice, sorghum, pearl millet, wheat, maize, soybean, sunflower and groundnut. In pulses, lentil, chick pea, pigeon pea and green pea are grown in the area. Among commercial crops cotton and sugarcane are prevalent here. Vegetables are also grown in the area viz. tomato, potato, brinjal, cabbage, radish, capsicum, chilli, onion, coriander. Gladiolus, jasmine, marigold and rose are grown for flower production. Mango is an important fruit crop in the area.

3.7 SOIL SURVEY

Intensive soil survey was carried out for Bastwad microwatershed using IRS-P6 Image. The scanned maps and image were geocoded, subset was created with the help of microwatershed boundary using *ERDAS imagine 8.7*. After intensive traversing, pedon locations were selected in the microwatershed depending upon soil heterogeneity. Freshly dug pedons were studied for their morphological features. In between pedons, surface samples were collected to ascertain soil homogeneity and soil boundaries were fixed.

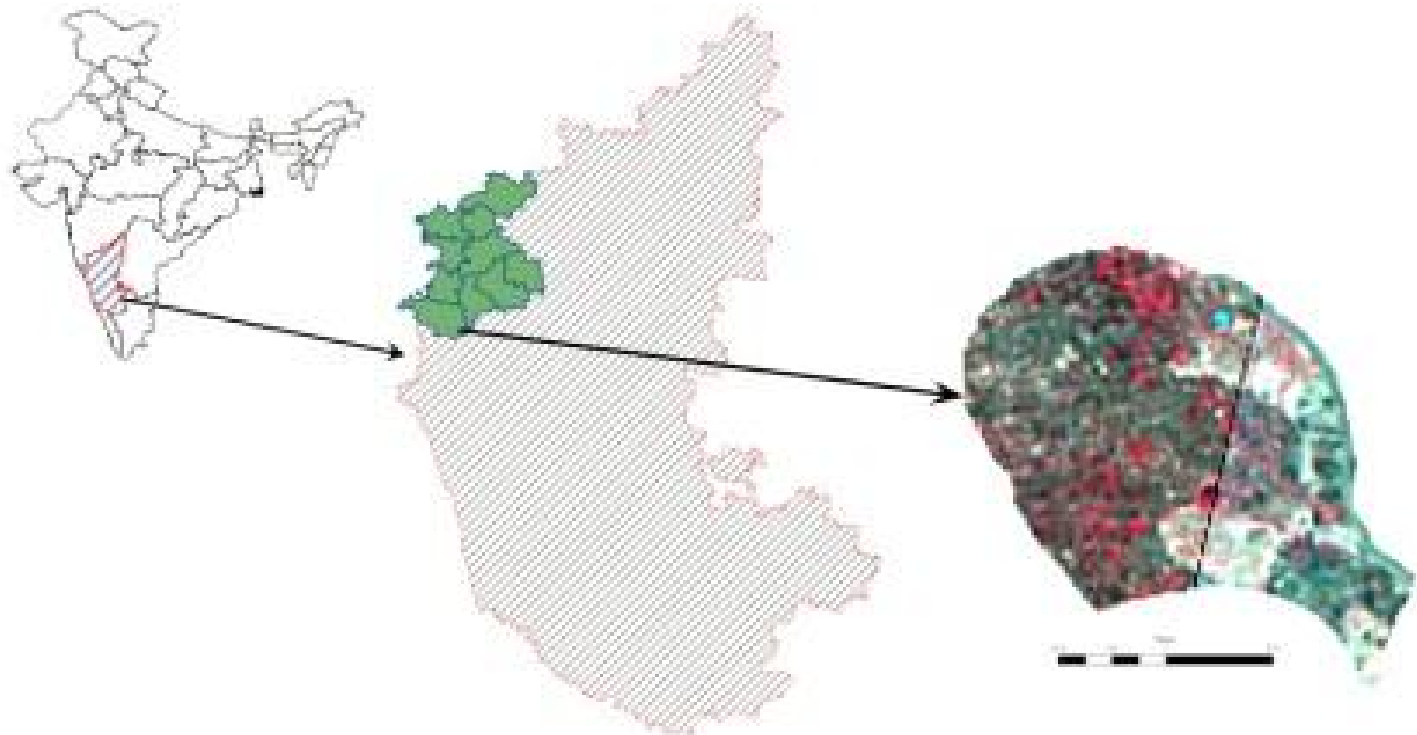


Fig. 1. Location of Bastwad microwatershed

Fig.1. Location of Bastwad microwatershed



Plate 1. Landscape of upland pedons



Plate 2. Landscape of midland pedons



Plate 3. Landscape of lowland pedons

Table 1. Long-term average (2001-2010) of rainfall and temperature of Bastwad microwatershed area (Belgaum district, Karnataka)

Month	Mean of 2001-2010			RH (%)
	Rainfall (mm)	Temperature (°C)		RH
		Maximum	Minimum	
January	1.0	29.9	14.2	64.0
February	5.0	32.8	15.7	71.5
March	8.3	34.9	18.4	80.1
April	70.1	36.1	20.5	89.4
May	110.6	34.7	21.1	92.8
June	253.9	29.0	20.9	95.5
July	322.7	26.7	20.4	97.6
August	195.9	26.2	19.9	87.9
September	174.8	28.1	19.5	80.6
October	108.1	29.6	18.8	78.3
November	44.8	29.6	16.9	70.2
December	1.0	29.0	14.4	65.0
Total	1296.3	30.6	18.4	81.1

3.8 DESCRIPTION OF PEDONS

Ten pedons were selected from the microwatershed on soil heterogeneity and topography basis for the present investigation. Geographical locations of the pedons are listed in Table 2 and are depicted in Fig. 2.

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 morphological properties were described as per Soil Survey Staff (1951). The horizons were identified and designated according to revisions in Soil Taxonomy (Soil Survey Staff, 1999).

Pedon -1 (cf. Plate 4)

Location	: 15°48'13.1"N; 74°34'6.8" E
Altitude	: 840.94 m above MSL
Physiography	: Upland
Slope	: 8-15 %
Erosion	: Very severe
Drainage	: Well drained
Geology	: Basalt
Present land use	: Uncultivated

Horizon	Depth (cm)	Description
A1	0-10	Dark reddish brown (5YR 3/3); extremely gravelly sand, fine, weak, granular; slightly hard when dry, friable when moist, non sticky non plastic when wet; few very fine roots; pH 6.70; clear smooth boundary.
A2	10-30	Dark reddish brown (5YR 3/4); extremely gravelly sand, fine, weak, granular; slightly hard when dry, friable when moist, non sticky non plastic when wet; few very fine roots; pH 6.71; clear smooth boundary.
AC	30-55	Reddish brown (5YR 5/3); structureless soil mixed with weathered parent rock (basalt); very hard when dry and extremely firm when moist, non sticky non plastic when wet.
C	55-65	Reddish grey (5YR 5/2); structureless; weathered parent rock (basalt).

Table 2. Geographical Locations of pedons

Sl. No.	Physiography	Pedon No.	location	
			Latitude	Longitude
1.	Upland	1	15°48'13.1"N	74°34'6.8" E
2.	Midland	2	15°48'17.6"N	74°34'04.4" E
		3	15°48'21.5"N	74°34'03.2" E
		4	15°48'26.8" N	74°33'58.6" E
		5	15°48'52.3" N	74°34'01.0" E
3.	Lowland	6	15°48'53.1" N	74°33'46.3" E
		7	15°48'32.4" N	74°33'18.9" E
		8	15°49'21.3" N	74°33'17.3" E
		9	15°49'05.2" N	74°32'54.5" E
		10	15°49'20.6" N	74°32'51.8" E

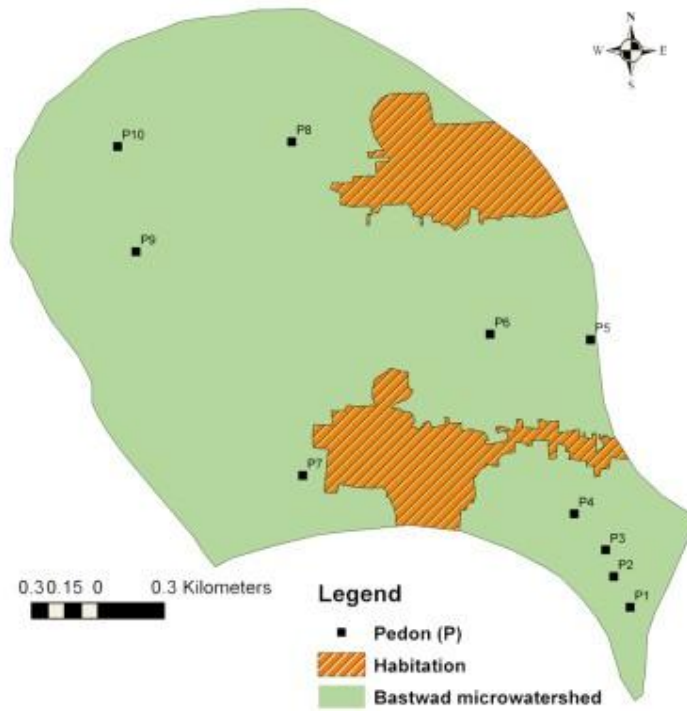


Fig. 2. Geographical locations of Pedons

Fig.2. Geographical locations of Pedons

Additional notes: Boulders on the surface; gravels up to 30 cm depth; parent rock from 30 cm.

Pedon -2 (cf. Plate 5)

Location	: 15°48'17.6"N; 74°34'04.4" E
Altitude	: 829.97 m above MSL
Physiography	: Midland
Slope	: 3-8%
Erosion	: Severe
Drainage	: Well drained
Geology	: Basalt
Present land use	: Sorghum, maize



Plate 4. Pedon 1



Plate 5. Pedon 2



Plate 6. Pedon 3

Horizon	Depth (cm)	Description
Ap	0-25	Very dark brown (10YR 2/2); gravelly sandy clay loam; medium moderate granular; slightly hard when dry, friable when moist, slightly sticky plastic when wet; few very fine roots; pH 8.25; diffuse smooth boundary; intense effervescence with HCl.
B1	25-50	Very dark grayish brown (10YR 3/2); gravelly sandy clay loam; fine moderate sub angular blocky; slightly hard when dry, friable when moist, slightly sticky plastic when wet; pH 7.76; diffuse smooth boundary; intense effervescence with HCl.
B2	50-70	Very dark brown (10YR 2/2); gravelly sandy clay loam; fine moderate sub angular blocky; moderately hard when dry, firm when moist, sticky and plastic when wet; pH 8.53; clear wavy boundary; intense effervescence with HCl.
BC	70-90+	Very dark brown (10YR 2/2); very gravelly sandy clay loam; fine moderate sub angular blocky; hard when dry, very firm when moist, sticky and plastic when wet; pH 8.60; diffuse boundary; intense effervescence with HCl.

Additional notes: CaCO₃ concretions distributed throughout the solum; parent rock starts from 75 cm.

Pedon -3 (cf. Plate 6)

Location	: 15°48'21.5"N; 74°34'03.2" E
Altitude	: 819.30 m above MSL
Physiography	: Midland
Slope	: 8-10%
Erosion	: Very severe
Drainage	: Well drained
Geology	: Basalt
Present land use	: Sorghum, maize, potato

Horizon	Depth (cm)	Description
Ap	0-10	Dark reddish brown (5YR 3/2); gravelly sandy loam; medium weak sub angular blocky; slightly hard when dry, friable when moist, slightly sticky and slightly plastic when wet; many fine roots; pH 6.52; diffuse smooth boundary.
Bt1	10-30	Dark reddish brown (5YR 3/4); gravelly sandy clay loam; fine strong sub angular blocky; thin clay skins were observed on peds with 10X lens; slightly hard when dry, friable when moist, slightly sticky and slightly plastic when wet; many fine roots; pH 6.85; clear smooth boundary.
Bt2	30-50	Dark reddish brown (5YR 3/3); gravelly sandy clay loam; fine strong sub angular blocky; thin clay skins were observed on peds with 10X lens; moderately hard when dry, firm when moist, slightly sticky and slightly plastic when wet; pH 6.90; clear smooth boundary.
BC	50-70	Dark reddish brown (5YR 3/3); gravelly sandy loam; fine strong sub angular blocky; hard when dry, very firm when moist, non-sticky and non-plastic when wet; pH 7.38; clear smooth boundary.
C	70-100	Yellowish red (5YR 4/6); gravelly sandy loam; fine strong sub angular blocky; hard when dry, very firm when moist, non-sticky and non-plastic when wet; pH 7.38; diffuse boundary.

Additional notes: Parent rock appears from 65 cm.

Pedon -4 (cf. Plate 7)

Location : 15°48'26.8" N; 74°33'58.6" E
Altitude : 806.11 m above MSL
Physiography : Midland
Slope : 5-7 %
Erosion : Severe
Drainage : Moderately well drained
Geology : Basalt
Present land use : Sorghum, maize, wheat, soybean

Horizon	Depth (cm)	Description
Ap	0-20	Very dark grayish brown (10YR 3/2); silty clay; medium, moderate granular; slightly hard when dry, friable when moist, sticky and plastic when wet; many fine roots; pH 7.91; diffuse smooth boundary.
A2	20-50	Very dark grayish brown (10YR 3/2); silty clay; fine strong sub angular blocky; moderately hard when dry, firm when moist, very sticky and very plastic when wet; few very fine roots; pH 8.11; clear smooth boundary.
Bss1	50-70	Very dark brown (10YR 2/2); clay; fine strong sub angular blocky; moderately hard when dry, firm when moist, very sticky and very plastic when wet; slickensides were prominent from 60 cm depth; pH 8.25; diffuse smooth boundary.
Bss2	70-95	Very dark brown (10YR 2/2); clay; fine strong sub angular blocky; hard when dry, very firm when moist, very sticky and very plastic when wet; prominent slickensides present; pH 8.42; diffuse smooth boundary.
Bss3	95-120+	Very dark brown (10YR 2/2); clay; fine strong sub angular blocky; very hard when dry, very firm when moist, very sticky and very plastic when wet; prominent slickensides present; pH 8.43; diffuse smooth boundary.

Additional notes: Wide and deep cracks up to 60 cm depth; slickensides appear from 60 cm and extend in entire solum.

Pedon -5 (cf. Plate 8)

Location : 15°48'52.3" N; 74°34'01.0" E

Altitude : 796.44 m above MSL

Physiography : Midland

Slope : 2-3 %

Erosion : Moderate

Drainage : Moderately well drained

Geology : Basalt

Present land use : Sorghum, maize, paddy, wheat, brinjal, chilli



Plate 7. Pedon 4



Plate 8. Pedon 5



Plate 9. Pedon 6



Plate 10. Pedon 7

Horizon	Depth (cm)	Description
Ap	0-15	Very dark brown (10YR 2/2); silty clay; medium moderate granular; slightly hard when dry, friable when moist, sticky and plastic when wet; few common roots; pH 7.36; clear smooth boundary
A2	15-40	Very dark brown (10YR 2/2); silty clay; fine strong sub angular blocky; slightly hard when dry, friable when moist, sticky and plastic when wet; few very fine roots; pH 7.59; gradual smooth boundary
Bw	40-70	Very dark grayish brown (10YR 3/2); clay; fine strong sub angular blocky; moderately hard when dry, firm when moist, sticky and plastic when wet; pH 7.50; clear smooth boundary
Bss1	70-110	Very dark grayish brown (10YR 3/2); clay; fine strong sub angular blocky; moderately hard when dry, firm when moist, sticky and very plastic when wet; slickensides were prominent from 90 and below; pH 7.40; diffuse smooth boundary
Bss2	110-150+	Very dark grayish brown (10YR 3/2); clay; fine strong sub angular blocky; moderately hard when dry, firm when moist, sticky and very plastic when wet; prominent slickensides were observed; pH 7.63; diffuse smooth boundary

Additional notes: Basalt rock fragments of various sizes up to 85 cm; slickensides appear from 60 cm depth and extend further in the solum.

Pedon -6 (cf. Plate 9)

Location	: 15 ⁰ 48'53.1" N; 74 ⁰ 33'46.3" E
Altitude	: 766.87 m above MSL
Physiography	: Lowland
Slope	: 2-3 %
Erosion	: Moderate
Drainage	: Moderately well drained
Geology	: Basalt
Present land use	: Sorghum, maize, sugarcane, groundnut, capsicum, tomato, potato,

Horizon	Depth (cm)	Description
Ap	0-20	Very dark grayish brown (10YR3/3); silty clay; medium moderate granular; slightly hard when dry, friable when moist, sticky and plastic when wet; many medium roots; pH 7.69; clear smooth boundary.
A2	20-50	Very dark grayish brown (10YR 3/2); silty clay; fine strong sub angular blocky; moderately hard when dry, firm when moist, sticky and plastic when wet; many medium roots; pH 8.26; clear smooth boundary.
B1	50-80	Very dark grayish brown (10YR 3/2); silty clay; fine strong sub angular blocky; moderately hard when dry, firm when moist, sticky and very plastic when wet; few common roots; pH 8.29; gradual smooth boundary.
B2ss1	80-100	Very dark brown (10YR 2/2); clay; fine strong sub angular blocky; moderately hard when dry, firm when moist, very sticky and very plastic when wet; few very fine roots; slickensides prominent from 80 cm depth; pH 8.13; diffuse boundary
B2ss2	100-120	Very dark grayish brown (10YR 3/2); clay; fine strong sub angular blocky; moderately hard when dry, firm when moist, very sticky and very plastic when wet; few very fine roots; prominent slickensides present; pH 8.34; diffuse boundary
B2ss3	120-150+	Very dark grayish brown (10YR 3/2); clay; fine strong sub angular blocky; moderately hard when dry, firm when moist, very sticky and very plastic when wet; slickensides were prominent; pH 8.33; diffuse boundary

Additional notes: Root distribution up to 75 cm; slickensides appear from 80 cm depth and extend further downwards.

Pedon -7 (cf. Plate 10)

Location : 15°48'32.4" N; 74°33'18.9" E

Altitude : 760.47 m above MSL

Physiography : Lowland

Slope : 1-3 %

Erosion : Moderate

Drainage : Moderately well drained

Geology : Basalt

Present land use : Sorghum, paddy, maize, sugarcane, groundnut, chilli, cabbage, marigold

Horizon	Depth (cm)	Description
Ap	0-25	Very dark brown (10YR2/2); silty clay; medium moderate granular; slightly hard when dry, friable when moist, slightly sticky and slightly plastic when wet; few common roots; pH 8.12; clear smooth boundary.
A2	25-50	Very dark brown (10YR 2/2); silty clay; fine strong sub angular blocky; hard when dry, firm when moist, sticky and plastic when wet; few very fine roots; pH 8.38; gradual wavy boundary.
Bss1	50-65	Very dark brown (10YR 2/2); clay; fine strong sub angular blocky; hard when dry, firm when moist, very sticky and very plastic when wet; slickensides were prominent from 50 cm depth; pH 8.46; diffuse smooth boundary.
Bss2	65-95	Very dark grayish brown (10YR 3/2); clay; fine strong sub angular blocky; hard when dry, firm when moist, very sticky and very plastic when wet; prominent slickensides were observed; pH 8.45; diffuse smooth boundary
Bss3	95-120	Very dark grayish brown (10YR 3/2); clay; fine strong sub angular blocky; hard when dry, firm when moist, very sticky and very plastic when wet; prominent slickensides were observed; pH 8.43; diffuse smooth boundary
Bss4	120-150+	Very dark brown (10YR 2/2); clay; fine strong sub angular blocky; hard when dry, firm when moist, very sticky and very plastic when wet; prominent slickensides were observed; pH 8.32; diffuse smooth boundary

Additional notes: Slickensides appear from 50 cm depth and extend further in the solum.

Pedon -8 (cf. Plate 11)

Location	: 15 ⁰ 49'21.3" N; 74 ⁰ 33'17.3" E
Altitude	: 750.41 m above MSL
Physiography	: Lowland
Slope	: 0-1 %
Erosion	: Slight
Drainage	: Moderately well drained
Geology	: Basalt
Present land use	: Maize, sugarcane, paddy, cabbage, onion, wheat, jasmine, rose



Plate 11. Pedon 8



Plate 12. Pedon 9



Plate 13. Pedon 10

Horizon	Depth (cm)	Description
Ap	0-18	Very dark grayish brown (10YR 3/2); silty clay; medium moderate granular; slightly hard when dry, friable when moist, slightly sticky and slightly plastic when wet; few very fine roots; pH 7.85; clear smooth boundary.
A2	18-40	Very dark grayish brown (10YR 3/2); silty clay; fine strong sub angular blocky; hard when dry, firm when moist, slightly sticky and slightly plastic when wet; few very fine roots; pH 7.65; clear smooth boundary.
B1	40-60	Very dark grayish brown (10YR 3/2); silty clay; fine strong sub angular blocky; hard when dry, firm when moist, sticky and plastic when wet; pH 8.08; diffuse smooth boundary.
B2	60-90	Very dark grayish brown (10YR 3/2); clay; fine strong sub angular blocky; hard when dry, firm when moist, very sticky and very plastic when wet; pH 7.91; diffuse smooth boundary
B3ss1	90-125	Very dark grayish brown (10YR 3/2); clay; fine strong sub angular blocky; hard when dry, firm when moist, very sticky and very plastic when wet; slickensides were prominent from 100 cm depth; pH 8.07; diffuse smooth boundary
B3ss2	125-150+	Very dark grayish brown (10YR 3/2); clay; fine strong sub angular blocky; hard when dry, firm when moist, very sticky and very plastic when wet; prominent slickensides were observed; pH 8.28; diffuse smooth boundary

Additional notes: Slickensides appear from 100 cm depth and go further deep in the solum.

Pedon -9 (cf. Plate 12)

Location : 15°49'05.2" N; 74°32'54.5" E

Altitude : 743.10 m above MSL

Physiography : Lowland

Slope : 0-1 %

Erosion : Moderate

Drainage : Moderately well drained

Geology : Basalt

Present land use : Paddy, potato, wheat, sugarcane, okra, cotton

Horizon	Depth (cm)	Description
Ap	0-30	Very dark grayish brown (10YR 3/2); silty clay; medium moderate granular; slightly hard when dry, friable when moist, lightly sticky and slightly plastic when wet; few common roots; pH 7.42; clear smooth boundary.
A2	30-40	Very dark brown (10YR 2/2); silty clay; fine strong sub angular blocky; slightly hard when dry, friable when moist, slightly sticky and slightly plastic when wet; few common roots; pH 8.15; gradual smooth boundary.
B ₁	40-60	Very dark grayish brown (10YR 3/2); clay; fine strong sub angular blocky; moderately hard when dry, firm when moist, very sticky and very plastic when wet; pH 8.52; diffuse smooth boundary.
B2	60-80	Very dark brown (10YR 2/2); clay; fine strong sub angular blocky; moderately hard when dry, firm when moist, very sticky and very plastic when wet; pH 8.62; diffuse smooth boundary
B3ss1	80-100	Very dark grayish brown (10YR 3/2); clay; fine strong sub angular blocky; hard when dry, firm when moist, very sticky and very plastic when wet; slickensides were prominent from 85 cm; pH 8.52; diffuse smooth boundary
B3ss2	100-140+	Very dark grayish brown (10YR 3/2); clay; fine strong sub angular blocky; hard when dry, firm when moist, very sticky and very plastic when wet; prominent slickensides were observed; pH 8.73; diffuse smooth boundary

Additional notes: Slickensides appear from 85 cm depth extending further down in the solum.

Pedon -10 (cf. Plate 13)

Location : 15^o49'20.6" N; 74^o32'51.8" E

Altitude : 743.10 m above MSL

Physiography : Lowland

Slope : 1-3 %

Erosion : Nil

Drainage : Moderately well drained

Geology : Basalt

Present land use : Paddy, sugarcane, cotton

Horizon	Depth (cm)	Description
Ap	0-20	Very dark brown (10YR 2/2); silty clay; medium moderate granular; slightly hard when dry, friable when moist, sticky and plastic when wet; few very fine roots; pH 7.23; clear smooth boundary.
A2	20-40	Very dark grayish brown (10YR 3/2); silty clay; fine strong sub angular blocky; slightly hard when dry, firm when moist, sticky and plastic when wet; few very fine roots; pH 7.11; gradual smooth boundary.
B1	40-60	Very dark grayish brown (10YR 3/2); silty clay; fine strong sub angular blocky; moderately hard when dry, firm when moist, very sticky and very plastic when wet; pH 8.14; diffuse smooth boundary.
B2ss1	60-80	Very dark grayish brown (10YR 3/2); clay; fine strong sub angular blocky; moderately hard when dry, firm when moist, very sticky and very plastic when wet; slickensides were prominent from 75 cm depth; pH 8.12; diffuse smooth boundary
B2ss2	80-110	Very dark grayish brown (10YR 3/2); clay; fine strong sub angular blocky; hard when dry, firm when moist, very sticky and very plastic when wet; prominent slickensides were observed; pH 8.04; diffuse smooth boundary
B2ss3	110-130+	Very dark grayish brown (10YR 3/2); clay; fine strong sub angular blocky; hard when dry, firm when moist, very sticky and very plastic when wet; prominent slickensides were observed; pH 7.90; diffuse smooth boundary

Additional notes: Slickensides appear from 75 cm depth and extend into deep solum.

3.8.2 Soil sampling

Horizon-wise soil samples were collected from all the pedons. Seventy four surface soil samples well distributed in the selected microwatershed were collected for assessment of soil fertility. Locations of the profile and surface samples were recorded with the help of GPS device.

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. The coarse fragments were washed, dried, weighed and expressed as per cent of whole soil.

3.10 METHODS OF SOIL ANALYSIS

3.10.1 Physical properties

3.10.1.1 Particle size analysis

Particle size distribution in soil samples was determined by international pipette method as described by Piper (1966) using sodium hydroxide as a dispersing agent. From the dispersed suspension an aliquot of clay + silt and clay were pipetted out from specified depth at their specific time intervals depending on the suspension temperature. The total sand obtained by repeated decantation of silt and clay was passed through 0.05 mm sieve. The fraction that was finer than 0.05 mm was added to silt determined initially by pipetting to have particle size classes as per USDA systems.

3.10.1.2 Bulk density (Mg/m^3)

Bulk density in each horizon was measured by clod method as described by Black (1965).

3.10.1.3 Maximum water holding capacity

Maximum water holding capacity of the soils was determined by using Keen Raczkowaski brass cup as described by Sankaram (1960).

3.10.2 Chemical properties

3.10.2.1 Soil Reaction

The soil pH was determined in 1:2.5 soil:water suspension by potentiometric method using glass electrode.

3.10.2.2 Electrical conductivity (EC)

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

3.10.2.3 Organic carbon

The organic carbon contents of a finely ground soil samples were determined by Walkely and Black's Wet Oxidation method as described by Jackson (1967) and were expressed in g kg^{-1} soil.

3.10.2.4 Exchangeable cations

Exchangeable cations were extracted by neutral normal ammonium acetate solution. 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, 1984). 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. Ammonium acetate method was employed for the soil samples which had low pH ($\text{pH} < 6.5$). Retained ammonium was estimated using distillation method.

3.10.2.6 Free calcium carbonate

The free calcium carbonate content of the soil was determined by acid neutralization method as described by USSL Staff (1954).

3.11 SOIL CLASSIFICATION

Based on the morphological, physical and chemical properties the soils were classified up to family level following USDA Soil Taxonomy (Soil Survey Staff, 1999 and 2006)

3.12 LAND EVALUATION

Land evaluation was carried out based on soil-site characteristics which are mentioned in Table 3.

3.12.1 Land capability classification

The land capability was 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). The criteria used for land capability classification are presented in Appendix I.

3.12.2 Soil-site suitability evaluation 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 in making groups 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 determined as per the guidelines proposed by Sehgal (1996). The criteria of soil site characteristics for suitability for irrigation are presented in Appendix II.

3.12.3 Soil-site suitability evaluation for crops

The structure of the classification is based on the FAO framework for land evaluation. The classification includes four categories: orders, classes, sub classes and units. There are two orders (S, 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 rice, wheat, maize, sorghum, pearl millet, groundnut, soybean, sunflower, Bengal gram (chickpea), pigeon pea, cotton, sugarcane, cabbage, potato, tomato, chilli, coconut, Sapota, guava, mango, rose and jasmine were evaluated based on the criteria suggested by Sehgal (1996). Soil-site suitability characteristics for the crops are presented in Appendix III to XXIV.

3.13 ASSESSMENT OF SOIL FERTILITY

3.13.1 Collection of soil samples

Soil samples (0-30 cm) at 8" interval were collected during May 2010. Exact sample locations were recorded using a GPS device. Processed soil samples were analyzed for nutrient availability by following standard analytical techniques. The details of geographical locations of surface soil samples are provided in Table 4.

3.13.2 Soil analysis for soil fertility evaluation

3.13.2.1 pH and EC

Soil pH, Electrical conductivity and organic carbon were estimated as described in section 3.10.2.1 and 3.10.2.2 respectively.

3.13.2.2 Available nitrogen

Available nitrogen was determined by modified alkaline permanganate method as described by Sharawat and Burford (1982).

3.13.2.3 Available phosphorus

Available phosphorus was determined by Olsen's method as described by Jackson (1967).

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 Black (1965).

3.13.2.6 Available sulphur

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

Table 3. Soil-site characteristics of microwatershed for land evaluation

Mapping unit	Climate			Landform characteristics			Physico-chemical characteristics (weighted averages)							Free CaCO ₃ (gkg ⁻¹)
	Rainfall (mm)	T. Max. (°C)	T. Min. (°C)	Slope (%)	Erosion	Drainage	Depth (cm)	Coarse fragments (%)	Texture	pH	OC (gkg ⁻¹)	CEC [cmol (p+)/kg]	Base saturation (%)	
BSD1-s-d4/D-e4	1296.3	30.6	18.4	8-15	V. severe	Well	35	70.0	s	6.70	2.2	8.33	39.3	10.4
BSD2-scl-d3/C-e3	1296.3	30.6	18.4	3-8	Severe	Well	90	24.7	scl	8.15	3.0	22.57	74.4	127.4
BSD3-scl-d3/D-e4	1296.3	30.6	18.4	3-8	V. severe	Well	70	27.8	scl	6.80	4.4	39.28	85.4	1.8
BSD4-c-d1/C-e2	1296.3	30.6	18.4	5-7	Severe	Mod. well	150+	4.4	c	8.03	6.1	44.90	90.4	6.7
BSD4-c-d1/B-e1	1296.3	30.6	18.4	1-3	Moderate	Mod. well	150+	7.9	c	7.50	6.7	42.87	87.3	5.9
BSD4-c-d1/A-e1	1296.3	30.6	18.4	0-1	Moderate	Mod. well	150+	10.4	c	8.03	6.0	40.66	83.8	5.7
HLG-c-d1/B-e2	1296.3	30.6	18.4	2-3	Moderate	Mod. well	150+	4.0	c	8.25	4.2	41.70	88.1	7.1
HLG-c-d1/B-e1	1296.3	30.6	18.4	2-3	Moderate	Mod. well	150+	8.8	c	7.85	5.7	42.07	85.1	7.4
HLG-c-d1/A-e1	1296.3	30.6	18.4	0-1	Slight	Mod. well	140+	4.7	c	7.91	5.9	42.92	83.6	5.3
HLG-c-d1/A-e0	1296.3	30.6	18.4	0-1	Nil	Poor	130+	10.3	c	7.49	8.3	45.86	85.6	4.5

Table 4. Geographical locations of surface soil samples

Sample No.	Latitude	Longitude	Sample No.	Latitude	Longitude
1	15°48'28.3"N	74°34'09.6"E	38	15°49'30.1"N	74°32'57.8"E
2	15°48'27.1"N	74°33'04.0"E	39	15°49'31.9"N	74°33'08.4"E
3	15°48'03.4"N	74°34'06.6"E	40	15°49'40.1"N	74°33'15.8"E
4	15°48'28.1" N	74°33'48.4E	41	15°49'25.3"N	74°33'00.1"E
5	15°48'21.9"N	74°33'47.9"E	42	15° 49'27.1"N	74°33'09.2"E
6	15°48'20.6"N	74°33'56.2"E	43	15°49'24.0"N	74°32'52.4"E
7	15°48'15.8"N	74°34'04.0"E	44	15°49'27.5"N	74°33'24.6"E
8	15°48'16.6"N	74°34'00.5"E	45	15°49'27.0"N	74°32'17.0"E
9	15°48'19.3"N	74°34'12.0"E	46	15°48'54.9"N	74°33'05.5"E
10	15°48'12.0"N	74°34'09.3"E	47	15°49'03.2"N	74°32'50.7"E
11	15°48'14.9"N	74°34'04.3"E	48	15°49'11.1"N	74°33'30.6"E
12	15°48'03.9"N	74°34'05.9"E	49	15°49'00.2"N	74°33'00.0"E
13	15°48'48.2"N	74°33'39.2"E	50	15°49'02.2"N	74°33'07.4"E
14	15°49'01.1"N	74°33'42.7"E	51	15°49'03.7"N	74°33'17.0"E
15	15°48'51.9"N	74°33'23.0"E	52	15°48'57.4"N	74°33'24.7"E
16	15°48'54.4"N	74°33'33.7"E	53	15°48'58.1"N	74°33'30.1"E
17	15°49'29.5"N	74°33'29.3"E	54	15°48'50.9"N	74°32'52.0"E
18	15°49'03.5"N	74°33'47.3"E	55	15°48'51.0"N	74°33'01.0"E
19	15°49'30.1"N	74°33'21.1"E	56	15°48'42.5"N	74°32'55.0"E
20	15°49'16.7"N	74°33'31.5"E	57	15°48'41.0"N	74°33'10.1"E
21	15°49'16.8"N	74°33'23.8"E	58	15°48'45.4"N	74°33'16.0"E
22	15°49'17.3"N	74°33'15.5"E	59	15°48'59.9"N	74°33'24.0"E
23	15°49'16.9"N	74°33'07.7"E	60	15°48'44.6"N	74°33'27.7"E
24	15°49'17.5"N	74°33'00.7"E	61	15°48'46.8"N	74°33'23.3"E
25	15°49'16.5"N	74°32'51.9"E	62	15°48'52.8"N	74°33'33.6"E
26	15°49'15.9"N	74°32'44.0"E	63	15°48'45.8"N	74°33'44.2"E
27	15°49'24.1"N	74°32'44.4"E	64	15°48'28.1"N	74°33'22.8"E
28	15°49'17.1"N	74°32'49.4"E	65	15°48'35.7"N	74°33'14.2"E
29	15°49'06.2"N	74°32'54.8"E	66	15°48'36.6"N	74°33'05.1"E
30	15°49'05.8"N	74°33'01.8"E	67	15°48'39.8"N	74°32'59.1"E
31	15°49'06.2"N	74°33'06.1"E	68	15°48'42.3"N	74°32'51.1"E
32	15°49'11.2"N	74°33'15.1"E	69	15°48'30.2"N	74°33'24.0"E
33	15°49'11.2"N	74°33'22.4"E	70	15°48'29.6"N	74°33'13.1"E
34	15°49'33.1"N	74°33'15.8"E	71	15°48'30.0"N	74°33'10.0"E
35	15°48'59.9"N	74°33'32.0"E	72	15°48'30.1"N	74°33'00.0"E
36	15°48'51.6"N	74°33'15.4"E	73	15°48'22.2"N	74°33'09.1"E
37	15°48'58.2"N	74°32'44.0"E	74	15°48'33.1"N	74°33'25.0"E

3.13.2.7 Available micronutrients

Available zinc, copper, iron and manganese were extracted using DTPA extractant as explained by Lindsay and Norvell (1978). The concentrations of zinc, copper, iron and manganese in the soil-extracts were quantified using Atomic Absorption Spectrometer.

3.14 PREPARATION OF THEMATIC MAPS USING GIS TECHNIQUES

3.14.1 Soil map

Based on field survey, laboratory investigation and using Remote Sensing and Geographical Information System, the soil series map of Bastwad microwatershed was prepared using *ERDAS imagine* and *ArcGIS 9.5*.

3.14.2 Soil-site suitability for crops

By comparing soil-site characteristics (Table 3) 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 *ArcGIS 9.5* 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 Bastwad microwatershed area was created in *ArcGIS 9.5*.

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 Bastwad microwatershed file was also opened and from the ``Surface menu`` of Arc View Spatial Analyst ``Interpolate grid`` option was selected.

On the output ``grid specification dialogue``, output grid extent chosen was same as Bastwad microwatershed and the interpolation method employed was spline. Then map was reclassified based on ratings of the respective nutrients.

4. EXPERIMENTAL RESULTS

Results of the analysis of morphological, physical and chemical characteristics of the selected 10 pedons and 74 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 microwatershed

4.1 MORPHOLOGICAL FEATURES OF PEDONS (Table 4)

Ten pedons were selected on the basis of soil heterogeneity and slope. Keeping in view the aspect of slope they were designated as pedon 1, pedon 2 and so on, up to pedon 10 in descending order of their altitude from mean sea level. Pedons were classified in to three categories *viz.* upland (Pedon 1), midland (Pedon 2, 3, 4 and Pedon 5) and lowland pedons (Pedon 6 to Pedon 10). The site characteristics and detailed description of the pedons are given in Chapter 3.

4.1.1 Depth (cf. Table 5)

Soil-depth is an important aspect of pedological importance. It provides information on soil age, pedogenetic processes, erosion and other geomorphogenetic phenomena taking place in the soil. Depth has been taken as an aspect of study in the present investigation. Upland pedon (Pedon 1) was of shallow depth (35 cm). Pedon 2 and 3 (midland pedons) were medium in depth (75 and 65 cm respectively). Lowland pedons were deep with more than 130 cm depth. Depth was related to the altitude and depth of the pedon location. Higher the altitude and slope shallower the pedons were and *vice versa*.

4.1.1 Colour (cf. Table 5)

The upland pedon (Pedon 1) was of red soil. Its hue was 5YR and value and chroma were ranging from 3 to 5 and 2 to 4 respectively. Midland pedons exhibited variation in soil colour. They had two different hues namely, 5YR (Pedon 3 was a red soil pedon) and 10 YR (Pedon 2, 4 and 5). Value, in all the midland pedons was ranging from 2 to 3 with chroma in the range of 2 to 4. In all the lowland pedons, hue was 10 YR indicating black colour. Value ranged from 2 to 3 but chroma was constant at 2.

4.1.2 Texture (cf. Table 6)

Upland pedon was gravelly sand in texture. Among midland pedons, pedon 2 and 3 were sandy clay loam in upper horizons and sandy loam in lower sola. Pedon 4 and 5 were silty clay in upper horizons and in lower horizons they were clays. The lowland pedons were similar in texture. They were silty clay in upper layers while in lower horizons they were clays.

4.1.3 Structure (cf. Table 5)

The soil structure in pedons under study was almost identical in all of them. It varied from surface to deeper horizons. Pedon 1 showed structure of fine weak granular structure throughout the solum. At the depths of 30-55 cm (AC) and 55-65 cm (C), soil was structureless. In midland and lowland pedons (Pedon 2 to 10), structure in the surface horizon (Ap) was fine weak granular to fine moderate granular whereas in the lower horizons it was fine strong sub angular blocky.

4.1.4 Consistency (cf. Table 5)

The dry consistency of the upland pedon (Pedon 1) was slightly hard in the surface horizon but lower horizons were very hard when dry. After moistening, its consistency ranged from friable to extremely firm in the surface and in the depths, respectively.

Table 5. Morphological properties of pedons

Pedon No.	Horizon	Depth (cm)	Colour	Structure	Consistency			Roots	Boundary	Other salient features
					Dry	Moist	Wet			
Pedon 1	A1	0-10	5YR 3/3	f1gr	sh	fr	sopo	fc	cs	Boulders on the surface; gravels up to 30 cm depth; parent rock appears from 35 cm
	A2	10-30	5YR 3/4	f1gr	sh	fr	sopo	fc	cs	
	AC	30-55	5YR 5/3	0	vh	efi	sopo	-	cs	
	C	55-65	5YR 5/2	0	vh	efi	sopo	-	cs	
Pedon 2	Ap	0-16	10YR 2/2	m2gr	sh	fr	sssp	vff	ds	CaCO ₃ concretions distributed throughout the solum; parent rock starts from 75 cm.
	B1	16-40	10YR 3/2	f3sbk	sh	fr	sssp	vff	ds	
	B2	40-70	10YR 2/2	f3sbk	mh	fi	sp	-	cw	
	BC	70-90	10YR 2/2	f3sbk	h	vfi	sp	-	cw	
Pedon 3	Ap	0-10	5YR 3/2	m1gr	sh	fr	sssp	fm	ds	Parent rock appears from 65 cm.
	Bt1	10-30	5YR 3/4	f3sbk	sh	fr	sssp	fm	cs	
	Bt2	30-50	5YR 3/3	f3sbk	mh	fi	sssp	-	cs	
	BC	50-70	5YR 3/3	f3sbk	h	vfi	sopo	-	cs	
	C	70-100	5YR 4/6	f3sbk	h	vfi	sopo	-	as	
Pedon 4	Ap	0-20	10YR 3/2	m2gr	sh	fr	sp	fm	ds	Wide and deep cracks up to 60 cm depth; slickensides appear from 60 cm and extend in entire solum.
	A2	20-50	10YR 3/2	f3sbk	mh	fi	vsvp	vff	cs	
	Bss1	50-70	10YR 2/2	f3sbk	mh	fi	vsvp	vff	ds	
	Bss2	70-95	10YR 2/2	f3sbk	h	vfi	vsvp	-	ds	
	Bss3	95-120+	10YR 2/2	f3sbk	vh	vfi	vsvp	-	ds	
Pedon 5	Ap	0-15	10YR 2/2	m2gr	sh	fr	sp	fc	cs	Basalt rock fragments of various sizes up to 85 cm; slickensides appear from 90 cm depth and extend further in the solum.
	A2	15-40	10YR 2/2	f3sbk	sh	fr	sp	vff	gs	
	Bw	40-80	10YR 3/2	f3sbk	mh	fi	sp	-	cs	
	Bss1	80-120	10YR 3/2	f3sbk	mh	fi	svp	-	ds	
	Bss2	120-150+	10YR 3/2	f3sbk	mh	fi	svp	-	ds	
Pedon 6	Ap	0-20	10YR 3/3	m2gr	sh	fr	sp	mm	cs	Root distribution up to 75 cm; slickensides appear from 80 cm depth and extend further downwards.
	A2	20-50	10YR 3/2	f3sbk	mh	fi	sp	mm	cs	
	B1	50-80	10YR 3/2	f3sbk	mh	fi	svp	fc	gs	
	B2ss1	80-100	10YR 2/2	f3sbk	mh	fi	vsvp	vff	ds	
	B2ss2	100-120	10YR 3/2	f3sbk	mh	fi	vsvp	vff	ds	
	B2ss3	120-150+	10YR 3/2	f3sbk	mh	fi	vsvp	-	ds	

Table 5. Contd.....

Pedon No.	Horizon	Depth (cm)	Colour	Structure	Consistency			Roots	Boundary	Other salient features
					Dry	Moist	Wet			
Pedon 7	Ap	0-25	10YR 2/2	m2gr	sh	fr	sssp	fc	cs	Slickensides appear from 50 cm depth and extend further in the solum.
	A2	25-50	10YR 2/2	f3sbk	h	fi	sp	vff	gw	
	Bss1	50-65	10YR 2/2	f3sbk	h	fi	vsvp	-	ds	
	Bss2	65-95	10YR 3/2	f3sbk	h	fi	vsvp	-	ds	
	Bss3	95-120	10YR 3/2	f3sbk	h	fi	vsvp	-	ds	
	Bss4	120-150+	10YR 2/2	f3sbk	h	fi	vsvp	-	ds	
Pedon 8	Ap	0-18	10YR 3/2	m2gr	sh	fr	sssp	vff	cs	Slickensides appear from 100 cm depth and go further deep in the solum.
	A2	18-40	10YR 3/2	f3sbk	sh	fr	sssp	vff	cs	
	B1	40-60	10YR 3/2	f3sbk	mh	fi	sp	-	ds	
	B2	60-90	10YR 3/2	f3sbk	h	fi	vsvp	-	ds	
	B3ss1	90-125	10YR 3/2	f3sbk	h	fi	vsvp	-	ds	
	B3ss2	125-150+	10YR 3/2	f3sbk	h	fi	vsvp	-	ds	
Pedon 9	Ap	0-30	10YR 3/2	m2gr	sh	fr	sssp	fc	cs	Slickensides appear from 140 cm depth extending further down in the solum.
	A2	30-40	10YR 2/2	f3sbk	sh	fr	sp	fc	gs	
	B1	40-60	10YR 3/2	f3sbk	mh	fi	sp	-	ds	
	B2	60-80	10YR 2/2	f3sbk	h	fi	vsvp	-	ds	
	B3ss1	80-100	10YR 3/2	f3sbk	h	fi	vsvp	-	ds	
	B3ss2	100-140+	10YR 3/2	f3sbk	h	fi	vsvp	-	ds	
Pedon 10	Ap	0-20	10YR 2/2	m2gr	sh	fr	sp	vff	cs	Slickensides appear from 75 cm depth and extend into deep solum
	A2	20-40	10YR 3/2	f3sbk	sh	fr	sp	vff	gs	
	B1	40-60	10YR 3/2	f3sbk	mh	fi	vsvp	-	ds	
	B2ss1	60-80	10YR 3/2	f3sbk	mh	fi	vsvp	-	ds	
	B2ss2	80-110	10YR 3/2	f3sbk	h	fi	vsvp	-	ds	
	B2ss3	110-130+	10YR 3/2	f3sbk	h	fi	vsvp	-	ds	

Wet consistency was non-sticky and non-plastic throughout the solum. Among midland pedons, in pedon 2, consistency varied from slightly hard to hard when dry. On moistening it became friable to very firm. The wet consistency varied from slightly sticky and slightly plastic to sticky and plastic. Pedon 3 was slightly hard to hard in dry consistency that changed to friable and very firm on moistening. Wet consistency was slightly sticky and slightly plastic to non-sticky and non-plastic in the lower depths.

Similarly, pedon 4 and 5 were slightly hard to hard in dry consistency and remained friable to very firm in moist consistency in the solum. It was sticky and plastic to very plastic and very sticky in the lower layers of soil. Lowland pedons (Pedons 6, 7, 8, 9 and 10) belonged to valley portion of the study area and showed similar trends in different consistencies. They were slightly hard to very hard in consistency when dry. Moist consistency was in the range of friable, firm and very firm that varied along the depth of the solum. Wet consistency varied from non-sticky and non-plastic to very sticky and very plastic along the depth of horizons.

4.1.5 Special features of the pedons (cf. Table 5)

Pedons exhibited some special features which served as criteria for soil classification and land evaluation. Pedon 1 (upland) was extremely gravelly in the surface horizon and had parent rock at a depth of 35 cm. Among midland pedons, pedon 2 exhibited a high content of free calcium carbonate that was evenly distributed throughout the solum. Parent rock was at 75 cm depth. Pedon 3 possessed parent rock at 65 cm depth. It exhibited signs of clay illuviation in its Bt horizons. Clay films were observed around peds when viewed through 10X lens. A common feature of slickensides was observed in lowland pedons (pedon 4 to 10). In pedon 4, wide and deep cracks were observed up to 60 cm depth which ended with appearance of slickensides from the same depth. In pedon 5, upper 85 cm depth exhibited presence of some basalt (parent rock) fragment and boulders. Slickensides appeared at 90 cm depth. Pedon 6 showed slickensides at a depth of 80 cm. In pedons 7, 8, 9 and 10, slickensides were observed at the depths of 100, 100, 140 and 75 cm respectively.

4.2 PHYSICAL PROPERTIES OF PEDONS

4.2.1 Particle size distribution (cf. Table 6)

A certain trend in variation of particle size distribution was discernible. Sand was a major portion of upland pedon (Pedon 1). Major part of the study area is under medium to deep black soils. Gravel was not a significant portion of pedon samples except pedons 1, 2 and 3 (upland and midland pedons) and that did not follow definite trend.

Total sand content in upland pedon varied from 89.1 to 89.5 per cent and did not follow any trend. In midland pedons, total sand content ranged from 2.3 to 70.5 per cent. In upper horizons it was higher compared to that in lower ones. Total sand content decreased with the altitude of the pedon locations of midland pedons. The total sand content of the lowland pedons ranged from 1.9 to 11.7 per cent and decreased with depth of the horizons.

Silt content of the upland pedon was in the range of 3.2 to 3.9 per cent. In midland pedons silt content varied from 13.1 to 43.9 per cent. It decreased with the depth of the pedons and inverse was true with the altitude of the pedon locations. Lowland pedons exhibited silt content in the range of 17.1 to 44.6 per cent. This decreased with the depth too.

Clay content of the upland pedon ranged from 6.6 to 11.4 per cent. It had no certain trend in variation. Midland pedons possessed clay content range of 8.0 to 70.6 per cent. It increased with the altitude as well as depths of the pedons. Lowland pedons were rich in clay compared to other pedons. The clay content ranged from 46.5 to 74.2 per cent and it increased from the surface to lower solum.

4.2.2 Bulk density (cf. Table 6)

Bulk density in upland and midland pedons (especially pedon 1, 2 and 3) was higher compared to that in lowland pedons. It ranged from 1.35 to 1.57 Mg m⁻³. In midland pedons (Pedon 4 and 5) its range was from 1.21 to 1.35 Mg m⁻³. In lowland pedons bulk density had a range from 1.20 to 1.40 Mg m⁻³.

Table 6. Physical properties of pedons

Pedon No.	Horizon	Depth (cm)	Gravel of whole soil	Total sand (2.00-0.05 mm)	Silt (0.05-0.002 mm)	Clay (< 0.002 mm)	Textural class	BD (Mg m ⁻³)	-----%-----	
									MWHC	FC
Pedon 1	A1	0-10	70	89.1	3.4	7.5	s	1.53	16.57	8.29
	A2	10-30	62	85.4	3.2	11.4	s	1.54	16.61	8.30
	AC	30-55	75	89.5	3.9	6.6	s	1.57	10.14	5.7
	C	55-65	–	–	–	–	–	–	–	–
Pedon 2	Ap	0-16	22	58.0	13.5	28.5	scl	1.35	45.55	22.78
	B1	16-40	27	58.2	15.0	26.8	scl	1.51	47.14	23.57
	B2	40-60	24	61.1	15.1	23.8	scl	1.56	47.33	23.67
	BC	60-90+	40	67.9	13.1	19.0	sl	1.57	48.17	24.09
Pedon 3	Ap	0-10	25	62.3	19.5	18.2	sl	1.41	25.79	12.90
	Bt1	10-30	27	58.1	19.6	22.3	scl	1.45	33.33	16.67
	Bt2	30-50	30	59.0	18.4	22.6	scl	1.48	38.11	19.06
	BC	50-70	34	70.5	21.5	8.0	sl	1.51	10.26	5.13
	C	70-100	31	65.4	23.5	11.1	sl	–	12.47	6.24
Pedon 4	Ap	0-20	5	11.6	38.6	49.8	sic	1.21	48.86	24.43
	A2	20-50	4	13.9	32.0	54.1	sic	1.26	55.21	27.61
	Bss1	50-70	3	5.4	30.2	64.4	c	1.29	60.57	30.29
	Bss2	70-95	3	6.5	27.8	65.7	c	1.30	61.43	30.72
	Bss3	95-120+	1	4.1	29.8	66.1	c	1.32	62.61	31.31
Pedon 5	Ap	0-15	5	10.7	43.1	46.2	sic	1.23	46.32	23.16
	A2	15-40	8	9.1	43.9	47.0	sic	1.34	51.63	25.82
	Bw	40-70	9	8.4	32.5	59.1	c	1.34	54.32	27.16
	Bss1	70-110	7	2.3	27.1	70.6	c	1.35	58.63	29.32
	Bss2	110-150+	3	6.1	23.7	70.2	c	1.35	61.34	30.67
Pedon 6	Ap	0-20	8	10.4	43.1	46.5	sic	1.20	47.42	23.71
	A2	20-50	12	9.1	43.9	47.0	sic	1.32	48.36	24.18

Table 6. Contd.....

Pedon No.	Horizon	Depth (cm)	Gravel of whole soil	Total sand (2.00-0.05 mm)	Silt (0.05-0.002 mm)	Clay (< 0.002 mm)	Textural class	BD (Mg m ⁻³)	MWHC	FC
									-----%-----	
	B1	50-80	6	8.4	42.5	49.1	sic	1.35	51.48	25.74
	B2ss1	80-100	2	7.1	23.3	69.6	c	1.37	58.32	29.16
	B2ss2	100-120	2	8.7	21.1	70.2	c	1.36	59.81	29.91
	B2ss3	120-150+	2	8.7	17.1	74.2	c	1.37	59.94	29.97
Pedon 7	Ap	0-25	3	8.0	40.9	51.1	sic	1.22	50.76	25.38
	A2	25-50	5	8.1	38.3	53.6	sic	1.29	49.88	24.94
	Bss1	50-65	1	2.8	29.5	67.7	c	1.35	57.35	28.68
	Bss2	65-95	2	6.0	26.2	67.8	c	1.36	59.01	29.51
	Bss3	95-120	1	4.7	27.6	67.7	c	1.37	60.68	30.34
	Bss4	120-150+	1	4.6	27.6	67.8	c	1.38	62.87	31.44
Pedon 8	Ap	0-18	15	7.4	41.8	50.8	sic	1.21	47.64	23.82
	A2	18-40	8	3.9	44.0	52.1	sic	1.25	51.32	25.66
	B1	40-60	4	3.0	44.6	52.4	sic	1.34	57.38	28.69
	B2	60-90	5	1.9	40.3	57.8	c	1.38	59.68	29.84
	B3ss1	90-125	3	3.9	27.8	68.3	c	1.39	61.31	30.66
	B3ss2	125-150+	1	3.6	27.9	68.5	c	1.40	60.69	30.35
Pedon 9	Ap	0-30	5	5.0	42.0	53.0	sic	1.27	54.36	27.18
	A2	30-40	7	6.1	41.6	52.3	sic	1.30	56.58	28.29
	B1	40-60	3	2.8	41.5	55.7	c	1.36	55.36	27.68
	B2	60-80	2	7.5	37.2	55.3	c	1.36	58.10	29.05
	B3ss1	80-100	2	3.6	28.6	67.8	c	1.37	61.77	30.89
	B3ss2	100-140	1	3.5	28.6	67.9	c	1.37	63.33	31.67
Pedon 10	Ap	0-20	16	11.7	40.1	48.2	sic	1.23	45.48	22.74
	A2	20-40	21	7.8	42.9	49.3	sic	1.26	47.56	23.78
	B1	40-60	17	7.3	41.2	51.5	sic	1.31	50.55	25.28
	B2ss1	60-80	11	4.2	27.9	67.9	c	1.35	61.49	30.75
	B2ss2	80-110	5	4.2	27.1	68.7	c	1.35	64.13	32.07
	B2ss3	110-130+	3	4.0	27.4	68.6	c	1.38	64.88	32.44

4.2.3 Maximum water holding capacity (MWHC) (cf. Table 6)

Maximum water holding capacity in upland pedons was low and possessed a range from 10.14 to 16.61 per cent. In midland pedons MWHC ranged from 10.26 to 62.61 per cent and it increased with depth of the pedons. It also increased with the reduction in altitude of the pedons. The lowland pedons possessed high MWHC among all the pedons under study. MWHC of lowland pedons ranged from 45.58 to 64.88 per cent. MWHC increased from surface to the lower horizons and followed the trend in clay variation in pedons.

4.3 CHEMICAL PROPERTIES OF PEDONS

4.3.1 Soil reaction (pH) (cf. Table 7)

Upland pedon was neutral in soil reaction with a pH range of 6.70 to 6.71. In midland pedons, pH ranged from 6.52 to 8.60 (neutral to alkaline) showing variations along depth and altitude of the pedons. pH increased with increasing depths and decreasing altitudes of the pedons. Lowland pedons were neutral to alkaline in pH with the pH range of 7.11 to 8.73. There, it increased from surface to the lower horizons.

4.3.2 Electrical conductivity (EC) (cf. Table 7)

Electrical conductivity of pedon samples was lesser than 4 dSm^{-1} hence it was below the safe limit. In pedon samples EC was increasing along the depth of the solum. In upland pedon it was 0.11 dS m^{-1} . The EC ranges in midland and lowland pedons were 0.05 to 0.39 dS m^{-1} and 0.09 to 0.45 dS m^{-1} , respectively.

4.3.3 Organic carbon (cf. Table 7)

Organic carbon in the upland pedon was low and ranged from 2.1 to 2.2 g kg^{-1} . Midland pedons had the organic carbon range from 0.4 to 9.8 g kg^{-1} while an organic carbon range from 0.4 to 9.9 g kg^{-1} was observed in the lowland pedons. When compared, the lowland pedons were higher in organic carbon status than the remaining ones. The organic carbon content decreased with increasing altitudes as well as depths of pedons.

4.3.4 Exchangeable cations (cf. Table 8)

Ca was the dominant cation in all the pedons except pedon 1 and 3 where sodium approached calcium in amounts. The order of dominance of cations was $\text{Ca} > \text{Mg} > \text{K} > \text{Na}$ for all the pedons.

In upland pedons, exchangeable Ca ranged from 2.27 to $2.64 \text{ cmol}(+) \text{ kg}^{-1}$. In midland and lowland pedons Ca ranges were 2.80 to $26.10 \text{ cmol}(+) \text{ kg}^{-1}$ and 18.00 to $31.10 \text{ cmol}(+) \text{ kg}^{-1}$, respectively.

Exchangeable Mg ranges in upland, midland and lowland pedons were 2.05 to $2.23 \text{ cmol}(+) \text{ kg}^{-1}$, 1.02 to $24.20 \text{ cmol}(+) \text{ kg}^{-1}$ and 8.30 to $23.90 \text{ cmol}(+) \text{ kg}^{-1}$, respectively.

Exchangeable Na was in the ranges of 0.17 to $0.32 \text{ cmol}(+) \text{ kg}^{-1}$, 0.30 to $6.00 \text{ cmol}(+) \text{ kg}^{-1}$ and 3.20 to $6.40 \text{ cmol}(+) \text{ kg}^{-1}$ in upland, midland and lowland pedons, respectively.

Exchangeable K had ranges of 0.33 to $0.41 \text{ cmol}(+) \text{ kg}^{-1}$, 0.50 to $9.00 \text{ cmol}(+) \text{ kg}^{-1}$ and 2.30 to $8.40 \text{ cmol kg}^{-1}$ in upland, midland and lowland pedons, respectively.

4.3.5 Cation exchange capacity (CEC) (cf. Table 8)

CEC of the pedons varied both location-wise and depth-wise. In upland pedon, it varied from 5.12 to $6.33 \text{ cmol (p+) kg}^{-1}$ and increased with depth. Midland pedons exhibited CEC in a range of 5.57 to $64.93 \text{ cmol (p+) kg}^{-1}$ which increased from surface to lower sola in pedons. In lowland pedons high CEC was observed in the range of 39.83 to $66.31 \text{ cmol (p+) kg}^{-1}$ which also increased with depth. In both midland and lowland pedons, CEC followed the trend on clay variation in pedons.

4.3.6 Base saturation (cf. Table 8)

In almost all the pedons, base saturation exhibited an increase with increasing depth. It also followed the trend of clay increase in the pedons.

Table 7. Chemical properties of pedons

Pedon No.	Horizon	Depth (cm)	pH	EC (dSm ⁻¹)	O.C. (gkg ⁻¹)	Free CaCO ₃ (gkg ⁻¹)
Pedon 1	A1	0-10	6.70	0.11	2.2	1.4
	A2	10-30	6.71	0.11	2.2	0.9
	AC	30-55	6.70	0.12	2.1	0.6
	C	55-65	–	–	–	–
Pedon 2	Ap	0-16	8.25	0.16	4.0	133.2
	B1	16-40	7.76	0.39	3.1	117.5
	B2	40-60	8.53	0.15	2.2	134.5
	BC	60-90+	8.60	0.21	1.3	140.5
Pedon 3	Ap	0-10	6.52	0.08	9.8	2.1
	Bt1	10-30	6.85	0.05	4.4	2.0
	Bt2	30-50	6.90	0.15	1.8	1.5
	BC	50-70	7.38	0.10	0.4	0.7
Pedon 4	C	70-100	6.96	0.22	0.9	0.6
	Ap	0-20	7.91	0.21	8.4	7.1
	A2	20-50	8.11	0.12	4.6	6.5
	Bss1	50-70	8.25	0.16	2.4	5.2
Pedon 5	Bss2	70-95	8.42	0.11	1.1	4.7
	Bss3	95-120+	8.43	0.18	0.9	3.3
	Ap	0-15	7.36	0.08	8.4	6.9
	A2	15-40	7.59	0.18	7.1	5.5
Pedon 6	Bw	40-70	7.50	0.17	5.8	5.7
	Bss1	70-110	7.40	0.07	5.1	6.3
	Bss2	110-150+	7.63	0.17	5.2	5.8
	Ap	0-20	7.69	0.09	8.9	5.8
	A2	20-50	8.26	0.10	4.0	5.7
	B1	50-80	8.29	0.09	2.2	4.1
Pedon 7	B2ss1	80-100	8.13	0.12	1.3	4.3
	B2ss2	100-120	8.34	0.16	0.4	3.4
	B2ss3	120-150+	8.33	0.14	0.4	3.3
	Ap	0-25	8.12	0.23	4.9	7.6
	A2	25-50	8.38	0.25	3.5	6.5
	Bss1	50-65	8.46	0.27	1.8	6.7
Pedon 8	Bss2	65-95	8.45	0.27	0.9	6.3
	Bss3	95-120	8.43	0.28	0.4	5.8
	Bss4	120-150+	8.32	0.27	0.4	4.6
	Ap	0-18	7.85	0.10	8.4	7.9
	A2	18-40	7.65	0.16	4.9	8.0
	B1	40-60	8.08	0.17	4.0	6.3
Pedon 9	B2	60-90	7.91	0.22	2.2	5.6
	B3ss1	90-125	8.07	0.16	1.3	5.1
	B3ss2	125-150+	8.28	0.33	0.4	4.7
	Ap	0-30	7.42	0.41	8.9	7.0
	A2	30-40	8.15	0.26	4.4	3.9
	B1	40-60	8.52	0.24	2.2	3.3
Pedon 10	B2	60-80	8.62	0.21	0.9	3.6
	B3ss1	80-100	8.52	0.45	0.9	3.1
	B3ss2	100-140+	8.73	0.23	1.3	3.7
	Ap	0-20	7.23	0.12	9.9	6.8
	A2	20-40	7.11	0.15	8.3	3.7
	B1	40-60	8.14	0.14	6.7	3.1
Pedon 10	B2ss1	60-80	8.12	0.15	3.1	3.3
	B2ss2	80-110	8.04	0.18	2.2	3.4
	B2ss3	110-130+	7.90	0.15	0.4	3.1

Table 8. Exchangeable cations and cation exchange capacity in pedons

Pedon No.	Horizon	Depth (cm)	Ca	Mg	Na	K	CEC	BS	ESP
			-----cmol(p+) kg ⁻¹ -----					-----%-----	
Pedon 1	A1	0-10	2.64	2.23	0.32	0.41	6.33	88.5	5.06
	A2	10-30	2.48	2.05	0.22	0.36	5.51	92.7	4.03
	AC	30-55	2.27	2.07	0.17	0.33	5.12	94.4	3.25
	C	55-65	–	–	–	–	–		
Pedon 2	Ap	0-16	12.50	5.80	0.70	0.50	21.88	89.1	3.20
	B1	16-40	15.30	8.70	0.50	1.30	27.41	94.1	1.82
	B2	40-60	14.70	8.20	0.80	0.80	27.31	89.7	2.93
	BC	60-90+	7.30	4.90	0.60	0.50	15.46	86.0	3.88
Pedon 3	Ap	0-10	9.50	2.20	0.90	1.60	14.94	95.0	6.02
	Bt1	10-30	10.30	9.50	2.00	5.30	29.29	92.5	6.83
	Bt2	30-50	12.60	5.20	1.40	6.00	26.44	95.3	5.30
	BC	50-70	10.12	2.40	0.30	2.80	16.19	96.5	1.85
	C	70-100	2.80	1.02	0.30	0.80	5.57	88.3	5.39
Pedon 4	Ap	0-20	16.50	16.10	4.00	3.60	44.93	89.5	8.90
	A2	20-50	18.20	16.80	4.20	3.80	46.21	93.1	9.09
	Bss1	50-70	23.40	20.90	5.20	4.70	57.41	94.4	9.06
	Bss2	70-95	25.00	21.40	5.40	4.80	58.83	96.2	9.18
	Bss3	95-120+	25.70	23.20	5.80	8.20	64.33	97.8	9.02
Pedon 5	Ap	0-15	18.20	15.00	4.30	9.00	48.12	96.6	8.94
	A2	15-40	15.50	14.40	4.20	6.80	42.87	95.4	9.80
	Bw	40-70	22.90	18.40	5.30	6.80	54.66	97.7	9.70
	Bss1	70-110	26.10	24.20	6.00	6.40	64.93	96.6	9.24
	Bss2	110-150+	25.20	23.30	5.80	6.10	64.04	94.3	9.06
Pedon 6	Ap	0-20	18.00	10.00	3.30	4.49	39.83	89.9	8.29
	A2	20-50	22.20	12.10	4.20	6.80	48.21	94.0	8.71
	B1	50-80	19.50	11.00	3.80	6.40	43.17	94.3	8.80
	B2ss1	80-100	31.10	16.10	6.00	6.40	62.13	95.9	9.66
	B2ss2	100-120	26.40	17.60	5.60	7.00	61.69	91.7	9.08
	B2ss3	120-150+	25.70	17.20	5.40	6.90	59.83	92.3	9.03
Pedon 7	Ap	0-25	22.40	10.60	3.90	5.30	45.16	93.4	8.64
	A2	25-50	22.40	11.20	4.20	4.60	46.23	91.7	9.09
	Bss1	50-65	21.20	11.00	4.10	4.50	44.42	91.9	9.23
	Bss2	65-95	22.60	11.90	4.60	4.80	47.43	92.6	9.70
	Bss3	95-120	27.00	13.80	4.70	5.60	55.13	92.7	8.53
	Bss4	120-150+	29.00	15.50	5.60	7.30	61.66	93.1	9.08
Pedon 8	Ap	0-18	22.40	9.50	3.40	4.50	43.61	91.3	7.80
	A2	18-40	22.20	9.30	3.30	4.50	44.23	88.9	7.46
	B1	40-60	22.20	9.40	3.20	4.70	44.32	89.1	7.22
	B2	60-90	25.10	10.90	3.40	5.20	51.37	86.8	6.62
	B3ss1	90-125	27.00	14.00	4.10	5.70	56.65	89.7	7.24
	B3ss2	125-150+	28.70	13.40	5.10	8.40	60.19	92.4	8.47
Pedon 9	Ap	0-30	25.20	8.60	4.60	4.70	48.34	89.2	9.52
	A2	30-40	23.60	8.30	4.30	4.50	45.57	89.3	9.44
	B1	40-60	24.20	9.60	4.60	5.20	49.47	88.1	9.30
	B2	60-80	24.60	9.30	4.30	5.10	49.59	87.3	8.67
	B3ss1	80-100	29.70	11.30	5.30	6.20	59.41	88.4	8.92
	B3ss2	100-140	29.10	12.10	6.10	6.60	60.87	88.5	10.02
Pedon 10	Ap	0-20	22.10	17.60	3.70	2.30	52.96	86.3	6.99
	A2	20-40	26.00	18.30	4.00	2.40	56.25	90.1	7.11
	B1	40-60	25.60	20.40	5.90	2.60	59.38	91.8	9.94
	B2ss1	60-80	25.30	21.70	5.50	2.80	60.69	91.1	9.06
	B2ss2	80-110	26.60	22.70	4.90	2.90	63.48	89.9	7.72
	B2ss3	110-130+	28.00	23.90	6.40	3.10	66.31	92.6	9.65

Upland pedon (pedon 1) had base saturation in the range of 88.5-94.4 per cent. In midland pedons (pedon 2 to 5), base saturation ranged from 86.0-97.8 per cent. Lowland pedons (pedon 6 to 10) were high in base saturation. The range was from 86.3 to 95.9 per cent.

4.3.7 Exchangeable sodium percentage (ESP) (cf. Table 8)

ESP of the pedons was related to their pH. In pedon 1 and 3, where pH was low, a comparatively low ESP was observed. Reverse was the trend for remaining pedons where soil reaction was alkaline. In upland pedons, ESP ranged from 3.25 to 5.06 per cent. For midland and lowland pedons ESP ranges were 8.82 to 9.8 per cent and 6.62 to 10.02 per cent, respectively.

4.3.7 Free calcium carbonate (CaCO₃) (cf. Table 7)

In upland pedon, free CaCO₃ content ranged from 0.6 to 1.4 g kg⁻¹. Among all the pedons under study pedon 2 was calcareous and exhibited violent effervescence with dilute HCl solution. Free CaCO₃ content of pedon 2 ranged from 117.5 to 140.5 g kg⁻¹ with an irregular pattern of distribution along depth. Rest of the midland pedons and all the lowland pedons had very low amounts of free CaCO₃ that ranged from 0.6 to 8.0 g kg⁻¹. Free CaCO₃ content was decreasing from surface to lower depths of the 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 Soil Taxonomy (Soil Survey Staff, 2006). 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 sub-surface horizons, soil depth, mineralogy, texture, soil chemical properties and drainage are considered. The classification of the pedons under study is given below.

Pedon	Soil classification
Pedon 1	Hydrous skeletal sandy, super active, isohyperthermic, Lithic Ustorthents
Pedon 2	Loamy, super active, calcareous, isohyperthermic, Typic Haplustepts
Pedon 3	Fine loamy, super active, isohyperthermic, Typic Haplustalfs
Pedon 4, 5, 6, 7, 8, 9, 10	Very fine, super active, isohyperthermic, Typic Haplusterts

4.4.2 Soil mapping unit (Fig. 3)

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. Five soil series were identified under the study area. The soils of Bastwad are designated as BSD 1-4 and are represented by pedons 1, 2, 3, 4, 7 and 9 while the soils of Halaga are designated as HLG and were represented by pedons 5, 6, 8 and 10. The soils of Bastwad microwatershed were mapped into 10 mapping units based on observations from the pedons representing them. Mapping units are derived from name of the series, soil texture, and soil depth vs. slope and erosion class and are presented in Table 9.

4.5 LAND EVALUATION

4.5.1 Land capability classification (cf. Table 10)

Land capability classification (LCC) is an interpretive 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, consistency, permeability, depth of soil and soil reaction. Each of the above factor have definite role to play in behaviour of soil and its management. Soil-site characteristics of soil units (Table 3) are matched with the criteria for land capability classification (Appendix I). The land capability classification of the microwatershed and extent of their existence in the microwatershed are given below in the following table. The details of land capability classification of the area are provided in Table 10.

Mapping unit No.	Pedon No.	Mapping unit	Land capability sub-class	Area (ha)
1	1	BSD1-s-d4/D-e4	VII _s	7.96
2	2	BSD2-scl-d3/C-e3	IV _{tsf}	24.28
3	3	BSD3-scl-d3/D-e4		
4	4	BSD4-c-d1/C-e2	III _{twsf}	23.13
5	7	BSD4-c-d1/B-e1	III _{sf}	35.78
6	9	BSD4-c-d1/A-e1	IV _w	125.0
7	5	HLG-c-d1/B-e2		
8	6	HLG-c-d1/B-e1	IV _f	118.4
9	8	HLG-c-d1/A-e1	III _{sf}	71.8
10	10	HLG-c-d1/A-e0	IV _w	44.39

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

There is no class I and class II land in the study area. The pedons belong to three land capability classes namely III, IV and VII with different limitations for land-use.

4.5.2 Soil-site suitability for irrigation (cf. Table 11)

The soil properties from the study area (Table 3) were matched with degree of limitations for surface irrigation (Appendix II). Mapping unit 1 belonged to class VII (Uncultivable) in land capability classification so it was not considered for the study of suitability for irrigation. The soil mapping unit 6, 9 and 10 were not suitable for irrigation (N11) as they had limitations of depth (only mapping unit 1) and drainage. Mapping unit 4, 5, 7 and 8 belong to land irrigability sub-class S3_s (marginally suitable) which manifests a limitation of texture. Mapping unit No. 2 and 3 were marginally suitable and were classified as S3_l and S3_{lc} respectively owing to their limitations of slope, depth and sodicity.

4.5.3 Soil-site suitability evaluation for different crops

The optimum requirements of a crop are always region-specific. Climate and soil-site parameters play significant role to maximize crop yields. The kind and degree of limitations were evaluated and results are presented below. The soil properties from the study area (Table 3) were matched with soil-site suitability criteria (Appendix III–XXIV) of different crops and arrived at soil-site suitability sub-class.

Mapping unit 1 was a class VII land and did not qualify for evaluation for suitability for crops. Therefore, the description of crops in the following sub-heads does not involve mapping unit 1.

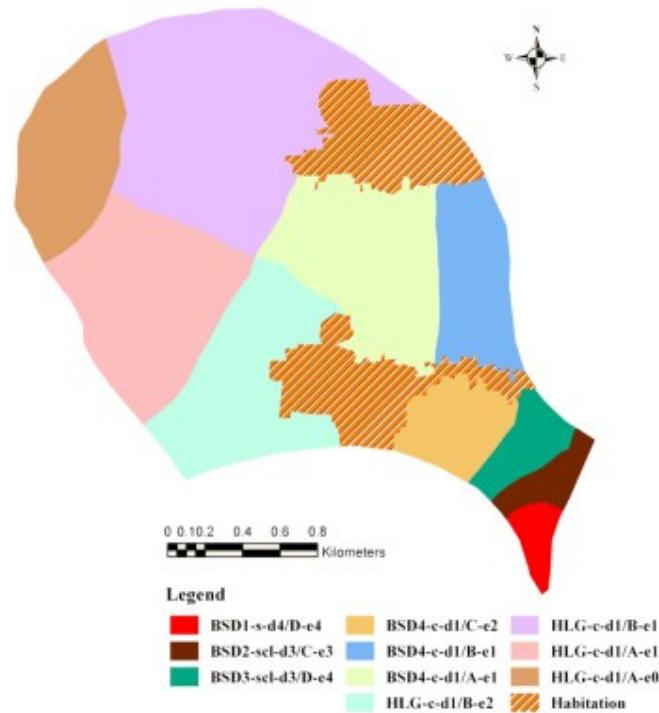


Fig. 3. Soil mapping units of Bastwad microwatershed

Fig.3. Soil mapping units of Bastwad microwatershed

4.5.3.1 Rice (cf. Table 12)

Mapping unit 2 and 4 were currently unsuitable for cultivation of rice as it showed severe limitation of slope. Mapping unit 3 and 6 were marginally suitable for rice with moderate limitations of climate, slope, drainage and nutrient availability. Rest of the mapping units was moderately suitable with slight limitations of climate, drainage, slope and sodicity.

4.5.3.2 Wheat (cf. Table 13)

Mapping units 3 and 5 to 10 were moderately suitable for cultivation of wheat as they were limited by slight limitation of slope, climate and texture. Mapping unit 2 and 4 were marginally suitable for wheat with the moderate limitation of slope.

4.5.3.3 Maize (cf. Table 14)

Mapping unit 2 was currently unsuitable for maize cultivation with severe limitation of slope. Mapping unit 3 was moderately suitable owing to slight limitations of depth and slope. Other mapping units of the study area were marginally suitable with moderate limitations of texture, slope and drainage.

4.5.3.4 Sorghum (cf. Table 15)

Mapping unit 2 and 10 were marginally suitable for sorghum cultivation with moderate limitations of slope and drainage. Other mapping units were moderately suitable with moderate limitations of climate and slope.

4.5.3.5 Pearl millet (cf. Table 16)

Soil mapping units 2 and 4 to 10 of the microwatershed were marginally suitable for pearl millet cultivation with moderate limitations of slope, calcareousness, texture and drainage. Mapping unit 3 was moderately suitable with slight limitations of climate, slope and depth.

Table 9. Brief description of soil mapping units and their extent

Mapping unit No.	Pedon No.	Mapping legend*	Brief description	Area (ha)
1	1	BSD1-s-d4/D-e4	Soils are shallow, well drained, excessively gravelly sand. Steep sloping (8-15%) with very severe erosion (Lithic Ustorthents).	7.96
2	2	BSD2-scl-d3/C-e3	Soils are moderately deep, well drained, gravelly sandy clay loam. Moderately sloping (3-8%) with severe erosion (Typic Haplustepts).	9.87
3	3	BSD3-scl-d3/D-e4	Soils are moderately deep, well drained, gravelly sandy clay loam. Gently sloping (8-10%) with very severe erosion (Typic Haplustalfs).	14.41
4	4	BSD4-c-d1/C-e2	Soils are deep, moderately well drained, clay. Slightly sloping (5-7%) with severe erosion (Typic Haplusterts).	23.13
5	7	BSD4-c-d1/B-e1	Soils are deep, moderately well drained, clay. Slightly sloping (2-3%) with moderate erosion (Typic Haplusterts).	35.78
6	9	BSD4-c-d1/A-e1	Soils are deep, moderately well drained, clay. Gently sloping (2-3%) with moderate erosion (Typic Haplusterts).	65.0
7	5	HLG-c-d1/B-e2	Soils are deep, moderately well drained, clay. Gently sloping (1-3%) with moderate erosion (Typic Haplusterts).	60.0
8	6	HLG-c-d1/B-e1	Soils are deep, moderately well drained, clay. Slightly sloping (0-1%) with slight erosion (Typic Haplusterts).	118.4
9	8	HLG-c-d1/A-e1	Soils are deep, moderately well drained, clay. Slightly sloping (0-1%) with moderate erosion (Typic Haplusterts).	71.8
10	10	HLG-c-d1/A-e0	Soils are deep, poorly drained, clay. Slightly sloping (0-1%) with nil erosion (Typic Haplusterts).	44.39

*Mapping legend: Soil series-Texture-Depth class/ Slope class-Erosion class

Table 10. Land capability classification of Bastwad microwatershed

Mapping unit	Topography (t)		Drainage (w)	Physical soil characteristics (s)				Pedon development	Soil fertility factors (f)			LCC
	Slope	Erosion		Texture	Coarse fragments	Sub-surface coarse fragments	Soil depth		CEC	BS	OC	
BSD1-s-d4/D-e4	IV	IV	I	V	IV	IV	IV	VII	IV	IV	IV	VIIIs
BSD2-scl-d3/C-e3	III	III	II	IV	III	III	II	II	I	III	IV	IVsf
BSD3-scl-d3/D-e4	III	IV	II	IV	III	III	II	I	I	II	IV	IVtsf
BSD4-c-d1/C-e2	III	III	III	III	II	II	I	II	I	I	III	IIItwsf
BSD4-c-d1/B-e1	II	II	II	III	II	II	I	II	I	I	III	IIIsf
BSD4-c-d1/A-e1	I	II	IV	III	II	II	I	II	I	I	III	IVw
HLG-c-d1/B-e2	II	II	II	III	II	II	I	II	I	I	IV	IVf
HLG-c-d1/B-e1	II	II	II	III	II	II	I	II	I	I	III	IIIsf
HLG-c-d1/A-e1	I	I	IV	III	II	II	II	II	I	I	IV	IVwf
HLG-c-d1/A-e0	I	I	IV	III	II	II	II	II	I	I	II	IVw

Table 11. Soil-site suitability classification for irrigation

Mapping unit	Landform characteristics (l)			Physical characteristics (s)	Chemical characteristics (c)			Overall limitation	Suitability class
	Slope	Drainage	Depth	Texture	EC	ESP	Free CaCO ₃		
BSD1-s-d4/D-e4	3	0	4	3	0	1	0	4×1	N1I
BSD2-scl-d3/C-e3	1	1	3	2	0	0	1	3×1	S3I
BSD3-scl-d3/D-e4	1	1	3	2	0	3	0	3×2	S3Ic
BSD4-c-d1/C-e2	2	2	0	3	0	1	0	3×1	S3s
BSD4-c-d1/B-e1	0	1	0	3	0	1	0	3×1	S3s
BSD4-c-d1/A-e1	0	4	1	3	0	2	0	4×1	N1I
HLG-c-d1/B-e2	1	1	0	3	0	1	0	3×1	S3s
HLG-c-d1/B-e1	1	1	0	3	0	1	0	3×1	S3s
HLG-c-d1/A-e1	0	4	0	3	0	1	0	4×1	N1I
HLG-c-d1/A-e0	0	4	1	3	0	1	0	4×1	N1I

Table 12. Soil-site suitability classification for rice

Mapping unit	Climate			Landform characteristics		Physico-chemical characteristics					Overall limitation	Suitability sub-class
	Rainfall	Mean temperature in growing season	RH	Slope	Drainage	Depth	Texture	pH	ESP	CaCO ₃		
BSD1-s-d4/D-e4	-	-	-	-	-	-	-	-	-	-	-	Uncultivable
BSD2-scl-d3/C-e3	S1	S2	S1	N1	S3	S1	S2	S2	S1	S1	S3×4	N1t
BSD3-scl-d3/D-e4	S1	S2	S1	S3	S3	S2	S2	S1	S2	S1	S3×2	S3tw
BSD4-c-d1/C-e2	S1	S2	S1	N1	S2	S1	S1	S2	S1	S1	N1×1	N1t
BSD4-c-d1/B-e1	S1	S2	S1	S2	S2	S1	S1	S1	S1	S1	S3×1	S3c
BSD4-c-d1/A-e1	S1	S2	S1	S1	S2	S1	S1	S2	S1	S1	S2×3	S2cwl
HLG-c-d1/B-e2	S1	S2	S1	S2	S2	S1	S1	S1	S1	S1	S2×3	S2ctw
HLG-c-d1/B-e1	S1	S2	S1	S2	S2	S1	S1	S1	S1	S1	S2×3	S2ctw
HLG-c-d1/A-e1	S1	S2	S1	S1	S2	S1	S1	S1	S2	S1	S2×3	S2cwn
HLG-c-d1/A-e0	S1	S2	S1	S1	S2	S1	S1	S1	S1	S1	S2×2	S2cw

Table 13. Soil-site suitability classification for wheat

Mapping unit	Climate	Landform characteristics		Physico-chemical characteristics					Overall limitation	Suitability sub-class
	Mean temperature in growing season	Slope	Drainage	Depth	Texture	pH	OC	ESP		
BSD1-s-d4/D-e4	-	-	-	-	-	-	-	-	-	Uncultivable
BSD2-scl-d3/C-e3	S2	S3	S1	S1	S1	S1	S2	S1	S3×1	S3t
BSD3-scl-d3/D-e4	S2	S2	S1	S1	S1	S1	S1	S1	S2×3	S2ct
BSD4-c-d1/C-e2	S2	S3	S1	S1	S2	S1	S1	S1	S3×1	S3t
BSD4-c-d1/B-e1	S2	S1	S1	S1	S2	S1	S1	S1	S2×2	S2cs
BSD4-c-d1/A-e1	S2	S1	S1	S1	S2	S1	S1	S1	S2×2	S2cs
HLG-c-d1/B-e2	S2	S1	S1	S1	S2	S1	S2	S1	S2×2	S2cs
HLG-c-d1/B-e1	S2	S1	S1	S1	S2	S1	S1	S1	S2×2	S2cs
HLG-c-d1/A-e1	S2	S1	S1	S1	S2	S1	S1	S2	S2×2	S2cs
HLG-c-d1/A-e0	S2	S1	S3	S1	S2	S1	S1	S1	S2×2	S2cs

4.5.3.6 Bengal gram (cf. Table 17)

Soil mapping units 2 to 10 were marginally suitable for gram cultivation. They showed moderate limitations of climate, slope, depth and drainage.

4.5.3.7 Pigeonpea (cf. Table 18)

Mapping units 5 to 9 were moderately suitable with slight limitations of drainage and texture. Mapping unit 2, 3, 4 and 10 were marginally suitable for pigeon pea cultivation with moderate limitations of slope, drainage and depth.

4.5.3.8 Groundnut (cf. Table 19)

Mapping unit 10 was currently unsuitable for groundnut cultivation due to severe limitations of drainage. Mapping units 2 to 9 were marginally suitable owing to moderate limitations of slope and calcareousness.

4.5.3.9 Soybean (cf. Table 20)

Mapping unit 2 was currently unsuitable due to severe limitations of slope. Mapping unit 4 and 10 were marginally suitable due to moderate limitations of slope and drainage. Mapping unit 3 and 5, 6, 7, 8 and 9 were moderately suitable owing to slight limitations of slope, texture and drainage.

4.5.3.10 Sunflower (cf. Table 21)

Mapping unit 10 was currently unsuitable due to severe limitation of drainage. Other mapping units (2 to 9) were marginally suitable for sunflower due to moderate limitations of slope, depth, and texture.

4.5.3.11 Cotton (cf. Table 22)

Mapping unit 2 and 4 were currently unsuitable owing to severe limitations of slope and nutrient availability. Mapping unit 3 and 10 were marginally suitable with limitations of texture, slope and drainage. Others were moderately suitable with slight limitations of nutrient availability.

4.5.3.12 Sugarcane (cf. Table 23)

Mapping unit 2 was currently unsuitable with severe limitation of slope. Other mapping units were marginally suitable with moderate limitations of slope, texture, depth and drainage.

4.5.3.13 Cabbage (cf. Table 24)

Mapping unit 3 was moderately suitable owing to slight limitations of climate, slope and depth. Mapping units 2 and 4 to 10 were marginally suitable with moderate limitations of slope, texture and drainage.

4.5.3.14 Chilli (cf. Table 25)

Mapping unit 10 was currently unsuitable for chilli cultivation with severe limitations of drainage. Mapping units 2 to 9 were marginally suitable with moderate limitations of climate, drainage, texture, slope and nutrient availability.

4.5.3.15 Potato (cf. Table 26)

Mapping unit 2 was currently unsuitable for potato with severe limitation of slope. Mapping unit 4 to 10 was potentially unsuitable for potato cultivation with very severe limitation of texture (clay). Mapping unit 3 was marginally suitable with moderate limitations of slope.

4.5.3.16 Tomato (cf. Table 27)

Mapping units 2 to 10 were marginally suitable with moderate limitation of climate, slope, texture and drainage.

Table 14. Soil-site suitability classification for maize

Mapping unit	Climate		Landform characteristics		Physico-chemical characteristics					Overall limitation	Suitability sub-class
	Rainfall	Mean temperature in growing season	Slope	Drainage	Depth	Texture	OC	pH	ESP		
BSD1-s-d4/D-e4	-	-	-	-	-	-	-	-	-	-	Uncultivable
BSD2-scl-d3/C-e3	S1	S1	N1	S1	S1	S1	S2	S1	S1	N1×1	N1t
BSD3-scl-d3/D-e4	S1	S1	S2	S1	S2	S1	S1	S1	S1	S2×2	S2tr
BSD4-c-d1/C-e2	S1	S1	S3	S2	S1	S3	S1	S1	S2	S3×2	S3ts
BSD4-c-d1/B-e1	S1	S1	S1	S2	S1	S3	S1	S1	S2	S3×1	S3s
BSD4-c-d1/A-e1	S1	S1	S1	S2	S1	S3	S1	S1	S2	S3×1	S3s
HLG-c-d1/B-e2	S1	S1	S1	S2	S1	S3	S2	S1	S2	S3×1	S3s
HLG-c-d1/B-e1	S1	S1	S1	S2	S1	S3	S1	S1	S2	S3×1	S3s
HLG-c-d1/A-e1	S1	S1	S1	S2	S1	S3	S1	S1	S3	S3×2	S3s
HLG-c-d1/A-e0	S1	S1	S1	S3	S1	S3	S1	S1	S2	S3×2	S3ws

Table 15. Soil-site suitability classification for sorghum

Mapping unit	Climate				Landform characteristics		Physico-chemical characteristics								Overall limitation	Suitability sub-class
	Rain-fall	Max. Temp	Min. Temp.	RH	Slope	Drainage	Depth	Texture	pH	OC	CEC	BS	ESP	CaCO ₃		
BSD1-s-d4/D-e4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Uncultivable
BSD2-scl-d3/C-e3	S1	S1	S2	S1	S3	S1	S2	S1	S1	S1	S1	S1	S1	S2	S3×1	S3t
BSD3-scl-d3/D-e4	S1	S1	S2	S1	S2	S1	S1	S1	S1	S1	S1	S1	S1	S1	S2×2	S2ct
BSD4-c-d1/C-e2	S1	S1	S2	S1	S2	S1	S1	S1	S1	S1	S1	S1	S1	S1	S2×3	S2ct
BSD4-c-d1/B-e1	S1	S1	S2	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S2×2	S2c
BSD4-c-d1/A-e1	S1	S1	S2	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S2×2	S2c
HLG-c-d1/B-e2	S1	S1	S2	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S2×2	S2c
HLG-c-d1/B-e1	S1	S1	S2	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S2×2	S2c
HLG-c-d1/A-e1	S1	S1	S2	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S2×2	S2ct
HLG-c-d1/A-e0	S1	S1	S2	S1	S1	S3	S1	S1	S1	S1	S1	S1	S2	S1	S3×1	S3w

Table 16. Soil-site suitability classification for pearl millet

Mapping unit	Climate		Landform characteristics		Physico-chemical characteristics						Overall limitation	Suitability sub-class
	Rainfall	Mean temperature in growing season	Slope	Drainage	Depth	Texture	pH	OC	ESP	CaCO ₃		
BSD1-s-d4/D-e4	-	-	-	-	-	-	-	-	-	-	-	Uncultivable
BSD2-scl-d3/C-e3	S1	S2	S3	S1	S1	S1	S1	S2	S1	S3	S3×2	S3tn
BSD3-scl-d3/D-e4	S1	S2	S2	S1	S2	S1	S1	S1	S1	S1	S2×3	S2ctr
BSD4-c-d1/C-e2	S1	S2	S3	S2	S1	S3	S1	S1	S1	S1	S3×2	S3ts
BSD4-c-d1/B-e1	S1	S2	S1	S2	S1	S3	S1	S1	S1	S1	S3×1	S3s
BSD4-c-d1/A-e1	S1	S2	S1	S2	S1	S3	S1	S1	S1	S1	S3×1	S3s
HLG-c-d1/B-e2	S1	S2	S1	S2	S1	S3	S1	S2	S1	S1	S3×1	S3s
HLG-c-d1/B-e1	S1	S2	S1	S2	S1	S3	S1	S1	S1	S1	S3×1	S3s
HLG-c-d1/A-e1	S1	S2	S1	S2	S1	S3	S1	S1	S2	S1	S3×1	S3s
HLG-c-d1/A-e0	S1	S2	S1	S3	S1	S3	S1	S1	S1	S1	S3×2	S3ws

Table 17. Soil-site suitability classification for bengal gram (chickpea)

Mapping unit	Climate		Landform characteristics		Physico-chemical characteristics				Overall limitation	Suitability sub-class
	Rainfall	Mean temperature in growing season	Slope	Drainage	Depth	Texture	pH	ESP		
BSD1-s-d4/D-e4	-	-	-	-	-	-	-	-	-	Uncultivable
BSD2-scl-d3/C-e3	S1	S3	S3	S1	S3	S1	S2	S1	S3×3	S3ctr
BSD3-scl-d3/D-e4	S1	S3	S2	S1	S2	S1	S1	S2	S3×1	S3c
BSD4-c-d1/C-e2	S1	S3	S3	S2	S1	S2	S2	S1	S3×2	S3ct
BSD4-c-d1/B-e1	S1	S3	S1	S2	S1	S2	S1	S1	S3×1	S3c
BSD4-c-d1/A-e1	S1	S3	S1	S2	S1	S2	S2	S2	S3×1	S3c
HLG-c-d1/B-e2	S1	S3	S1	S2	S1	S2	S2	S2	S3×1	S3c
HLG-c-d1/B-e1	S1	S3	S1	S2	S1	S2	S1	S2	S3×1	S3c
HLG-c-d1/A-e1	S1	S3	S1	S2	S1	S2	S1	S2	S3×1	S3c
HLG-c-d1/A-e0	S1	S3	S1	S3	S1	S2	S1	S2	S3×2	S3cw

Table 18. Soil-site suitability classification for pigeonpea

Mapping unit	Climate		Landform characteristics		Physico-chemical characteristics				Overall limitation	Suitability sub-class
	Rainfall	Mean temperature in growing season	Slope	Drainage	Depth	Texture	pH	ESP		
BSD1-s-d4/D-e4	-	-	-	-	-	-	-	-	-	Uncultivable
BSD2-scl-d3/C-e3	S1	S1	S3	S1	S2	S1	S2	S1	S3×1	S3t
BSD3-scl-d3/D-e4	S1	S1	S2	S1	S3	S1	S1	S2	S3×1	S3r
BSD4-c-d1/C-e2	S1	S1	S3	S2	S1	S2	S2	S1	S3×1	S3t
BSD4-c-d1/B-e1	S1	S1	S1	S2	S1	S2	S1	S1	S2×2	S2ws
BSD4-c-d1/A-e1	S1	S1	S1	S2	S1	S2	S1	S1	S2×2	S2ws
HLG-c-d1/B-e2	S1	S1	S1	S2	S1	S2	S1	S1	S2×2	S2ws
HLG-c-d1/B-e1	S1	S1	S1	S2	S1	S2	S1	S1	S2×2	S2ws
HLG-c-d1/A-e1	S1	S1	S1	S2	S1	S2	S1	S1	S2×2	S2ws
HLG-c-d1/A-e0	S1	S1	S1	S3	S1	S2	S1	S2	S3×1	S3w

Table 19. Soil-site suitability classification for groundnut

Mapping unit	Climate		Landform characteristics		Physico-chemical characteristics					Overall limitation	Suitability sub-class
	Rainfall	Mean temperature in growing period	Slope	Drainage	Depth	Texture	pH	ESP	CaCO ₃		
BSD1-s-d4/D-e4	-	-	-	-	-	-	-	-	-	-	Uncultivable
BSD2-scl-d3/C-e3	S1	S1	S3	S1	S1	S1	S1	S1	S2	S3×1	S3t
BSD3-scl-d3/D-e4	S1	S1	S2	S1	S2	S1	S1	S2	S3	S3×1	S3n
BSD4-c-d1/C-e2	S1	S1	S2	S2	S1	S2	S1	S2	S3	S3×1	S3n
BSD4-c-d1/B-e1	S1	S1	S1	S2	S1	S2	S1	S2	S3	S3×1	S3n
BSD4-c-d1/A-e1	S1	S1	S1	S2	S1	S2	S1	S2	S3	S3×1	S3n
HLG-c-d1/B-e2	S1	S1	S1	S2	S1	S2	S1	S2	S3	S3×1	S3n
HLG-c-d1/B-e1	S1	S1	S1	S2	S1	S2	S1	S2	S3	S3×1	S3n
HLG-c-d1/A-e1	S1	S1	S1	S2	S1	S2	S1	S2	S3	S3×1	S3n
HLG-c-d1/A-e0	S1	S1	S1	N1	S1	S2	S1	S3	S3	N1×1	N1w

Table 20. Soil-site suitability classification for soybean

Mapping unit	Climate			Landform characteristics		Physico-chemical characteristics					Overall limitation	Suitability sub-class	
	Rainfall	Mean temperature in growing season	RH	Slope	Drainage	Depth	Texture	pH	OC	ESP			
BSD1-s-d4/D-e4	-	-	-	-	-	-	-	-	-	-	-	-	Uncultivable
BSD2-scl-d3/C-e3	S1	S1	S1	N1	S1	S1	S1	S1	S2	S1	N1×1	N1t	
BSD3-scl-d3/D-e4	S1	S1	S1	S2	S1	S2	S1	S1	S2	S1	S2×3	S2trl	
BSD4-c-d1/C-e2	S1	S1	S1	S3	S2	S1	S1	S1	S1	S1	S3×1	S3t	
BSD4-c-d1/B-e1	S1	S1	S1	S1	S2	S1	S1	S1	S1	S1	S2×1	S2w	
BSD4-c-d1/A-e1	S1	S1	S1	S1	S2	S1	S1	S1	S1	S1	S2×1	S2w	
HLG-c-d1/B-e2	S1	S1	S1	S1	S2	S1	S1	S1	S1	S1	S2×1	S2w	
HLG-c-d1/B-e1	S1	S1	S1	S1	S2	S1	S1	S1	S1	S1	S2×1	S2w	
HLG-c-d1/A-e1	S1	S1	S1	S1	S2	S1	S1	S1	S1	S1	S2×1	S2w	
HLG-c-d1/A-e0	S1	S1	S1	S1	S3	S1	S1	S1	S1	S2	S3×1	S3w	

Table 21. Soil-site suitability classification for sunflower

Mapping unit	Climate		Landform characteristics		Physico-chemical characteristics				Overall limitation	Suitability sub-class
	Rainfall	Mean temperature in growing season	Slope	Drainage	Depth	Texture	pH	ESP		
BSD1-s-d4/D-e4	-	-	-	-	-	-	-	-	-	Uncultivable
BSD2-scl-d3/C-e3	S1	S1	S3	S1	S2	S2	S2	S1	S3×1	S3t
BSD3-scl-d3/D-e4	S1	S1	S2	S1	S3	S2	S1	S2	S3×1	S3r
BSD4-c-d1/C-e2	S1	S1	S3	S2	S1	S3	S1	S1	S3×2	S3ts
BSD4-c-d1/B-e1	S1	S1	S1	S2	S1	S3	S1	S1	S3×1	S3s
BSD4-c-d1/A-e1	S1	S1	S1	S2	S1	S3	S1	S2	S3×1	S3s
HLG-c-d1/B-e2	S1	S1	S1	S2	S1	S3	S2	S2	S3×1	S3s
HLG-c-d1/B-e1	S1	S1	S1	S2	S1	S3	S1	S2	S3×1	S3s
HLG-c-d1/A-e1	S1	S1	S1	S2	S1	S3	S1	S2	S3×1	S3s
HLG-c-d1/A-e0	S1	S1	S1	N1	S1	S3	S1	S2	N1×1	N1w

Table 22. Soil-site suitability classification for cotton

Mapping unit	Climate			Landform characteristics		Physico-chemical characteristics								Overall limitation	Suit-ability sub-class
	Rain-fall	Mean temperature in growing season	RH	Slope	Drainage	Depth	Texture	pH	OC	CEC	BS	ESP	CaCO ₃		
BSD1-s-d4/D-e4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Uncultivable
BSD2-scl-d3/C-e3	S1	S1	S1	N1	S1	S2	S3	S2	S3	N1	S2	S1	N1	N1×3	N1tl
BSD3-scl-d3/D-e4	S1	S1	S1	S3	S1	S2	S3	S1	S2	S2	S1	S1	S1	S3×2	S3ts
BSD4-c-d1/C-e2	S1	S1	S1	N1	S1	S1	S1	S1	S2	S1	S1	S1	S1	N1×1	N1t
BSD4-c-d1/B-e1	S1	S1	S1	S1	S1	S1	S1	S1	S2	S1	S1	S1	S1	S2×1	S2l
BSD4-c-d1/A-e1	S1	S1	S1	S1	S1	S1	S1	S1	S2	S1	S1	S1	S1	S2×1	S2l
HLG-c-d1/B-e2	S1	S1	S1	S1	S1	S1	S1	S2	S2	S1	S1	S1	S1	S2×2	S2l
HLG-c-d1/B-e1	S1	S1	S1	S1	S1	S1	S1	S1	S2	S1	S1	S1	S1	S2×1	S2l
HLG-c-d1/A-e1	S1	S1	S1	S1	S1	S1	S1	S1	S2	S1	S1	S1	S1	S2×1	S2l
HLG-c-d1/A-e0	S1	S1	S1	S1	S3	S1	S1	S1	S1	S1	S1	S2	S1	S3×1	S3w

Table 23. Soil-site suitability classification for sugarcane

Mapping unit	Climate		Landform characteristics		Physico-chemical characteristics					Overall limitation	Suitability sub-class	
	Mean temperature in growing season	RH	Slope	Drainage	Depth	Texture	pH	CEC	ESP			
BSD1-s-d4/D-e4	-	-	-	-	-	-	-	-	-	-	-	Uncultivable
BSD2-scl-d3/C-e3	S2	S1	N1	S1	S2	S1	S1	S1	S1	N1×1	N1t	
BSD3-scl-d3/D-e4	S2	S1	S2	S1	S3	S1	S1	S1	S1	S3×1	S3r	
BSD4-c-d1/C-e2	S2	S1	S3	S2	S1	S3	S1	S1	S1	S3×2	S3ts	
BSD4-c-d1/B-e1	S2	S1	S1	S2	S1	S3	S1	S1	S1	S3×1	S3s	
BSD4-c-d1/A-e1	S2	S1	S1	S2	S1	S3	S1	S1	S2	S3×1	S3s	
HLG-c-d1/B-e2	S2	S1	S1	S2	S1	S3	S1	S1	S2	S3×1	S3s	
HLG-c-d1/B-e1	S2	S1	S1	S2	S1	S3	S1	S1	S2	S3×1	S3s	
HLG-c-d1/A-e1	S2	S1	S1	S2	S1	S3	S1	S1	S1	S3×1	S3s	
HLG-c-d1/A-e0	S2	S1	S1	S3	S1	S3	S1	S1	S2	S3×2	S3ws	

Table 24. Soil-site suitability classification for cabbage

Mapping unit	Climate	Landform characteristics		Physico-chemical characteristics						Overall limitation	Suitability sub-class
	Mean temperature in growing season	Slope	Drainage	Depth	Texture	pH	CEC	ESP	CaCO ₃		
BSD1-s-d4/D-e4	-	-	-	-	-	-	-	-	-	-	Uncultivable
BSD2-scl-d3/C-e3	S2	S3	S1	S1	S1	S2	S1	S2	S1	S3×1	S3t
BSD3-scl-d3/D-e4	S2	S2	S1	S2	S1	S1	S1	S1	S1	S2×3	S2ctr
BSD4-c-d1/C-e2	S2	S3	S2	S1	S3	S2	S1	S2	S1	S3×2	S3ts
BSD4-c-d1/B-e1	S2	S1	S2	S1	S3	S1	S1	S2	S1	S3×1	S3s
BSD4-c-d1/A-e1	S2	S1	S2	S1	S3	S2	S1	S2	S1	S3×1	S3s
HLG-c-d1/B-e2	S2	S1	S2	S1	S3	S2	S1	S2	S1	S3×1	S3s
HLG-c-d1/B-e1	S2	S1	S2	S1	S3	S2	S1	S2	S1	S3×1	S3s
HLG-c-d1/A-e1	S2	S1	S2	S1	S3	S2	S1	S2	S1	S3×1	S3s
HLG-c-d1/A-e0	S2	S1	S3	S1	S3	S1	S1	S2	S1	S3×2	S3ws

Table 25. Soil-site suitability classification for chilli

Mapping unit	Climate		Landform characteristics		Physico-chemical characteristics					Overall limitation	Suitability sub-class	
	Rainfall	Mean temperature in growing season	Slope	Drainage	Depth	Texture	pH	OC	ESP			
BSD1-s-d4/D-e4	-	-	-	-	-	-	-	-	-	-	-	Uncultivable
BSD2-scl-d3/C-e3	S3	S2	S3	S1	S1	S1	S2	S2	S1	S3×2	S3ct	
BSD3-scl-d3/D-e4	S3	S2	S2	S1	S2	S1	S1	S3	S1	S3×2	S3cl	
BSD4-c-d1/C-e2	S3	S2	S3	S2	S1	S3	S2	S2	S2	S3×3	S3cts	
BSD4-c-d1/B-e1	S3	S2	S1	S2	S1	S3	S2	S2	S2	S3×2	S3cs	
BSD4-c-d1/A-e1	S3	S2	S1	S2	S1	S3	S2	S2	S2	S3×2	S3cs	
HLG-c-d1/B-e2	S3	S2	S1	S2	S1	S3	S2	S2	S2	S3×2	S3cs	
HLG-c-d1/B-e1	S3	S2	S1	S2	S1	S3	S2	S2	S2	S3×2	S3cs	
HLG-c-d1/A-e1	S3	S2	S1	S3	S1	S3	S2	S2	S1	S3×2	S3cl	
HLG-c-d1/A-e0	S3	S2	S1	N1	S2	S3	S2	S1	S3	N1×1	N1w	

4.5.3.17 Mango (cf. Table 28)

Mapping unit 3 was potentially unsuitable for mango with very severe limitation of depth. Mapping units 5 to 9 were moderately suitable with slight limitations of climate, depth and texture. Other mapping units (2, 4 and 10) were marginally suitable with moderate limitations of slope, drainage, depth.

4.5.3.18 Guava (cf. Table 29)

All mapping units (2 to 10) were marginally suitable with moderate limitations of climate, slope, calcareousness (in mapping unit 2) and drainage.

4.5.3.19 Sapota (cf. Table 30)

Mapping unit 5 was moderately suitable with slight limitations of climate, drainage and texture. Others (2 to 4 and 6 to 10) were marginally suitable with moderate limitations of drainage (in 6 to 10), slope and depth.

4.5.3.20 Coconut (cf. Table 31)

Mapping unit 10 was currently unsuitable with severe limitation of drainage. Mapping units 2, 3 and 5 were marginally suitable for coconut with moderate limitations of climate, depth and texture. Other mapping units (4, 6, 7, 8 and 10) were moderately suitable with slight limitations of climate, depth and texture.

4.5.3.21 Rose (cf. Table 32)

Mapping unit 2 was moderately suitable with slight limitations of slope and depth. Other mapping units (3 to 10) were marginally suitable with moderate limitations of texture, depth and drainage.

4.5.3.22 Jasmine (cf. Table 33)

Mapping unit 3 was moderately suitable owing to slight limitations of climate, slope and depth. Mapping unit 2 and 4 to 10 were marginally suitable with moderate limitations of slope, texture and drainage.

4.6 FERTILITY STATUS OF SOILS

4.6.1 Soil reaction (cf. Table 34)

pH of surface soil samples ranged from 6.22 to 8.42 with an average value of 7.48 and standard deviation of 0.52. There was decrease in pH along the altitude of the spot. Hill samples had lower pH compared to those from valley zone of Bastwad microwatershed. 5.3 per cent samples of the total of 75 were in acidic range (6.22–6.42), 42.7 per cent were in neutral range (6.5–7.5) and remaining 52 per cent samples were recorded to have alkaline soil reaction in the range of 7.51–8.42.

4.6.2 Electrical conductivity (cf. Table 34)

EC in surface samples ranged from 0.20 to 1.03 dSm⁻¹ with an average of 0.24 dSm⁻¹. Standard deviation was high (0.22 dSm⁻¹) showing a high degree of spatial variability in EC of soils of Bastwad microwatershed. Again lower values of EC could be correlated with altitude as there was an increase in EC with decrease in altitude.

4.6.3 Organic carbon (cf. Table 34)

In surface soils, organic carbon ranged from 1.3 to 11.5 g kg⁻¹. The average organic carbon content of the microwatershed was 7.3 g kg⁻¹ with a standard deviation of 3.2 g kg⁻¹. Organic carbon content increased from higher to lower altitudes. The organic carbon status of the microwatershed was good. 2.7 per cent of the samples were low in organic carbon status followed by 25.3 per cent in medium range and 52 per cent in high range of organic carbon. Organic carbon status was higher in low-lying valley area of the microwatershed as compared to that of the hilly zone.

Table 26. Soil-site suitability classification for potato

Mapping unit	Climate	Landform characteristics		Physico-chemical characteristics						Overall limitation	Suitability sub-class
	Mean temperature in growing season	Slope	Drainage	Depth	Texture	pH	OC	CEC	ESP		
BSD1-s-d4/D-e4	-	-	-	-	-	-	-	-	-	-	Uncultivable
BSD2-scl-d3/C-e3	S2	N1	S1	S1	S2	S1	S2	S1	S1	N1×1	N1t
BSD3-scl-d3/D-e4	S2	S3	S1	S2	S2	S1	S2	S1	S1	S3×1	S3t
BSD4-c-d1/C-e2	S2	S3	S2	S1	N2	S1	S1	S1	S1	N2×1	N2s
BSD4-c-d1/B-e1	S2	S1	S2	S1	N2	S1	S1	S1	S1	N2×1	N2s
BSD4-c-d1/A-e1	S2	S1	S2	S1	N2	S1	S1	S1	S2	N2×1	N2s
HLG-c-d1/B-e2	S2	S1	S2	S1	N2	S1	S1	S1	S2	N2×1	N2s
HLG-c-d1/B-e1	S2	S1	S2	S1	N2	S1	S1	S1	S2	N2×1	N2s
HLG-c-d1/A-e1	S2	S1	S2	S1	N2	S1	S1	S1	S3	N2×1	N2s
HLG-c-d1/A-e0	S2	S1	S3	S1	N2	S1	S1	S1	S2	N2×1	N2s

Table 27. Soil-site suitability classification for tomato

Mapping unit	Climate		Landform characteristics		Physico-chemical characteristics						Overall limitation	Suitability sub-class	
	Total rainfall	Mean temp in growing season	Slope	Drainage	Depth	Texture	pH	CEC	ESP	CaCO ₃			
BSD1-s-d4/D-e4	-	-	-	-	-	-	-	-	-	-	-	-	Uncultivable
BSD2-scl-d3/C-e3	S3	S1	S3	S1	S1	S1	S2	S1	S1	S2	S3×2	S3ct	
BSD3-scl-d3/D-e4	S3	S1	S2	S1	S2	S1	S1	S1	S1	S1	S3×1	S3c	
BSD4-c-d1/C-e2	S3	S1	S3	S2	S1	S3	S2	S1	S2	S1	S3×3	S3cts	
BSD4-c-d1/B-e1	S3	S1	S1	S2	S1	S3	S2	S1	S2	S1	S3×2	S3cs	
BSD4-c-d1/A-e1	S3	S1	S1	S2	S1	S3	S2	S1	S2	S1	S3×2	S3cs	
HLG-c-d1/B-e2	S3	S1	S1	S2	S1	S3	S2	S1	S2	S1	S3×2	S3cs	
HLG-c-d1/B-e1	S3	S1	S1	S2	S1	S3	S2	S1	S2	S1	S3×2	S3cs	
HLG-c-d1/A-e1	S3	S1	S1	S2	S1	S3	S2	S1	S1	S1	S3×2	S3cs	
HLG-c-d1/A-e0	S3	S1	S1	S3	S1	S3	S2	S1	S2	S1	S3×3	S3cws	

Table 28. Soil-site suitability classification for mango

Mapping unit	Climate	Landform characteristics		Physico-chemical characteristics						Overall limitation	Suitability sub-class
	Mean temperature in growing season	Slope	Drainage	Depth	Texture	pH	OC	ESP	CaCO ₃		
BSD1-s-d4/D-e4	-	-	-	-	-	-	-	-	-	-	Uncultivable
BSD2-scl-d3/C-e3	S2	S3	S1	S3	S1	S1	S2	S1	S2	S3×2	S3tr
BSD3-scl-d3/D-e4	S2	S2	S1	N2	S1	S1	S2	N1	S1	N2×1	N2r
BSD4-c-d1/C-e2	S2	S3	S2	S2	S2	S1	S1	S2	S1	S3×1	S3t
BSD4-c-d1/B-e1	S2	S1	S1	S2	S2	S1	S1	S1	S1	S2×3	S2crs
BSD4-c-d1/A-e1	S2	S1	S2	S2	S2	S1	S1	S1	S1	S2×3	S2crs
HLG-c-d1/B-e2	S2	S1	S2	S2	S2	S1	S2	S1	S1	S2×3	S2crs
HLG-c-d1/B-e1	S2	S1	S2	S2	S2	S1	S1	S1	S1	S2×3	S2crs
HLG-c-d1/A-e1	S2	S1	S2	S2	S2	S1	S1	S1	S1	S2×3	S2crs
HLG-c-d1/A-e0	S2	S1	S3	S2	S2	S1	S1	S2	S1	S3×1	S3w

Table 29. Soil-site suitability classification for guava

Mapping unit	Climate	Landform characteristics		Physico-chemical characteristics					Overall limitation	Suitability sub-class
	Mean temperature in growing season	Slope	Drainage	Depth	Texture	pH	ESP	CaCO ₃		
BSD1-s-d4/D-e4	-	-	-	-	-	-	-	-	-	Uncultivable
BSD2-scl-d3/C-e3	S3	S2	S1	S2	S1	S2	S1	S3	S3×2	S3cn
BSD3-scl-d3/D-e4	S3	S2	S1	S3	S1	S1	S1	S1	S3×2	S3cr
BSD4-c-d1/C-e2	S3	S3	S2	S1	S2	S1	S1	S1	S3×2	S3ct
BSD4-c-d1/B-e1	S3	S1	S2	S1	S2	S1	S1	S1	S3×1	S3c
BSD4-c-d1/A-e1	S3	S1	S2	S1	S2	S1	S2	S1	S3×1	S3c
HLG-c-d1/B-e2	S3	S1	S2	S1	S2	S2	S2	S1	S3×1	S3c
HLG-c-d1/B-e1	S3	S1	S2	S1	S2	S1	S2	S1	S3×1	S3c
HLG-c-d1/A-e1	S3	S1	S2	S1	S2	S1	S2	S1	S3×1	S3c
HLG-c-d1/A-e0	S3	S1	S3	S1	S2	S1	S2	S1	S3×2	S3cw

Table 30. Soil-site suitability classification for sapota

Mapping unit	Climate	Landform characteristics		Physico-chemical characteristics				Overall limitation	Suitability sub-class
	Mean temperature in growing season	Slope	Drainage	Depth	Texture	pH	ESP		
BSD1-s-d4/D-e4	-	-	-	-	-	-	-	-	Uncultivable
BSD2-scl-d3/C-e3	S2	S3	S1	S2	S1	S2	S1	S3×1	S3t
BSD3-scl-d3/D-e4	S2	S2	S1	S3	S1	S1	S1	S3×1	S3r
BSD4-c-d1/C-e2	S2	S3	S2	S1	S2	S1	S1	S3×1	S3t
BSD4-c-d1/B-e1	S2	S1	S2	S1	S2	S1	S1	S2×3	S2cws
BSD4-c-d1/A-e1	S2	S1	S3	S1	S2	S1	S2	S3×1	S3w
HLG-c-d1/B-e2	S2	S1	S3	S1	S2	S2	S2	S3×1	S3w
HLG-c-d1/B-e1	S2	S1	S3	S1	S2	S1	S2	S3×1	S3w
HLG-c-d1/A-e1	S2	S1	S3	S2	S2	S1	S1	S3×1	S3w
HLG-c-d1/A-e0	S2	S1	S3	S2	S2	S1	S2	S3×1	S3w

Table 31. Soil-site suitability classification for coconut

Mapping unit	Climate	Landform characteristics		Physico-chemical characteristics			Overall limitation	Suitability sub-class
	Mean temperature in growing season	Slope	Drainage	Depth	Texture	pH		
BSD1-s-d4/D-e4	-	-	-	-	-	-	-	Uncultivable
BSD2-scl-d3/C-e3	S2	S2	S1	S3	S1	S2	S3×1	S3r
BSD3-scl-d3/D-e4	S2	S1	S1	S3	S1	S2	S3×1	S3r
BSD4-c-d1/C-e2	S2	S1	S1	S2	S2	S1	S2×3	S2crs
BSD4-c-d1/B-e1	S2	S1	S1	S2	S2	S1	S2×3	S3crs
BSD4-c-d1/A-e1	S2	S1	S1	S2	S2	S1	S2×3	S2crs
HLG-c-d1/B-e2	S2	S1	S1	S2	S2	S1	S2×3	S2crs
HLG-c-d1/B-e1	S2	S1	S1	S2	S2	S1	S2×3	S2crs
HLG-c-d1/A-e1	S2	S1	S1	S2	S2	S1	S2×3	S2crs
HLG-c-d1/A-e0	S2	S1	N1	S2	S2	S1	N1×1	N1w

Table 32. Soil-site suitability classification for rose

Mapping unit	Climate	Landform characteristics		Physico-chemical characteristics						Overall limitation	Suitability sub-class
	Mean temperature in growing season	Slope	Drainage	Depth	Texture	pH	CEC	ESP	CaCO ₃		
BSD1-s-d4/D-e4	-	-	-	-	-	-	-	-	-	-	Uncultivable
BSD2-scl-d3/C-e3	S1	S2	S1	S2	S1	S1	S1	S1	S2	S2×2	S2tr
BSD3-scl-d3/D-e4	S1	S1	S1	S3	S1	S1	S1	S2	S2	S3×1	S3r
BSD4-c-d1/C-e2	S1	S2	S2	S1	S3	S1	S1	S1	S2	S3×1	S3s
BSD4-c-d1/B-e1	S1	S1	S2	S1	S3	S1	S1	S1	S2	S3×1	S3s
BSD4-c-d1/A-e1	S1	S1	S2	S1	S3	S1	S1	S1	S2	S3×1	S3s
HLG-c-d1/B-e2	S1	S1	S2	S1	S3	S1	S1	S1	S2	S3×1	S3s
HLG-c-d1/B-e1	S1	S1	S2	S1	S3	S1	S1	S1	S2	S3×1	S3s
HLG-c-d1/A-e1	S1	S1	S2	S1	S3	S1	S1	S1	S2	S3×1	S3s
HLG-c-d1/A-e0	S1	S1	S3	S1	S3	S1	S1	S1	S2	S3×2	S3ws

Table 33. Soil-site suitability classification for jasmine

Mapping unit	Climate	Landform characteristics		Physico-chemical characteristics						Overall limitation	Suitability sub-class	
	Mean temperature in growing season	Slope	Drainage	Depth	Texture	pH	CEC	ESP	CaCO ₃			
BSD1-s-d4/D-e4	-	-	-	-	-	-	-	-	-	-	-	Uncultivable
BSD2-scl-d3/C-e3	S2	S3	S1	S1	S1	S2	S1	S1	S1	S3×1	S3t	
BSD3-scl-d3/D-e4	S2	S2	S1	S2	S1	S1	S1	S1	S1	S2×3	S2ctr	
BSD4-c-d1/C-e2	S2	S3	S2	S1	S3	S2	S1	S1	S1	S3×2	S3ts	
BSD4-c-d1/B-e1	S2	S1	S2	S1	S3	S1	S1	S1	S1	S3×1	S3s	
BSD4-c-d1/A-e1	S2	S1	S2	S1	S3	S2	S1	S1	S1	S3×1	S3s	
HLG-c-d1/B-e2	S2	S1	S2	S1	S3	S2	S1	S1	S1	S3×1	S3s	
HLG-c-d1/B-e1	S2	S1	S2	S1	S3	S2	S1	S1	S1	S3×1	S3s	
HLG-c-d1/A-e1	S2	S1	S2	S1	S3	S2	S1	S1	S1	S3×1	S3s	
HLG-c-d1/A-e0	S2	S1	S3	S1	S3	S1	S1	S1	S1	S3×2	S3ws	

Table 34. Chemical properties of surface soil samples

Sample No.	pH	EC (dSm ⁻¹)	O.C. (g kg ⁻¹)	Sample No.	pH	EC (dSm ⁻¹)	OC (g kg ⁻¹)
1	6.53	0.20	1.3	39	6.94	0.14	6.20
2	6.77	0.07	1.3	40	7.65	0.37	9.80
3	7.76	0.09	7.5	41	7.33	0.15	11.50
4	7.07	0.14	9.3	42	7.95	0.12	5.30
5	7.28	0.11	8.9	43	7.19	0.15	8.00
6	7.58	0.06	1.8	44	7.65	0.19	8.00
7	7.68	0.08	8.4	45	8.35	0.22	8.90
8	8.14	0.10	4.4	46	7.43	0.18	6.70
9	7.99	0.93	7.1	47	7.45	0.16	11.10
10	6.35	0.11	11.5	48	7.36	0.18	3.10
11	6.42	0.09	2.7	49	8.10	0.16	5.30
12	6.22	0.07	2.0	50	7.77	0.20	8.90
13	7.07	0.15	1.3	51	7.09	0.07	9.30
14	7.08	0.1	3.1	52	6.95	0.05	4.90
15	6.95	0.08	1.3	53	7.15	0.09	8.40
16	6.6	0.05	2.7	54	7.40	0.08	9.30
17	6.64	0.09	8.9	55	7.55	0.14	9.80
18	7.54	0.2	1.8	56	7.30	0.11	8.00
19	7.67	0.32	10.2	57	7.45	0.11	8.90
20	8.1	0.30	6.7	58	7.53	0.09	8.40
21	7.65	0.29	10.6	59	7.23	0.16	10.20
22	8.34	0.22	11.5	60	6.93	0.05	6.20
23	7.85	0.17	6.6	61	7.30	0.83	4.90
24	7.25	0.15	2.2	62	6.30	0.71	9.80
25	7.17	0.17	9.8	63	7.04	0.73	6.20
26	7.25	0.16	6.7	64	7.92	0.16	5.80
27	7.57	0.15	5.3	65	8.42	0.29	10.60
28	7.4	0.13	10.6	66	7.75	1.03	10.60
29	7.51	0.15	9.8	67	8.32	0.15	8.40
30	8.1	0.13	7.1	68	8.07	0.15	10.20
31	7.32	0.17	6.7	69	8.23	0.20	4.00
32	8.37	0.34	7.1	70	7.95	0.45	9.80
33	7.53	0.22	10.6	71	7.88	0.38	10.20
34	8.05	0.40	10.2	72	7.55	0.81	10.20
35	8.40	0.30	7.1	73	7.54	0.80	7.50
36	7.59	0.21	7.5	74	7.98	0.65	9.80
37	7.28	0.16	1.3				
38	7.66	0.16	8.4	Mean	7.48	0.24	0.73
				S.D.	0.52	0.22	0.32
				Range	6.22-8.42	0.20-1.03	1.3-11.5

Table 35. Available major nutrient status of microwatershed

Sample No.	N	P ₂ O ₅	K ₂ O	Sample No.	N	P ₂ O ₅	K ₂ O
	-----kg ha ⁻¹ -----				-----kg ha ⁻¹ -----		
1	227.5	21.5	48.0	41	792.5	12.9	384.0
2	210.0	27.4	96.0	42	267.5	13.8	360.0
3	462.5	31.3	216.0	43	637.5	22.1	648.0
4	650.0	25.4	168.0	44	650.0	22.6	536.0
5	497.5	17.6	216.0	45	699.0	25.1	600.0
6	392.5	31.3	96.0	46	332.5	23.6	224.0
7	615.0	11.7	72.0	47	692.5	19.5	696.0
8	245.0	13.7	48.0	48	175.0	20.6	480.0
9	380.0	13.7	248.0	49	297.5	20.8	360.0
10	675.0	16.6	144.0	50	662.5	25.4	480.0
11	157.5	8.8	120.0	51	692.5	11.7	24.0
12	197.5	16.6	216.0	52	252.5	15.7	144.0
13	115.0	9.8	124.0	53	332.5	17.6	214.0
14	295.0	13.1	48.0	54	685.0	13.7	120.0
15	105.0	15.9	120.0	55	620.0	10.8	344.0
16	140.0	21.5	118.0	56	650.0	18.8	168.0
17	645.5	23.6	440.0	57	610.0	24.7	120.0
18	162.5	20.2	800.0	58	645.0	21.6	296.0
19	705.0	18.8	404.0	59	697.5	28.6	600.0
20	457.5	21.9	436.0	60	385.0	16.0	418.0
21	627.5	14.8	728.0	61	210.0	18.4	480.0
22	605.0	12.3	360.0	62	662.5	11.4	312.0
23	297.5	16.1	336.0	63	340.0	18.0	360.0
24	180.0	13.8	576.0	64	310.0	17.8	504.0
25	592.5	15.9	408.0	65	605.0	15.9	448.0
26	332.5	18.2	600.0	66	615.0	19.3	120.0
27	291.0	11.5	480.0	67	587.5	20.4	368.0
28	670.0	12.6	672.0	68	662.5	16.0	628.0
29	622.5	9.6	696.0	69	230.0	15.3	608.0
30	610.5	9.9	480.0	70	657.5	13.3	824.0
31	577.5	13.9	96.0	71	640.0	18.5	452.0
32	640.0	15.3	472.0	72	622.5	20.1	680.0
33	705.0	16.3	744.0	73	567.5	12.6	440.0
34	689.5	21.6	576.0	74	622.5	22.6	512.0
35	522.5	14.4	264.0				
36	587.5	24.2	888.0	Mean	482.9	17.9	378.57
37	157.5	17.7	144.0	SD	198.6	5.2	220.04
38	597.5	28.3	384.0	Range	105-792.5	8.8-31.3	24-888
39	332.5	13.9	468.0				
40	650.0	17.7	512.0				

Table 36. Available secondary nutrients status of microwatershed

Sample No.	Ca	Mg	S	Sample No.	Ca	Mg	S
	---cmol p(+) kg ⁻¹ ---		mg kg ⁻¹		---cmol p(+) kg ⁻¹ ---		mg kg ⁻¹
1	53.0	33.5	0.4	44	40.0	22.0	0.8
2	41.0	25.5	0.8	45	40.5	30.5	1.8
3	49.5	21.5	0.8	46	38.5	32.5	1.1
4	41.0	25.5	1.0	47	37.0	29.0	0.8
5	47.5	32.5	0.4	48	56.0	21.0	2.8
6	51.0	31.5	0.5	49	53.5	21.0	1.0
7	51.0	36.0	1.3	50	35.0	22.0	1.5
8	67.0	30.0	1.2	51	38.0	29.0	1.9
9	50.0	31.5	1.9	52	37.0	38.0	1.6
10	14.0	33.5	0.7	53	40.0	30.5	1.2
11	46.0	35.0	0.5	54	50.5	31.5	0.5
12	21.0	21.0	0.2	55	36.5	34.5	0.9
13	50.0	32.0	0.9	56	40.0	30.5	1.2
14	27.0	22.5	1.0	57	36.0	33.0	1.1
15	43.5	17.0	0.8	58	56.0	15.5	2.2
16	49.0	21.5	0.9	59	31.0	21.5	0.9
17	31.0	25.0	0.9	60	38.5	29.0	0.5
18	37.0	20.0	1.8	61	50.5	26.0	4.1
19	40.0	17.0	2.3	62	53.5	21.0	2.9
20	26.0	31.0	1.0	63	35.0	34.0	2.5
21	34.5	28.0	1.4	64	37.0	34.5	1.4
22	43.5	22.0	1.8	65	41.0	24.0	1.7
23	41.0	29.0	0.9	66	37.5	33.0	5.4
24	38.0	30.5	0.9	67	47.0	21.0	1.3
25	34.5	33.5	1.2	68	42.5	19.5	1.4
26	41.0	27.5	1.1	69	39.5	24.0	1.2
27	52.0	19.0	0.9	70	40.0	32.0	2.9
28	42.0	29.0	1.4	71	44.0	32.0	1.7
29	42.0	29.0	1.3	72	42.0	25.0	1.2
30	45.5	31.0	0.9	73	38.0	30.5	1.9
31	42.0	27.5	1.0	74	36.0	29.0	2.6
32	50.5	26.5	3.9				
33	30.5	39.0	1.2	Mean	40.6	27.1	1.5
34	23.0	13.5	1.9	SD	8.8	6.1	1.1
35	49.0	26.5	3.2	Range	14.0-67.0	9.5-41.0	0.2-7.7
36	35.5	28.0	1.9				
37	38.5	33.0	1.0				
38	30.5	41.0	7.7				
39	27.0	30.0	0.9				
40	49.5	9.5	1.7				
41	42.0	27.0	1.5				
42	45.5	24.5	1.0				
43	45.0	25.5	1.0				

Table 37. Available micronutrient status of microwatershed

Sample No.	Fe	Cu	Zn	Mn	Sample No.	Fe	Cu	Zn	Mn
	-----mg kg ⁻¹ -----					-----mg kg ⁻¹ -----			
1	41.34	8.22	0.57	46.83	39	28.94	11.24	1.31	34.96
2	43.04	10.14	0.60	46.13	40	24.90	12.36	1.57	49.71
3	38.95	6.79	0.56	40.72	41	25.04	15.53	1.24	41.96
4	21.39	20.19	0.52	30.56	42	40.54	12.03	1.18	44.67
5	24.52	10.51	2.35	38.95	43	21.15	8.67	0.65	41.76
6	39.70	13.30	1.22	45.75	44	42.39	17.10	1.54	41.53
7	18.17	14.13	0.34	26.63	45	24.55	11.11	0.92	42.69
8	18.05	15.20	0.52	20.39	46	29.31	10.28	1.48	45.13
9	0.62	1.74	0.62	9.80	47	32.09	8.13	0.95	37.63
10	10.83	6.63	0.79	2.74	48	29.42	6.33	0.81	46.54
11	73.48	26.64	1.86	58.02	49	24.39	6.96	1.18	37.13
12	33.04	7.32	0.65	47.97	50	25.62	6.69	8.25	25.70
13	28.65	11.56	1.52	56.67	51	18.91	17.98	1.57	25.81
14	32.47	11.49	1.73	37.30	52	16.56	12.07	1.68	20.64
15	22.79	4.75	0.31	22.05	53	26.95	9.65	0.34	34.94
16	29.49	16.79	1.39	46.09	54	42.09	11.05	1.30	43.13
17	54.16	14.82	1.30	47.53	55	41.44	32.39	0.75	44.65
18	61.99	20.38	2.27	49.78	56	36.87	12.77	1.27	52.64
19	31.58	12.14	0.34	38.78	57	29.99	10.85	0.56	42.09
20	23.40	12.35	0.32	26.50	58	25.41	8.82	0.72	40.98
21	22.21	9.22	0.25	15.07	59	21.73	7.92	0.91	33.44
22	21.10	12.13	1.54	49.67	60	58.95	14.19	1.92	56.88
23	18.01	8.57	0.92	9.13	61	50.28	8.55	0.11	43.40
24	21.47	10.42	1.11	30.01	62	14.68	5.90	1.08	32.43
25	40.38	10.84	1.40	36.86	63	25.14	4.96	1.25	47.96
26	42.39	11.41	1.39	47.63	64	20.70	6.66	1.77	51.60
27	36.02	12.18	1.85	39.86	65	19.57	11.63	1.38	21.81
28	38.93	11.41	1.58	41.17	66	20.35	9.02	0.92	22.80
29	35.55	10.71	1.30	46.96	67	18.28	11.62	3.56	14.46
30	18.78	5.89	1.65	52.76	68	18.55	13.93	1.30	22.88
31	23.64	6.86	1.57	25.36	69	20.75	12.25	1.69	17.22
32	26.75	6.50	1.14	40.47	70	14.55	9.97	0.97	24.09
33	11.86	14.48	0.99	13.55	71	20.67	12.14	1.82	27.72
34	26.49	9.65	2.73	44.21	72	26.17	19.75	1.29	29.96
35	15.91	7.61	3.19	37.95	73	25.54	10.63	0.50	44.40
36	15.56	10.04	1.05	8.85	74	28.89	12.81	1.92	33.84
37	27.87	14.62	1.29	48.83					
38	35.69	7.50	1.31	34.87	Mean	28.63	11.34	1.32	36.24
					SD	12.25	4.77	1.04	12.79
					Range	1.62-73.48	1.74-32.39	0.11-8.25	2.74-58.02

4.6.4 Available nitrogen (cf. Table 35)

Available N content varied from 105.0 kg ha⁻¹ to 792.5 kg ha⁻¹ with average of 486.84 kg ha⁻¹. The standard deviation was of 200.21 kg ha⁻¹ nitrogen. Out of 75 surface samples, 21.3 per cent was low, 22.6 per cent was medium and rest 59.1 per cent was recorded as being high in available nitrogen status.

4.6.5 Available phosphorus (cf. Table 35)

Available P₂O₅ varied from 8.8 kg ha⁻¹ to 31.3 kg ha⁻¹. The samples from low-lying area of watershed had low P content as compared to those of higher locations where red soils were observed. The average and standard deviation were 18.0 and 5.3 kg ha⁻¹ respectively. 65 per cent samples were low in available phosphorus and 35 per cent samples in medium range of P availability.

4.6.6 Available potassium (cf. Table 35)

The microwatershed was rich in available potassium. The available K ranged from 24 to 888 kg K₂O ha⁻¹ with an average of 378 kg K₂O ha⁻¹ and standard deviation was 219 kg K₂O ha⁻¹. Only 12 per cent samples were lying in lower range of K availability. 24 per cent were of medium K range and remaining 64 per cent samples were high in available potassium status.

4.6.7 Available sulphur (cf. Table 36)

Available S in soils (Table 36) ranged from 0.2 to 7.7 mg kg⁻¹. The mean was 5 mg kg⁻¹ with a standard deviation of 1.1 mg kg⁻¹ showing high spatial variation in available S. Available sulphur was higher in the low-lying area as compared to that of higher elevations.

4.6.8 Available micronutrients (cf. Table 37)

4.6.8.1 Available iron

Iron in Bastwad microwatershed soils ranged from 1.62 mg kg⁻¹ to 73.48 mg kg⁻¹. The average was 28.63 mg kg⁻¹ with a standard deviation of 12.25 mg kg⁻¹. Available Fe of entire watershed was above the critical limit (2.5 mg kg⁻¹).

4.6.8.2 Available manganese

Available manganese content of the study area ranged from 2.74 to 58.02 mg kg⁻¹. The mean and standard deviation were 36.24 mg kg⁻¹ and 12.79 mg kg⁻¹, respectively. Available Mn in the whole area was above the critical limit of 1.0 mg kg⁻¹.

4.6.8.3 Available copper

Available copper was in the range of 1.74-32.39 mg kg⁻¹ with mean and standard deviation of 11.34 mg kg⁻¹ and 4.77 mg kg⁻¹, respectively. The available Cu status of the microwatershed was above the critical limit of 0.2 mg kg⁻¹.

4.6.8.4 Available zinc

Available Zn of the study area ranged from 0.11 to 8.25 mg kg⁻¹. The average and standard deviation were 1.32 mg kg⁻¹ and 1.04 mg kg⁻¹, respectively. 17 per cent of the samples were below the critical range of Zn (0.6 mg kg⁻¹).

5. DISCUSSION

Rational utilization of our “finite” soil resources for sustained productivity needs information on nature and extent of distribution of different kinds of soils of an area, problems, potentials, capabilities and their suitability for various uses. All the above information could be available through systematic characterization and classification of soils of an area. In present study, ten profiles from Bastwad microwatershed of Belgaum district were selected for the investigation with objective to study their properties for characterization and classification according to the latest revisions of Soil Taxonomy. The pedons were examined for morphological features in the field and horizon samples were analyzed in laboratory for physical and chemical properties. Based on morphology, physical and chemical properties two soil series were identified in the study area. They were mapped as 10 soil mapping units (phases). Land evaluation was carried out utilizing FAO framework. Fertility status of the study area was assessed by analyzing soil samples from various locations in the area. The results obtained in the present study are discussed below.

SOIL CHARACTERIZATION, CLASSIFICATION AND MAPPING

5.1 MORPHOLOGICAL PROPERTIES

The soils of the study area were shallow, moderately deep to very deep. The depth of pedon 1, 2, 3 and 4 was comparatively less than that of lowland pedons (pedon 5–10). The depth of pedons indicated influence of topography on soil formation. Similar observations were also made by Maji *et al.* (2005) for analysing the landform and soil characteristics of Ringnabodi watershed of Nagpur district in sub-humid tropics of central India. There, with changing topographic position, the depth of soil changed from 33 to 140 cm and the coarse fragments decreased from 61 to 2 per cent.

The variation of depth in relation to physiography is mainly because of non-availability of adequate amount of water for prolonged period on upland soils associated with removal of finer particles and their deposition at lower plains. It has resulted in shallow soils in uplands and deeper soils in lowland physiographic units. The results obtained in the present study are in agreement with the findings of Ramprakash and Seshagiri Rao (2002).

Pedon 1 and 2 are eroded. In them the depth of C horizon is less as compared to other low-lying pedons. This was substantiated by the work of Gebrekidan and Mishra (2005) who reported that in soils in three toposequences of Amensis sub-catchment of Hirna watershed, the steep slopes were shallow whereas, they became deep along the topographic lows.

The varying degree of profile development between uplands and midlands is attributed to the removal and deposition of soil particles from different physiographic elements. These results are in conformity with the findings of Sharma and Gangwar (1997).

Soil colour was distributed according to altitudes of pedons. Pedons at higher positions were red 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. The pedons exhibited only two kinds of hue namely 5YR and 10 YR which correspond to red and black soils respectively. All the pedons (both red and black) were showing no change in hue along the depth. The above mentioned phenomenon could be attributed to rare vegetation on the upland positions leading to less organic carbon contents which eventually affects soil colour. The variation in colour is a function of chemical, organic and mineralogical composition, topographic position, textural makeup and moisture regimes of the soils. The results of the present study are in accordance with findings of Thangasamy *et al.* (2005) in Sivagiri microwatershed of Chittoor district in Andhra Pradesh. Colour value ranged from 3 to 5 in red soils and 2 to 3 in black soils. In black soils, chroma did not change along depth. This might be due to higher degree of pedoturbation, as *gilgais* were observed as a micro-relief on the black soil pedons. In pedon 1, weathered parent rock was observed just below the surface (0-30 cm) soil indicating very shallow soil depths owing to intensive erosion induced by slope.

The soil textures of the pedons at higher elevations (pedon 1–3) were sand to sandy clay loam while that of low-lying pedons (pedon 4–10) were ranging from clay loam, sandy clay and clay. This is attributed to deposition of finer fractions into low-lying lands from uplands. This indicates a close relationship between physiography and soil texture. These results are in conformity with the findings of Sharma *et al.* (1996) who reported that soils of in a toposequence over basaltic terrain of southern Rajasthan were loamy skeletal at higher elevations whereas, those of low-lying area were fine loamy.

The structure designates the mode of arrangement of the soil particles and their aggregates, therefore the structural variation in soils were useful to differentiate the horizon. The structure, in all the pedons under the study, varied from medium to fine, moderate to strong, granular in the surface horizon to fine, strong sub-angular blocky in deeper horizons. They were caused by higher clay content in deeper horizons and the pressure of over-lying horizons. Similar observations were also made by Singh and Agarwal (2003) in Entisols of Chandauli district in Uttar Pradesh

The consistency of all pedons varied from slightly hard to very hard, friable to extremely firm and non-sticky non-plastic to very sticky very plastic in dry, moist and wet ranges, respectively. Pedon 1 was gravelly so was non sticky and non plastic when wet as it is of highest elevation and is subjected to lower degree of weathering and soil formation. On moving from higher to lower topographic positions of pedons, consistency shifted towards very hard, very firm and very sticky very plastic conditions when dry, moist and wet, respectively. This might be due to increased clay content in deeper horizons along with decreasing altitude of pedons. Similar findings were also reported by Thangasamy *et al.* (2005) in black soils of in Sivagiri microwatershed of Chittoor district in Andhra Pradesh.

5.2 PHYSICAL PROPERTIES

Increase in clay content along with depth was observed in all the pedons. In upland pedon 2 and 5, the sub-surface horizons exhibited higher clay content as compared to surface horizons may be due to the addition of eroded materials from upslope and process of illuviation occurring during soil development. Similarly, illuviation process also affected the vertical distribution of silt and sand content. Similar observations were also made by Gabhane *et al.* (2006) in soils of microwatershed in Vidarbha region of Maharashtra. The clay content in pedons ranged from 7.5 to 74.2 per cent (Fig. 4).

The silt content ranged from 3.2 to 44.6 per cent in all the pedons. The silt content in low-lying pedons was decreasing towards depth. This could be referred to uniform weathering of the parent material (basalt) whereas pattern of vertical distribution of silt in upper pedons was exactly opposite to that of low-lying pedons. This might have happened due to non-uniform weathering of basalt owing to improper availability of water to support physico-chemical reactions. Some pedons (pedon 8, 9 10) showed irregular variations in silt contents in profile. This might be due to variation in weathering of parent material. These results are in agreement with the findings of Tripathi *et al.* (2009) in Banganala watershed of Kymore plateau and Satpura hills in Rewa district, Madhya Pradesh.

In pedons, sand fraction varied from 1.9 to 89.1. The surface horizons of pedons 1, 2 and 3 had higher portions of sand owing to erosive removal of finer soil fractions from soil which had been deposited in the low-lying pedons. Similar observations were also made by Gabhane *et al.*, (2006) in Vidarbha region of Maharashtra.

Water holding capacity of various pedons ranged from 16.57 to 64.88 per cent. These differences were due to the variation in clay and organic carbon content of the pedons. These results were reported by Ravikumar (2006) in soils of Malaprabha command of Karnataka and Thangasamy *et al.* (2005) in soils of Savagiri microwatershed in Chittoor district of Andhra Pradesh. The pedons exhibited less water holding capacity might be due to high sand and less clay content.

Bulk density of the pedon samples followed a common pattern of increasing with increasing depth. It was attributed to the pressure of the overlying horizons and diminishing amounts of organic matter. Similar results were quoted by Marathe *et al.* (2003) in mandarin orchards of Nagpur and in rice soils of Eastern region of Varanasi (Singh and Agrawal, 2005).

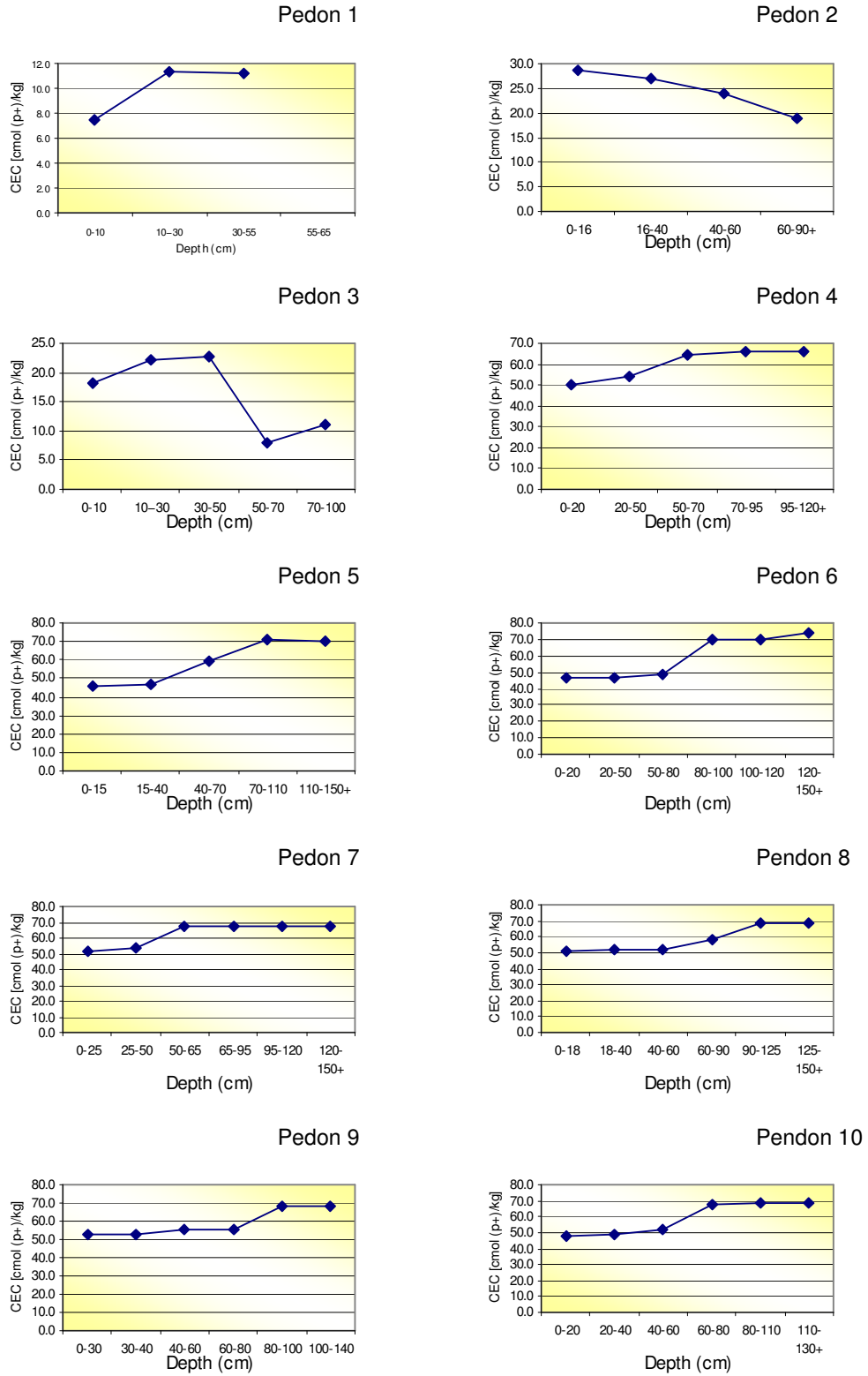


Fig. 4. Clay distribution in pedons

In addition, bulk density of red soils was higher than that of low-lying black soils. This was due to differences in texture and mineralogical constitution of the two types of soils (red soils were rich in heavy sand fraction while black soils were clays in texture). Ramprakash and Seshagiri Rao (2002) stated that the bulk density values of red soils were higher than black soils.

5.3 CHEMICAL PROPERTIES

In pedon 1, pH was 6.70-6.71. This might be due to leaching of bases from soils leaving behind acidic cations. Pedon 2 was calcareous in nature that is why an alkaline pH of 8.25 prevailed in the surface horizon. pH varied from 6.52 to 8.73 in pedons. The lower pH value in surface horizons is mainly due to leaching of bases owing to high rainfall whereas, in all the pedons C horizon 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).

Electrical conductivity of the pedons ranged from 0.05 to 0.45 dSm⁻¹. This indicates non-saline nature of the soils. Increased degree of electrical conductivity was measured in pedons (pedon 4–10) belonging to low-lying area of the microwatershed. This finding can be supported by the fact that salts from higher elevation might have washed down to these pedons rendering comparatively higher EC values. These results were similar to those of Sitanggang *et al.* (2006) in soils of Shikohpur watershed in Gurgaon district of Haryana. Conversely the pedons located at higher elevations were devoid of salts (thus low in EC) during the process of washing out. Pillai and Natarajan (2004) also reported similar low EC values indicating the non-saline nature of soils of Garakahalli watershed. EC also increased from upper to lower horizons within a pedon. This was attributed to accumulation of salts in the lower horizons caused by percolating rain-water.

Organic carbon content in all the pedons, tended to diminish while coming from higher to lower elevation. The distribution of organic carbon in these profiles is mainly associated with physiography and land use. These findings are in conformity with those of Walia *et al.* (1997). First, organic matter is driven by rain-waters down to the valleys enhancing their organic carbon status, secondly, elevated areas are first to drain and dry during non-raining months favouring thermal decomposition of organic matter during hot and dry days. These situations led to dearth of organic carbon in higher pedons and inverse was true for low-lying pedons.

The organic carbon content of surface soil was greater than sub-surface 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.

The exchangeable bases in all the pedons were in the order of Ca > Mg > K > Na on the exchange complex. From the distribution of Ca and Mg, it is evident that Ca shows the strongest relationship with all the species. Comparing these ions (Ca, Mg, K and Na), it was clear that Mg was present in low amount than Ca because of its higher mobility. These results are in conformity with findings of Sharma and Gangwar (1997). The low value of exchangeable monovalents, compared to divalents was due to preferential leaching of monovalents than divalents. In all the pedons, there was increase in exchangeable bases with depth owing to increasing clay content with depth.

Lowering of CEC was observed along the altitude of the pedons. This might be related to organic matter status and clay mineralogy of the pedons. Organic matter is inversely related to the altitude (height from mean sea-level) as explained earlier in 5.1.2.3. Since it is regarded as an independent factor of soil formation, topography plays very crucial role in determining clay mineralogical diversity of an area. Higher elevation pedons, namely 1 and 3 were expectedly dominated by kaolinite and other kinds of low activity clay. Low CEC in these pedons might be ascribed to this reason. In contrast to red soils on higher altitudes, black soils are located in low-lying valley area of the microwatershed.

Their formation and dominance of 2:1 type high activity clays (e.g. vermiculite, montmorillonite etc.) are expected. These clays might have been the logic for the high CEC of the pedons (pedon 4 to 10) (Fig. 5). Similar observations were made by Suresh Kumar *et al.* (2001) in soils developed on different geomorphic conditions which might be due to the clay content being significantly and positively correlated ($r=+0.40$) with CEC (Sharma and Anil Kumar, 2003).

Free CaCO_3 is an accumulation of precipitated calcium carbonate in the solum. This generally happens due to a negative precipitation-evapotranspiration (P-ET) balance and some geological properties (parent material). Pedon 2 had high percentage of free CaCO_3 throughout the depth. This could be due to excessively drained condition leading to desiccation and favouring CaCO_3 accumulation. Rest of the pedons were low-lying which recorded low amounts of free calcium carbonate owing to comparatively moist condition enough not to allow precipitation of free CaCO_3 in solum. Moisture status of soils and their altitude have previously been related and explained under 5.1.3.3.

5.4 CLASSIFICATION

Based on morphological characteristics of the pedons, physical, chemical characteristics of the soils and climate of the area, ten pedons from the study area were classified up to the family level according to the criteria laid down by the Soil Survey Staff (2006).

Upland pedon (pedon 1) was classified as Entisols at order level based on very low degree of soil formation and pedogenic horizon development. Among midland pedons, Cambic horizon was identified in pedon 2 at a depth of 16-60 cm and have the properties that do not meet the requirements for anthropic, histic, folistic, mollic, plaggen or umbric epipedon, a duripan or fragipan or argillic, calcic, gypsic, oxic, patrocalcic, petrogypsic, placic or spodic horizon and not part of Ap horizon. For all these properties pedon 2 qualified for the order Inceptisols. Pedon 3 belonged to the order Alfisols. The Bt horizon (10-50 cm) has a thickness of more than 7.5 cm and clay content increase of more than 8 per cent and presence of oriented clay bridging around sand grains and clay films on the ped surfaces. It does not have plaggen epipedon and have argillic epipedon with more than 35 per cent base saturation throughout the pedon. Hence the pedon qualifies for order Alfisols. Pedons 4, 5, 6, 7, 8, 9 and 10 were classified as Vertisols at order level as these pedons did not have lithic or paralithic contact within 50 cm of soil surface and had a weighted average of >30 per cent clay in all the horizons down to a depth of 1 m and possessed cracks that open and close periodically. These pedons have a layer of 25 cm or thicker, with an upper boundary within 100 cm of mineral soil surface that has slickensides with wedge-shaped peds.

The prevailing soil moisture regime is "Ustic". Based on this, Pedon 1, 2 and 3 were Ustorthents, Ustepts and Ustalfs, respectively. Similarly, remaining pedons (pedon 4 to 10) were Usterts at sub-order level.

Pedon 1 followed none of the criteria established for sub-orders in the order Entisols. So it was classified as Orthents. Pedon 2 did not have either duripan or calcic horizon and the base saturation was more than 60 per cent at a depth between 20 and 70 cm from the soil surface. These characters indicated that these pedons confirmed to the central concept of Ustepts. So, this pedon was grouped under Haplustepts at great group level. Similarly, the red soil pedon (pedon 3) was keyed out as Haplustalfs, as it did not have duripan, kandic and petro-calcic horizons. The pedons 4, 5, 6, 7, 8, 9 and 10 belonging to Vertisols were key out as Usterts at suborder level as they have cracks in normal year that are 5 mm or more wide through a thickness of 25 cm or more within 50 cm of mineral soil surface for 90 or more cumulative days per year. Whereas, pedon 8, 9, 10 and 11 key out as Haplusterts at great group level as they do not have salic, gypsic or calcic horizons.

Pedon 1 had a lithic contact at the depth of 55 cm and due to this it was classified as Lithic Ustorthents at sub-group level. At the sub-group level, pedon 2, 3 and pedon 4 to 10 do not exhibit inter-gradations with other taxa or an extra-gradation from the central concept, hence keyed out as Typic Haplustepts, Typic Haplustalfs and Typic Haplusterts respectively.

Classification of selected pedons at family level was made based on the (i) particle size class (ii) reaction class (iii) soil temperature class and (iv) cation exchange activity class.

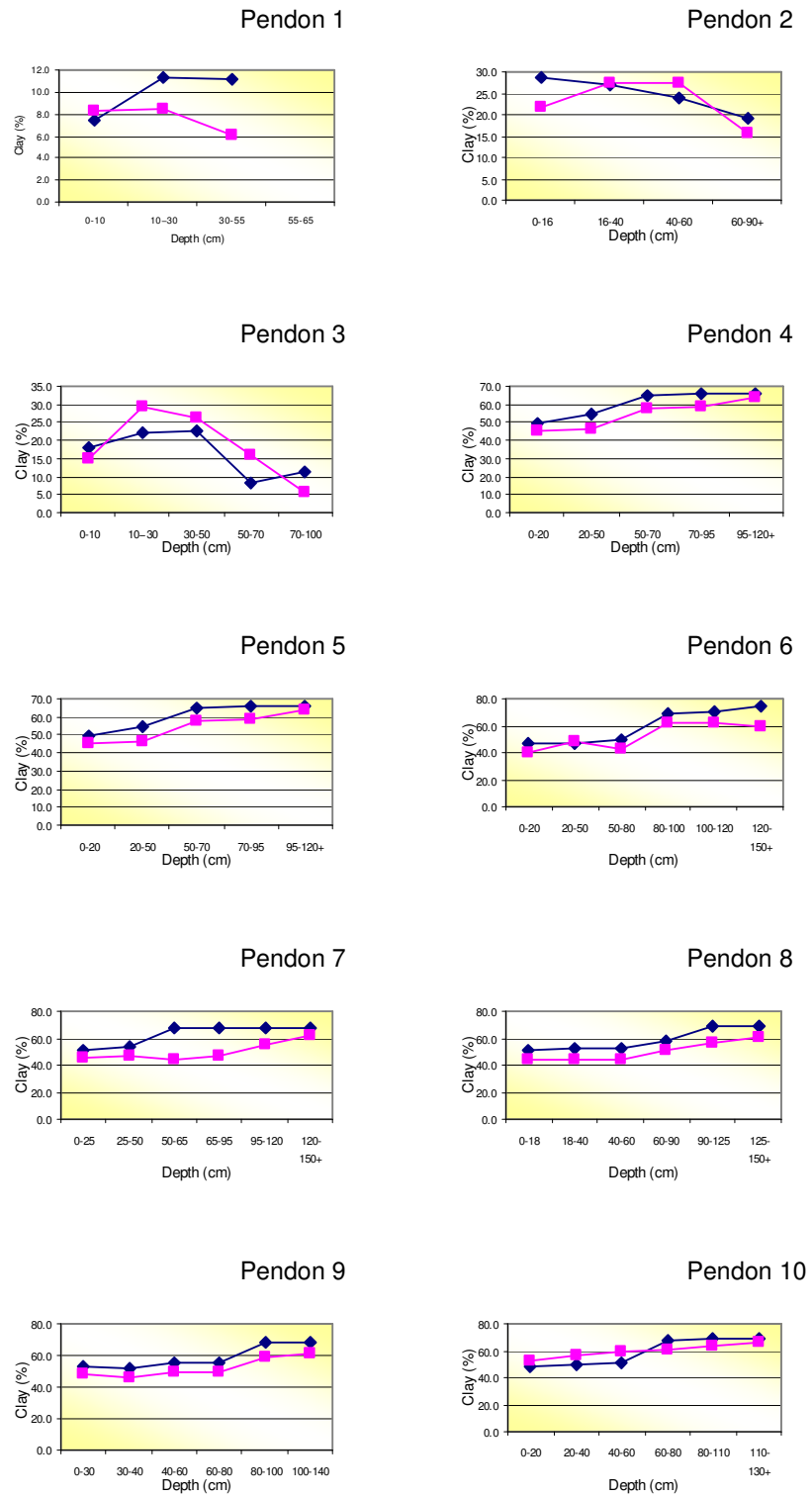


Fig. 5. Relationship between clay and CEC

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 differentiae appear in the family names.

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

Based on the criteria of above classes in their respective soil control section (Soil Survey Staff, 2006), the particle size class of pedons under study were very fine because of 60 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 6⁰C and mean annual temperature exceeds 22⁰C. The cation exchange activity class of pedons under study was super active, where CEC to clay content ratio exceeds 0.60 (Soil Survey Staff, 1999).

Pedon	Soil classification
Pedon 1	Hydrous skeletal, sandy, super active, isohyperthermic, Lithic Ustorthents
Pedon 2	Loamy, super active, calcareous, isohyperthermic, Typic Haplustepts
Pedon 3	Fine loamy, super active, isohyperthermic, Typic Haplustalfs
Pedon 4, 5, 6, 7, 8, 9, 10	Very fine, super active, isohyperthermic, Typic Haplusterts

The majority of the soils of Bastwad microwatershed are classified as Typic Haplusterts. Sahu *et al.* (2001) classified soils of Western Zone of Orissa in to 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 microwatershed (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.

5.5 SOIL MAP AND MAPPING UNITS

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 feature of the earth's surface.

Under the study area, five soil series (BSD 1 to 4 and HLG) were identified based on physiography and drainage and were mapped into 10 mapping units as different phases of soil series with the help of the software ArcGIS 9.5. The mapping legend is presented as e.g., BSD1-s-d4/D-e4, numerator represents the name of the series (e.g., BSD/HLG-Bastwad/Halaga) surface texture (s-sandy) and depth of the soil (d4 = 55 cm) and the dominator indicates slope (D = 8-15%) of the land and erosion status (e4 = very severe). The brief description and extent of soil series with phases is given in Table 9.

Maps of one or more soil future 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).

LAND EVALUATION

5.6 LAND CAPABILITY CLASSIFICATION (cf. Fig. 6)

Based on soil properties, the soils of Bastwad microwatershed have been classified into three land capability classes viz., III, IV and VII (Table 10). The upland pedon (pedon 1) was grouped under land capability sub-class VII_s. These soils had severe limitation of profile development characteristics therefore; they are not under cultivation at present. Whereas, midland pedons (pedon 2 and 3) were classified into IV_{sf} and IV_{tsf}, respectively, which is fairly good cultivable lands with severe limitations of texture and organic carbon content, hence application of organic manures and crop rotation with legumes can be followed in these soils. Among lowland pedons (pedon 4 to pedon 10), pedon 4, 6 and 7 were classified as III_ltsf, III_lsf and III_lsf respectively owing to the limitations of slope, drainage, erosion, texture and organic carbon in pedon 4 and that of texture and organic carbon in pedon 6 and 7. Pedon 5, 8, 9 and 10 were classified as IV_f, IV_{wf}, IV_w and IV_w, respectively. Pedon 5 had limitation of organic carbon status, pedon 8 exhibited limitation of drainage and organic carbon. Pedon 9 and 10 were with the limitation of drainage. With the improvement in drainage and soil fertility, the land capability of the low-lying area may be improved. Similar work was carried out by Tripathi *et al.* (2006) on four typical pedons representing major landforms of Kiar-Nagali microwatershed. The land capability classes ranged from II to VIII. The agricultural land belongs to class II and III. The lands had limitations of slope and texture.

5.7 SOIL- SITE SUITABILITY CLASSIFICATION FOR IRRIGATION (cf. Fig. 7)

The lands covered under mapping unit 1, 6, 9 and 10 were currently unsuitable for irrigation as the severe limitations of soil-depth (in pedon 1) and drainage (moderately well to poor in pedon 6, 9 and 10) were prominent in them. The mapping unit 2, 3, 4, 5, 7 and 8 were marginally suitable for irrigation due to moderate limitations of depth (90 to 100 cm), texture (clay) and ESP (>27 per cent). Rest of the land under remaining pedons was marginally suitable due to limitation imposed by heavy clay texture of lowland soils.

5.8 SOIL-SITE SUITABILITY FOR DIFFERENT CROPS

The performance of any crop is largely dependent on soil parameters (depth, drainage, texture *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.

Rice (cf. Fig. 8)

Soil texture and temperature are the crucial factors for the paddy cultivation. Mapping unit 1 was potentially unsuitable due to very severe limitations of slope (8-15%) and texture (gravelly sand) which were uncorrectable factors in crop production. Similarly, mapping unit 2 and 4 were currently unsuitable as they were severely limited by the factor of slope (3-8%). Rest of the lowland pedons was marginally suitable because of the moderate limitations imposed by mean seasonal temperature, slope, drainage and sodicity. Similar results were reported by Leelavathi (2007) in soils of Yerpedu Mandal of Chittoor district, Andhra Pradesh.

Wheat (cf. Fig. 9)

A well drained, medium texture soil and factors like drainage, lime content, temperature and relative humidity of the area play important role in wheat performance, therefore mapping unit 3 and 5 to 10 were moderately suitable for wheat. Mapping unit 2 and 4 were moderately limited by slope and it was marginally suitable. Tripathi *et al.* (2006) also reported similar results in landforms of Kiar-Nagali microwatershed.

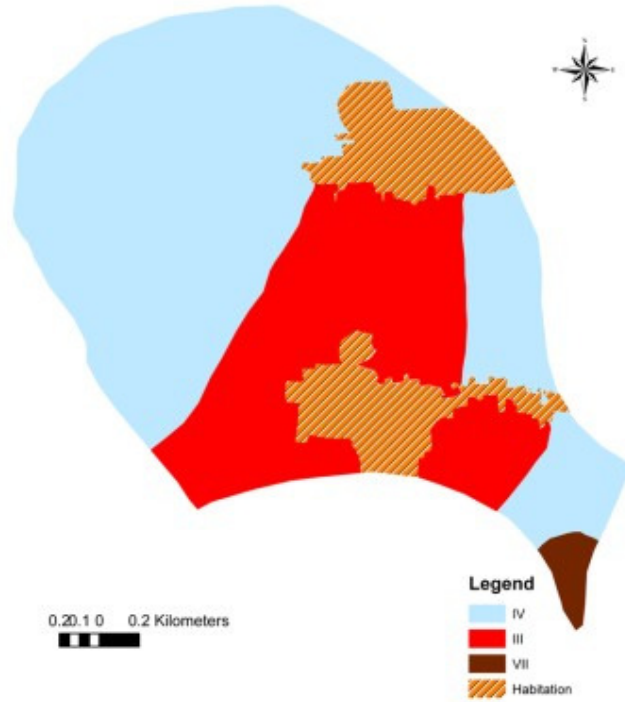


Fig. 6. Land capability classification for Bastward microwatershed
Fig. 6. Land capability classification for bastward microwatershed

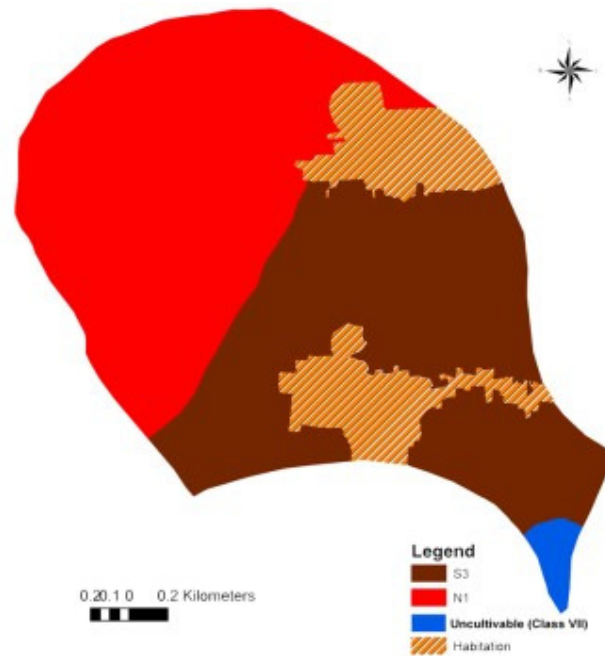


Fig. 7. Soil-site suitability map for irrigation
Fig. 7. Soil-site suitability map for irrigation

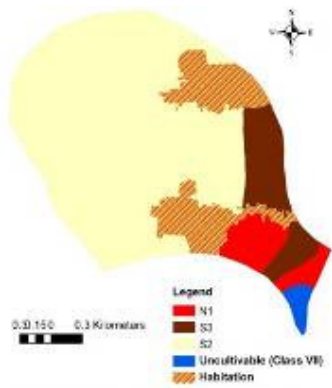


Fig. 8. Soil-site suitability map for rice

Fig.8. Soil-site suitability map for rice

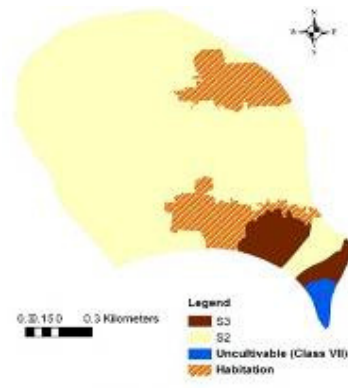


Fig. 9. Soil-site suitability map for wheat

Fig.9. Soil-site suitability map for wheat

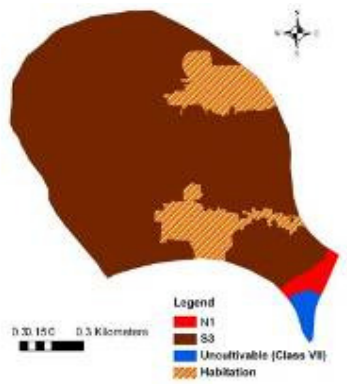


Fig. 10. Soil-site suitability map for maize

Fig.10. Soil-site suitability map for maize

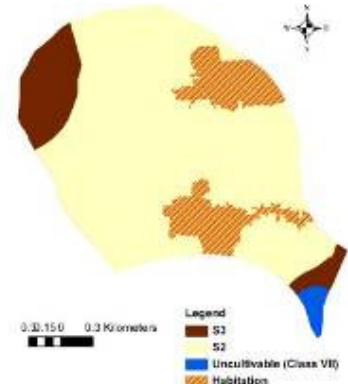


Fig. 11. Soil-site suitability map for sorghum

Fig.11. Soil-site suitability map for sorghum

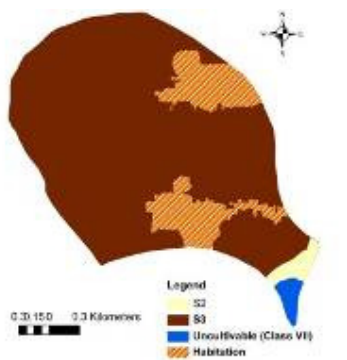


Fig. 12. Soil-site suitability map for pearl millet

Fig.12. Soil-site suitability map for pearl millet

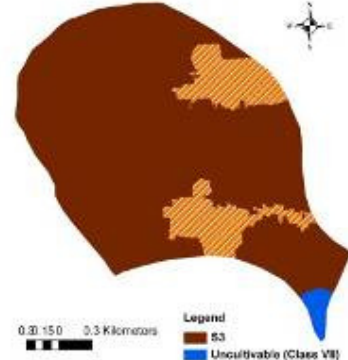


Fig. 13. Soil-site suitability map for bengal gram

Fig.13. Soil-site suitability map for bengal gram

Maize (cf. Fig. 10)

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%) and good drainage is required. Therefore, mapping unit 2 was currently unsuitable for maize production due to severe limitations of slope. Mapping unit 3 slightly limited by depth and slope. Rest of the pedons were marginally suitable owing to the moderate limitations of texture (fine clay), drainage. Similar results were reported by Tripathi *et al.* (2006) in a microwatershed of Kiar-Nagali.

Sorghum (cf. Fig. 11)

The factors that influence sorghum yields are soil depth, AWC, CEC, clay, exchangeable cations, slope *etc.* Mapping unit 2 and 10 were marginally suitable for sorghum cultivation as they had moderate limitations of mean seasonal temperature, and slope. Similar work was also carried out by Gabhane *et al.* (2006).

Pearl millet (cf. Fig. 12)

Rainfall, depth, texture and free CaCO₃ showed significant impact on yields of pearl millet (Van Wambeke and Rossiter, 1987). The soil depth of >75 cm, <10% CaCO₃ and clay texture were found to be favourable. Mapping unit 2 and 4 to 10 in the microwatershed exhibit moderate limitations of slope, calcareousness, texture and drainage for production of pearl millet. Thus they were marginally suitable. Mapping unit 3 was moderately suitable because it had slight limitations of climate, depth and slope.

Bengal gram (cf. Fig. 13)

Temperature, drainage, texture and rainfall are chief factors controlling bengal gram production. Mapping units 2 to 10 were marginally suitable for gram cultivation because they had moderate limitations of climate, slope, depth and drainage.

Pigeonpea (cf. Fig. 14)

Rainfall, temperature, slope, depth, AWC, texture and base saturation of soils significantly influence the yield of pigeonpea. The areas presented by Mapping unit 5, 6, 7, 8 and 9 were moderately suitable due to slight limitations of drainage and texture. Others were marginally suitable for pigeonpea cultivation because of moderate limitations of slope, drainage and depth. Similar work was also carried out by Gabhane *et al.* (2006) in Maharashtra.

Groundnut (cf. Fig. 15)

The factors that influence groundnut yield are rainfall, CaCO₃, drainage, temperature, texture, depth, slope, pH, CaCO₃ and CEC. The areas under mapping unit 10 were currently unsuitable for groundnut cultivation due to severe limitations of drainage. Remaining mapping units were marginally suitable because of the moderate limitations of slope and calcareousness (Mapping unit 2). Similar results were reported by Leelavathi (2007) in soils of Yerpedu Mandal of Chittoor district, Andhra Pradesh.

Soybean (cf. Fig. 16)

The factors that influence the soybean yields are soil depth, available moisture content, CEC, clay, exchangeable cations, slope *etc.* Land under mapping unit 2 was currently unsuitable due to severe limitations of slope. Lands under mapping unit 4 to 10 were marginally suitable owing to the moderate limitations of slope and drainage. Other mapping units were moderately suitable owing to their slope, texture and drainage. Similar works were reported by Wadodkar *et al.* (1996) in Vidarbha region.

Sunflower (cf. Fig. 17)

The factors influencing sunflower yield are rainfall, temperature, slope, BS, CaCO₃, CEC, depth *etc.* Land under mapping unit 10 was currently unsuitable due to limitation of drainage. Remaining land represented by other mapping units was marginally suitable for sunflower due to moderate limitations of slope, depth (in pedon 3), and texture.

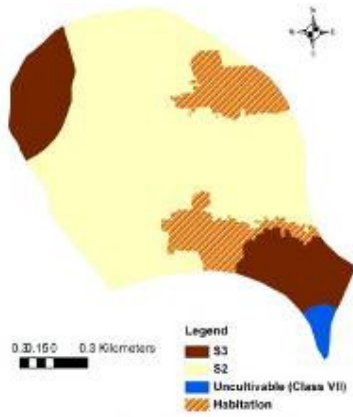


Fig. 14. Soil-site suitability map for pigeonpea

Fig.14. Soil-site suitability map for pigeonpea

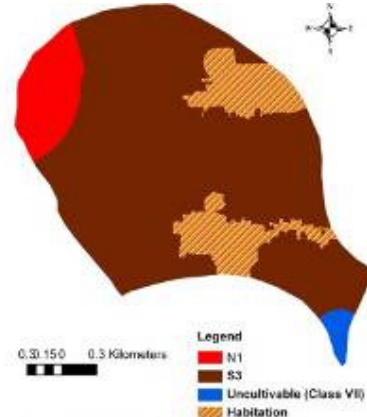


Fig. 15. Soil-site suitability map for groundnut

Fig.15. Soil-site suitability map for groundnut

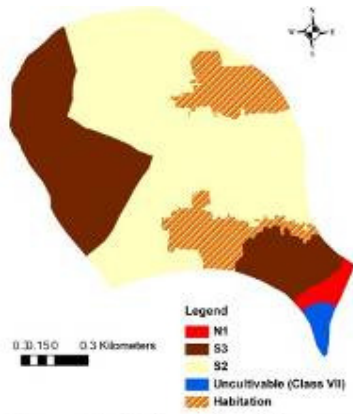


Fig. 16. Soil-site suitability map for soybean

Fig.16. Soil-site suitability map for soybean

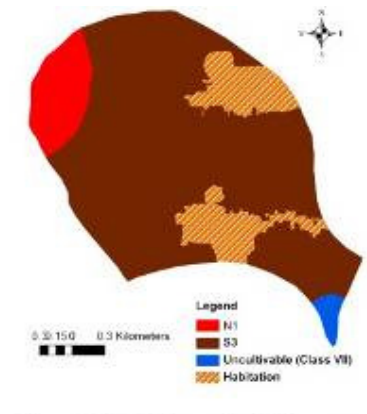


Fig. 17. Soil-site suitability map for sunflower

Fig.17. Soil-site suitability map for sunflower

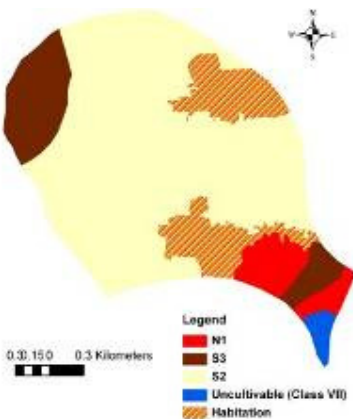


Fig. 18. Soil-site suitability map for cotton

Fig.18. Soil-site suitability map for cotton

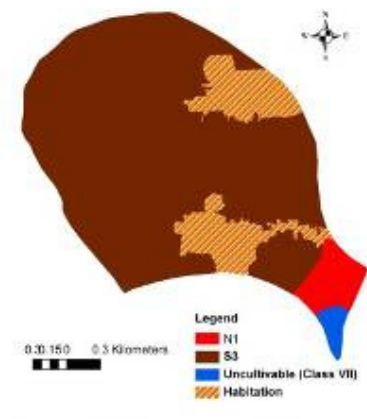


Fig. 19. Soil-site suitability map for sugarcane

Fig.19. Soil-site suitability map for Sugarcane

Cotton (cf. Fig. 18)

The yield-influencing factors on cotton in Vertisols are rainfall, soil depth and calcium carbonate. Lands under mapping unit 2 and 4 were currently unsuitable owing to severe limitations of slope and nutrient availability. Mapping unit 3 and 10 were marginally suitable owing to texture, slope and drainage. Other mapping units were moderately suitable due to slight limitations of nutrient availability. Similar work was also carried out by Gabhane *et al.* (2006).

Sugarcane (cf. Fig. 19)

The areas under mapping unit 2 and 3 were currently unsuitable (N1) due to severe limitations imposed by slope. Remaining land was marginally suitable due to moderate limitations of slope, texture, depth and drainage. Similar results were reported by Leelavathi (2007) in soils of Yerpedu Mandal of Chittoor district, Andhra Pradesh.

Cabbage (cf. Fig. 20)

Cabbage requires temperature and texture criteria for successful growth and development. Mapping unit 3 was moderately suitable (S2) due to slight limitations of slope, depth and climate. Mapping units 2 and 4 to 10 were marginally suitable with moderate limitations of slope, texture and drainage.

Chilli (cf. Fig. 21)

Rainfall, temperature, slope, depth, AWC, texture, sodicity and Base saturation of soils significantly influence the yield of chilli. The area under mapping unit 10 was currently unsuitable for chilli cultivation with severe limitations of drainage. Mapping units 2 to 9 were marginally suitable with moderate limitations of climate, drainage, texture, slope and nutrient availability.

Potato (cf. Fig. 22)

Slope, depth, texture and base saturation of soils significantly influence the potato yields. The lands under mapping unit mapping unit 2 was currently unsuitable for potato with severe limitation of slope. Mapping unit 4 to 10 was potentially unsuitable for potato cultivation with very severe limitation of texture (clay). Mapping unit 3 was marginally suitable with moderate limitations of slope.

Tomato (cf. Fig. 23)

Land under mapping units 2 to 10 were marginally suitable with moderate limitation of climate, slope, texture and drainage. The soils of Kiar-Nagali microwatershed were highly suitable for tomato cultivation as reported by Tripathi *et al.* (2006).

Mango (cf. Fig. 24)

Mapping unit 3 was potentially unsuitable for mango with very severe limitation of depth. Mapping units 5 to 9 were moderately suitable with slight limitations of climate, depth and texture. Other mapping units (2, 4 and 10) were marginally suitable with moderate limitations of slope, drainage, depth.

Guava (cf. Fig. 25)

All mapping units (2 to 10) were marginally suitable with moderate limitations of climate, slope, calcareousness (in mapping unit 2) and drainage.

Sapota (cf. Fig. 26)

Mapping unit 5 was moderately suitable with slight limitations of climate, drainage and texture. Others (2 to 4 and 6 to 10) were marginally suitable with moderate limitations of drainage (in 6 to 10), slope and depth.

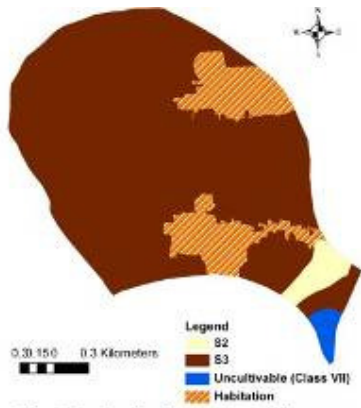


Fig. 20. Soil-site suitability map for cabbage

Fig.20. Soil-site suitability map for cabbage

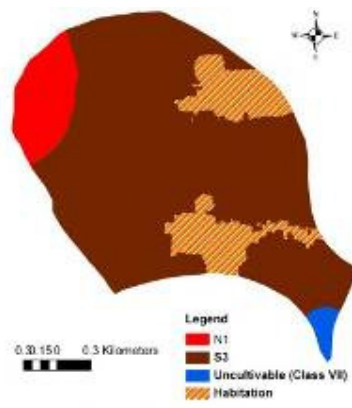


Fig. 21. Soil-site suitability map for chilli

Fig.21. Soil-site suitability map for chilli

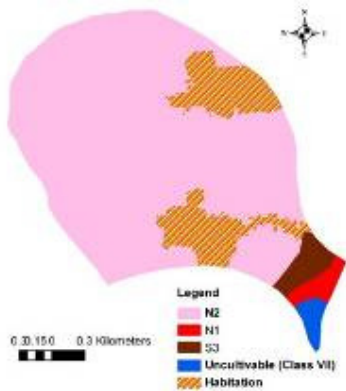


Fig. 22. Soil-site suitability map for potato

Fig.22. Soil-site suitability map for potato

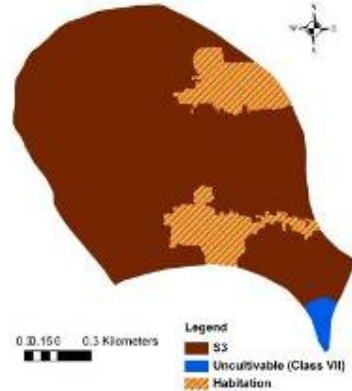


Fig. 23. Soil-site suitability map for tomato

Fig.23. Soil-site suitability map for tomato

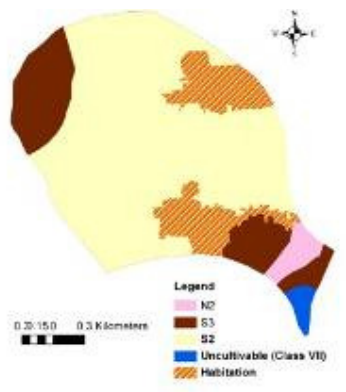


Fig. 24. Soil-site suitability map for mango

Fig.24. Soil-site suitability map for mango

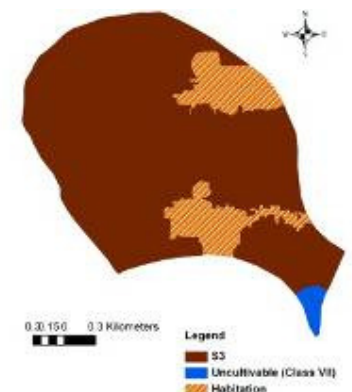


Fig. 25. Soil-site suitability map for guava

Fig.26. Soil-site suitability map for guava

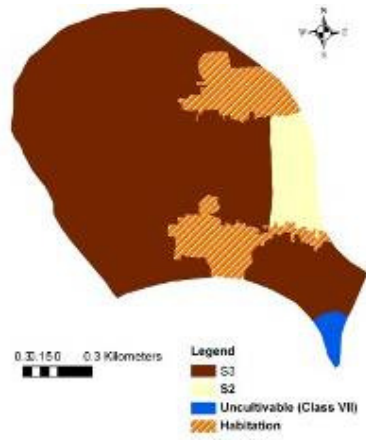


Fig. 26. Soil-site suitability map for sapota

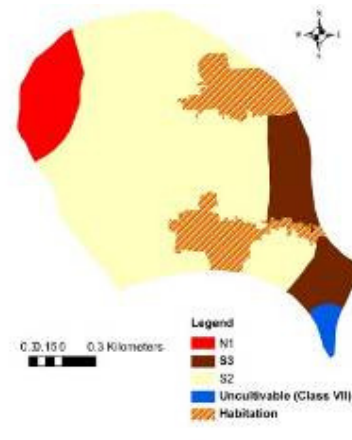


Fig. 27. Soil-site suitability map for coconut

Fig.26. Soil-site suitability map for sapota

Fig.27. Soil-site suitability map for acconut

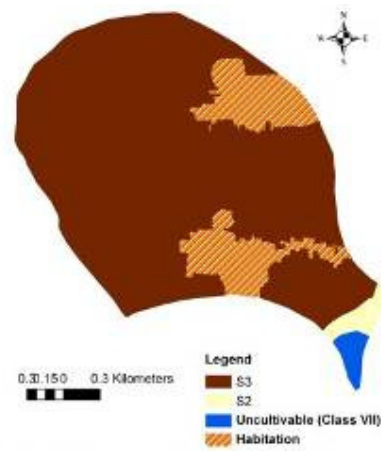


Fig. 28. Soil-site suitability map for rose

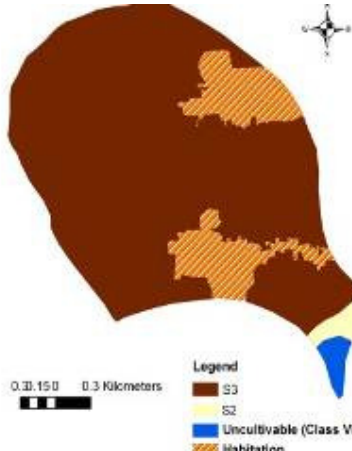


Fig. 29. Soil-site suitability map for jasmine

Fig.28. Soil-site suitability map for rose

Fig.29. Soil-site suitability map for jasmine

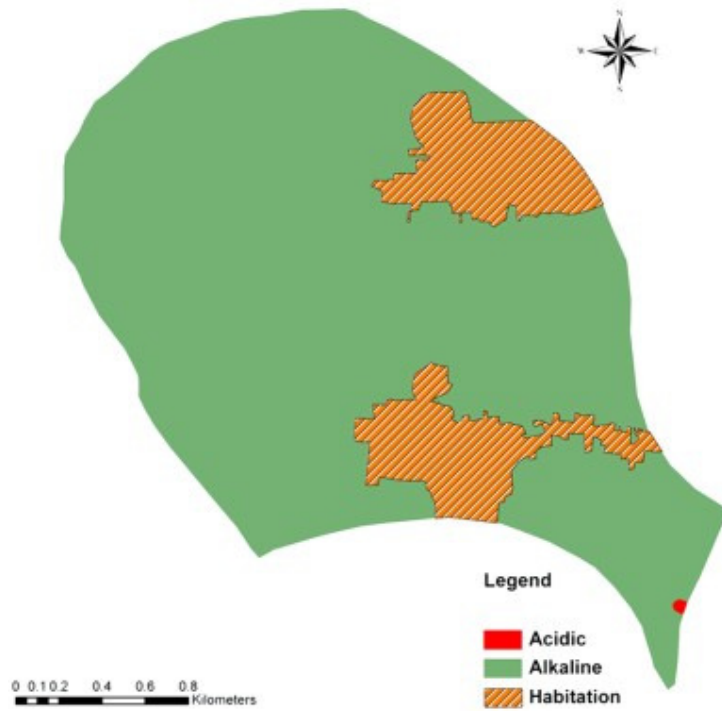


Fig. 30. Soil reaction (pH) status of Bastwad microwatershed

Fig.30. Soil reaction (pH) status of Bastwad microwatershed

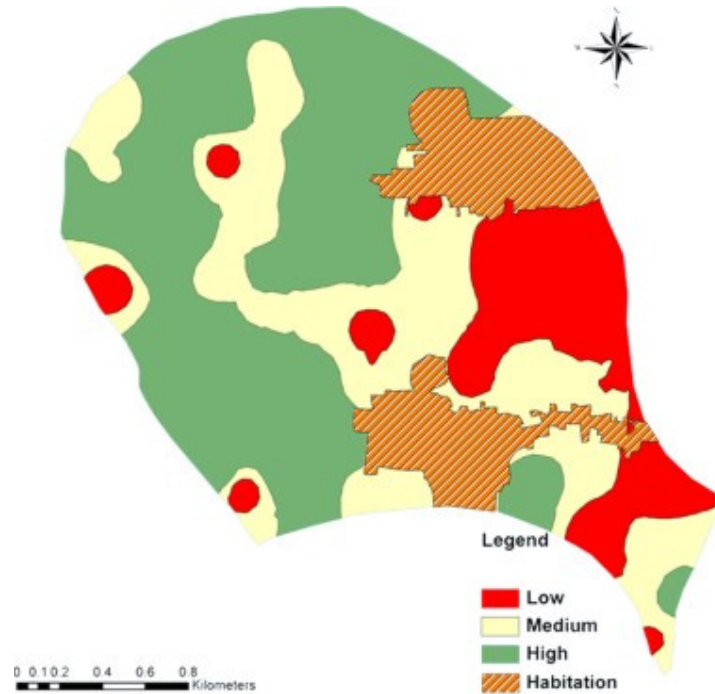


Fig. 31. Organic carbon status of Bastwad microwatershed

Fig.31. Organic carbon status of Bastwad microwatershed

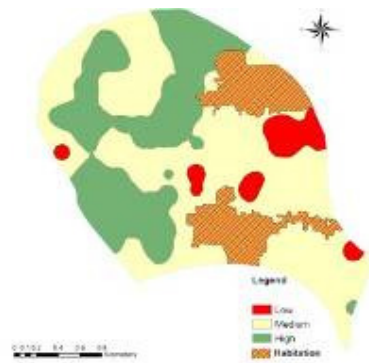


Fig. 32. Available N status of Bastwad Microwatershed

Fig.32. Available N status of Bastwad Microwatershed

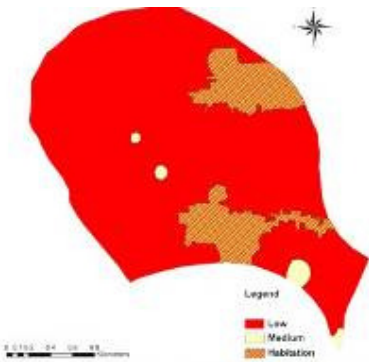


Fig. 33. Available P status of Bastwad microwatershed

Fig.33. Available P status of Bastwad Microwatershed

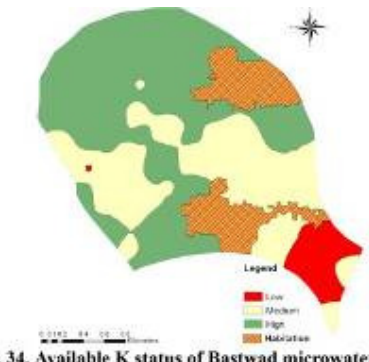


Fig. 34. Available K status of Bastwad microwatershed

Fig.34. Available K status of Bastwad Microwatershed

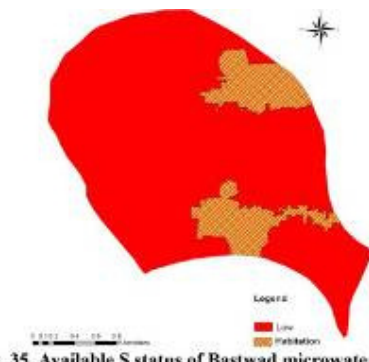


Fig. 35. Available S status of Bastwad microwatershed

Fig.35. Available S status of Bastwad microwatershed

Coconut (cf. Fig. 27)

The land belonging to mapping unit 10 was currently unsuitable with severe limitation of drainage. Mapping units 2, 3 and 5 were marginally suitable for coconut with moderate limitations of climate, depth and texture. Other mapping units (4, 6, 7, 8 and 10) were moderately suitable with slight limitations of climate, depth and texture.

Rose (cf. Fig. 28)

Mapping unit 2 was moderately suitable with slight limitations of slope and depth. Other mapping units (3 to 10) were marginally suitable with moderate limitations of texture, depth and drainage.

Jasmine (cf. Fig. 29)

Mapping unit 3 was moderately suitable owing to slight limitations of climate, slope and depth. Mapping unit 2 and 4 to 10 were marginally suitable with moderate limitations of slope, texture and drainage.

5.9 FERTILITY STATUS OF SOILS

pH and EC values of soils were ranging from 6.22 to 8.42 and 0.20 to 1.03 dSm⁻¹, respectively (Fig. 30). The probable reasons about their statuses have earlier been discussed in sections 5.1.3.1 and 5.1.3.2 respectively.

The organic carbon content of surface samples ranged from 0.13 to 1.15 g kg⁻¹ with majority with low organic carbon content (Fig. 31). The reason for low organic carbon content in these soils might be attributed to the prevalence of tropical condition, where the degradation of organic matter occurs at a faster rate coupled with little or no addition of organic manures and low vegetative cover on the fields, thereby leaving less chances of accumulation of organic carbon in the soils. Similar observations were also made by Nayak *et al.* (2002) in soils of Central Research Station OUAT, Bhubaneswar.

The available nitrogen in the study area ranged from 105.0 to 792.5 kg ha⁻¹ (Fig. 32). Major portion of the nitrogen pool is contributed by organic matter. The low available nitrogen content in this area is due to faster degradation and consequent removal of organic matter coupled with lesser nitrogen fertilization leading to nitrogen deficiency. The results obtained in the present study are in agreement with the findings of Govindarajan and Biswas (1968).

In the study area, available phosphorus varies from 8.8 kg ha⁻¹ to 31.3 kg ha⁻¹ (Fig. 33). This might be due to dominance of 2:1 type of clays in soils which have a net negative charge on their surfaces but P is adsorbed as PO₄⁻³ which requires a net positive charge to be adsorbed on clays. Also, the low-lying soils were poor in sesquioxides which could otherwise retain enough PO₄⁻³. In contrast to low-lying soil samples (black soil), samples from higher altitudes (red soil) had high P content owing to dominance of low activity clays (e.g. kaolinite) and higher amounts of sesquioxides.

The available K content was medium to high in status because of dominance of 2:1 type clay minerals in low-lying area with high K retention capacities (Fig. 34). Samples belonging to higher locations had coarse texture that was dominated with sand and silt size minerals with almost nil K retention.

Available S in soils ranged from 0.2 to 7.7 mg kg⁻¹ (Fig. 35). Sulphur also, like P, followed the pattern of organic carbon as organic carbon is the sole source of sulphur in soils. Black soils were comparatively better in organic carbon status so were they in available S status. Conversely, red soils were poor in organic carbon; they exhibited low available S status. Thus topography also influences available S status of soils. In addition, low status of sulphur can be attributed to low EC of soils. Similarly, Sharma and Gangwar (1997) noticed negative correlation between total sulphur and electrical conductivity.

The micronutrient status of the microwatershed was high, since no micronutrient except Zn (in few samples) was below the prescribed nutrient-specific critical limit (Fig. 36-39). The soils with higher free CaCO₃ (of the area belonging to Pedon 2) were comparatively low (not deficient) in available micronutrients which might be due to precipitation of Fe²⁺ by CaCO₃ soil and decrease the availability. Similar results were also observed by Ravikumar (2006) in Malaprabha command area of Karnataka.

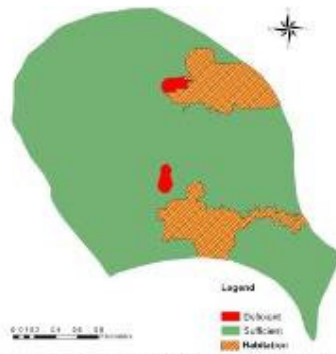


Fig. 39. Available Zn status of Bastwad microwatershed

Fig.39. Available Zn status of Bastwad Microwatershed

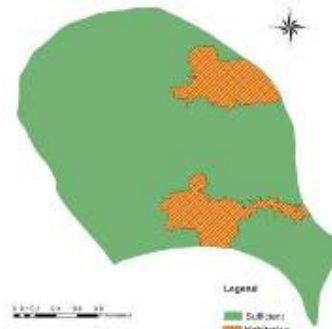


Fig. 37. Available Mn status of Bastwad microwatershed

Fig.37. Available Mn status of Bastwad microwatershed

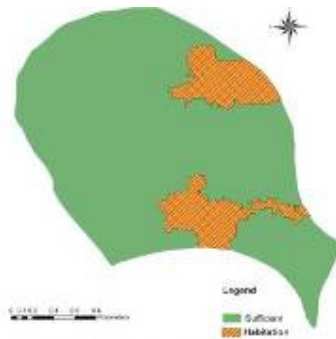


Fig. 38 . Available Cu status of Bastwad microwatershed

Fig.38. Available Cu status Bastwad microwatershed

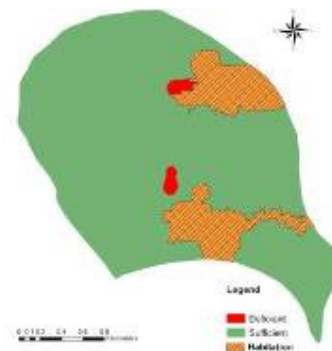


Fig. 39. Available Zn status of Bastwad microwatershed

Fig.39. Available Zn status of Bastwad microwatershed

Table 38. Crops under different suitability classes

Mapping units	S1	S2	S3	N1	N2
BSD1-s-d4/D-e4	UNCULTIVABLE LAND (CLASS VII) (7.96 ha)				
BSD2-scl-d3/D-e4	-	Pearl millet, Rose, Jasmine	Wheat, Maize, Sorghum, Bengal gram, Pigeonpea, Groundnut, Sunflower, Cabbage, Chilli, Tomato, Mango, Guava, Sapota, Coconut	Rice, Maize, Soybean, Cotton, Sugarcane, Potato	-
BSD3-scl-d3/C-e3	-	Wheat, Sorghum, Cabbage	Rice, Maize, Pearl millet, Bengal gram, Pigeonpea, Groundnut, Soybean, Sunflower, Cotton, Chilli, Potato, Tomato, Guava, Sapota, Coconut, Rose, Jasmine	Sugarcane	Mango
BSD4-c-d1/C-e2	-	Sorghum, Coconut	Wheat, Maize, Pearl millet, Bengal gram, Pigeonpea, Groundnut, Soybean, Sunflower, Sugarcane, Cabbage, Chilli, Tomato, Mango, Guava, Sapota, Rose, Jasmine	Rice, Cotton	Potato
BSD4-c-d1/B-e1	-	Sorghum, Pigeonpea, Soybean, Cotton, Mango, Sapota	Rice, Maize, Pearl millet, Bengal gram, Groundnut, Sunflower, Sugarcane, Cabbage, Chilli, Tomato, Guava, Coconut, Rose, Jasmine	-	Potato
BSD4-c-d1/A-e1	-	Rice, Wheat, Sorghum, Pigeonpea, Soybean, Cotton, Mango, Coconut	Maize, Pearl millet, Bengal gram, Groundnut, Sunflower, Sugarcane, Cabbage, Chilli, Tomato, Guava, Sapota, Rose, Jasmine	-	Potato
HLG-c-d1/B-e2	-	Rice, Wheat, Sorghum, Pigeonpea, Soybean, Cotton, Mango, Coconut	Maize, Pearl millet, Bengal gram, Groundnut, Sunflower, Sugarcane, Cabbage, Chilli, Tomato, Guava, Sapota, Rose, Jasmine	-	Potato
HLG-c-d1/B-e1	-	Rice, Wheat, Sorghum, Pigeonpea, Soybean, Cotton, Mango, Coconut	Maize, Pearl millet, Bengal gram, Groundnut, Sunflower, Sugarcane, Cabbage, Chilli, Tomato, Guava, Sapota, Rose, Jasmine	-	Potato
HLG-c-d1/A-e1	-	Rice, Wheat, Sorghum, Pigeonpea, Cotton, Mango	Maize, Pearl millet, Bengal gram, Groundnut, Soybean, Sunflower, Sugarcane, Cabbage, Chilli, Tomato, Guava, Sapota, Rose, Jasmine	-	Potato
HLG-c-d1/A-e0	-	Rice, Wheat	Maize, Sorghum, Pearl millet, Bengal gram, Pigeonpea, Groundnut, Soybean, Cotton, Sugarcane, Cabbage, Chilli, Tomato, Mango, Guava, Sapota, Rose, Jasmine	Groundnut, Sunflower, Chilli, Coconut	Potato

Table 39. Area of crops under each suitability class for Bastwad microwatershed

Crops	Land area (cultivable) under suitability classes in ha (%)				
	S1	S2	S3	N1	N2
Rice	-	359.59 (79.8)	50.19 (11.1)	33.00 (7.3)	-
Wheat	-	418.54 (92.9)	33.00 (7.3)	-	-
Maize	-	-	440.87 (97.8)	9.87 (2.2)	-
Sorghum	-	396.48 (88.0)	54.26 (12.0)	-	-
Pearl millet	-	9.87 (2.2)	440.87 (97.8)	-	-
Bengal gram	-	-	442.78 (98.2)	-	-
Pigeonpea	-	350.98 (77.9)	91.80 (20.4)	-	-
Groundnut	-	-	398.39 (88.4)	44.39 (9.8)	-
Soybean	-	279.18 (61.9)	153.73 (34.1)	9.87 (2.2)	-
Sunflower	-	-	398.39 (88.4)	44.39 (9.8)	-
Cotton	-	350.98 (77.9)	58.81 (13.0)	33.00 (7.3)	-
Sugarcane	-	-	418.50 (92.8)	24.28 (5.4)	-
Cabbage	-	428.37 (95.0)	14.48 (3.2)	-	-
Chilli	-	-	398.39 (88.4)	44.39 (9.8)	-
Potato	-	-	14.41 (3.2)	9.87 (2.2)	418.50 (92.8)
Tomato	-	-	492.78 (109.3)	-	-
Mango	-	350.91 (77.9)	77.39 (17.2)	-	14.41 (3.2)
Guava	-	-	442.76 (98.2)	-	-
Sapota	-	357.78 (79.4)	407.00 (90.3)	-	-
Coconut	-	315.20 (69.9)	60.00 (13.3)	44.39 (9.8)	-
Rose	-	9.87 (2.2)	432.91 (96.0)	-	-
Jasmine	-	9.87 (2.2)	432.91 (96.0)	-	-

Total area of Bastwad microwatershed is 450.74 ha.

Values in parentheses indicate percentage of total area of the microwatershed

6. SUMMARY AND CONCLUSION

A study was undertaken to characterize and classify the soils of a microwatershed in Agro-climatic zone 8 of Karnataka in order to assess their land capability, soil-site suitability for irrigation and suitability for various crops.

Ten soil profiles representing the study area were selected based on the topography from various physiographic units identified in the area by field survey. The soils were described in the field for their morphological properties and later characterized in the laboratory for their physical and chemical properties and classified up to family level for the microwatershed. Soil-site suitability for some important crops was also evaluated for the microwatershed. In between profiles, seventy four surface samples (0-30 cm) were drawn from the field and were analyzed for fertility status. The findings of all the investigations are summarized below.

Depth of the soils ranged from shallow to deep, the solum thickness increased from upper to the lower slopes in the study area. The colour of the soils varied from dark reddish brown to reddish gray in upland pedon, this was found to be influenced mainly by the degree of weathering of the parent material, erosion hazard low organic matter content, warmer temperature regime and high rainfall existing in the area. The colour varied from dark grayish brown to very dark grayish brown in lowlands. This might be influenced by the topography and impeded drainage in the sub-surface layers.

The texture of soils was found to vary from extremely gravelly sand to clay. The texture of lowland physiographic units was finer than upland and midlands mainly due to lateral movement of finer fractions from uplands and midlands. Presence of argillic horizon was noticed in midland pedon (pedon 3) due to downward translocation of clay and its deposition in the sub-surface horizons, whereas; slickensides were very prominent in lowland pedons (pedon 4-10).

The common structure was granular in surface horizons, whereas, sub-surface horizons exhibited sub-angular blocky structure.

Soil reaction of upland soils was slightly acidic to neutral which is attributed to occurrence of leaching of bases from the soil along with runoff and drainage water due to high rainfall and slopes existing in the area. In lowlands, the soil reaction was neutral to slightly alkaline due to deposition of bases from the upper physiographic units. The electrical conductivity of all the pedons was negligible, which indicates non-saline nature of soil and good leaching.

The organic carbon content in all the pedons varied between low to medium due to low vegetative cover. Soil erosion and warmer climate lead to low accumulation of organic carbon in the study area.

The cation exchange capacity of the soil varied from low to moderate. The upland physiographic units were low in cation exchange capacity values than midlands and lowlands owing to their low clay content, low organic matter, predominance of sesquioxides and 1:1 type of clay minerals, whereas lowlands exhibited moderate CEC values due to higher clay content and predominance of 2:1 type clayminerals.

In all the pedons, calcium was most dominant cation followed by magnesium throughout the profile. The upland and midland pedons have low exchangeable cations than lowland counterparts, because of excessive drainage from uplands. The base saturation was found to be between medium (uplands) to high (lowlands) in the study area due to variation in the texture and physiography.

Majority of the area was low to medium in available nitrogen. The low available nitrogen content is attributed to the low organic carbon due to warmer climate and low vegetative cover coupled with little nitrogen fertilization. Available P ranged from low to medium in amounts. The microwatershed was rich in available potassium only hill-top positions were deficient due to intensive weathering and run-off of K along with waters. Entire area was low in available sulphur status owing to low EC of soils.

Based on morphological, physical, and meteorological data, the soils of Bastwad microwatershed were classified up to family level as follows.

Pedon	Soil classification
Pedon 1	Hydrous skeletal, sandy, super active, isohyperthermic, Lithic Ustorthents
Pedon 2	Loamy, super active, calcareous, isohyperthermic, Typic Haplustepts
Pedon 3	Fine loamy, super active, isohyperthermic, Typic Haplustalfs
Pedon 4, 5, 6, 7, 8, 9, 10	Very fine, super active, isohyperthermic, Typic Haplusterts

Five soil series have been identified and mapped in to 10 mapping units. These mapping units were evaluated for their land capability based on the inherent soil characteristics, external land features and environmental factors. There are eight land capability subclasses in the study area, viz. III_{sf}, III_{twsf}, IV_{sf}, IV_{tsf}, IV_w, IV_{vf}, IV_{wf} and VII_s.

The site characteristics of the mapping units of the study area (Cultivable land) were matched with the soil-site suitability requirements of important crops like rice, wheat, maize, sorghum, pearl millet, chickpea, pigeonpea, soybean, groundnut, sunflower, cotton, sugarcane, chilli, cabbage, potato, tomato, mango, guava, sapota, coconut, rose and jasmine for their suitability evaluation. The mapping units on midlands were moderately to marginally suitable for majority of the crops because of limitations of drainage and slope. Hence they require mechanical measures to bring the soil under desirable suitability class. The mapping units on lowlands were also marginally suitable for all the crops except coconut, sapota, sorghum, pigeonpea and rice due to limitations of drainage and sodicity. In essence, of all the mapping units, some were unsuitable for crops just because of the permanent limitations of climate (mean seasonal temperature), soil-depth and heavy clay texture of the soils.

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Appendix I : Soil-site characteristics of pedons (weighted averages)

Pedon No.	pH	EC (dSm ⁻¹)	OC (g/kg)	CaCO ₃ (g/kg)	CEC (cmol kg ⁻¹)	BS (%)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	BD (Mg m ⁻³)	MWHC (%)	FC (%)
Pedon 1	6.70	0.11	2.2	10.4	18.33	39.3	70.0	89.1	3.4	7.5	1.53	16.57	8.29
Pedon 2	8.15	0.25	3.0	127.4	22.57	74.4	24.7	59.1	14.6	26.3	1.47	46.78	23.39
Pedon 3	6.80	0.10	4.4	1.8	39.28	85.4	27.8	59.3	19.1	21.6	1.45	45.73	22.87
Pedon 4	8.03	0.16	6.1	6.7	44.90	90.4	4.4	13.0	34.6	52.4	1.24	50.27	25.14
Pedon 5	7.50	0.16	6.7	5.9	42.87	87.3	7.9	9.1	38.1	52.9	1.37	51.98	25.99
Pedon 6	8.03	0.10	6.0	5.7	40.66	83.8	10.4	9.6	43.6	46.8	1.27	47.98	23.99
Pedon 7	8.25	0.24	4.2	7.1	41.70	88.1	4.0	8.1	39.6	52.4	1.26	50.32	25.16
Pedon 8	7.85	0.15	5.7	7.4	42.07	85.1	8.8	4.7	43.5	51.8	1.29	52.24	26.12
Pedon 9	7.91	0.33	5.9	5.3	42.92	83.6	4.7	4.5	41.8	53.8	1.31	55.06	27.53
Pedon 10	7.49	0.14	8.3	4.5	45.86	85.6	10.3	8.9	41.4	49.7	1.27	47.86	23.93

Appendix II: Soil site suitability criteria (crop requirements) for rice

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	30-34	35-38 21-29	39-40 15-20	>40 <15
	Total rainfall	mm	1110-1250	900-1110	750-900	<750
Land quality	Land characteristics					
Oxygen availability to roots	Soil drainage	Class	Imperfectly drained	Moderately well drained	Well drained; somewhat excessively drained	Excessively drained
	Free from flooding (duration)	Months	>4	3-4	2-3	
	Depth of water	cm	<10	10-20	>20-40	>40
Nutrient availability	Texture	Class	c, sic, cl, sicl, sc	scl, sil, l	sl, ls	s
	pH	1:2.5	5.5-6.5	6.4-7.5 4.5-5.4	7.6-8.5	>8.5 <4.5
	CaCO ₃ in root zone	%	<15	15 to 25	25 to 30	>30
Rooting conditions	Effective soil depth	cm	>75	51 to 75	25 to 50	<25
Soil toxicity	Salinity (EC saturation extract)	dS/m	<3	3 to 6	6 to 10	>10
	Sodicity (ESP)	%	<15	15 to 40	40 to 50	>50
Erosion hazard	Slope	%	0 to 1	1-3	3-5	>5

Flooding is considered for rainfed rice; Source; NBSS and LUP (1990)

Note: s-sand; ls-loamy sand; sl-sandy loam; scl-sandy clay loam; cl-clay loam; sil-silt loam; l-loam; sic-silty clay; sc-sandy clay; c-clay

Appendix III: 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					
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
	Stoniness	%	<15	15-35	>35	
Soil toxicity	Salinity (EC saturation extract)	dS/m	<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

C+ = Clay (45-60%), c++=Clay>60%

Appendix IV: 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	750-90	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	>20	15-20	10-15	
	OC	%	High	Medium	Low	
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Stoniness	%	Non gravely	15-35	35-50	>50
Soil toxicity	Salinity (EC saturation extract)	dS/m	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	

C(n-s)=Non swelling clay soils; C(ss)=Shrink-swell clay soils

Appendix V: 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 >9.0
	pH	1:2.5	6.0-8.0	5.5-5.9 8.1-8.5	<5.5 8.6-9.0	
	CEC	C mol (p+)/kg	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
	Stoniness	%	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	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: NBSS and LUP (1994)

Appendix VI: 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	%				
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	<1.0	1.0-2.0	2.0-4.0	
	Sodicity (ESP)	%	<15	15-20	20-35	
Erosion hazard	Slope	%	<3	3-5	5-10	>10

SS-Shrink-swell

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

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	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	l, sil, cl, scl	Sic, sicl, c	Sl, c>60%	
	pH	1:2.5	6.0-7.5	7.6-8.0; 5.5-5.7	8.1-9.0; 4.5-5.4	>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	<1.0	1.0-2.0	>2.0	
	Sodicity (ESP)	%	<10	10-15	>15	
Erosion hazard	Slope	%	<3	3-5	5-10	

Appendix VIII: 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	<1.0	1.0-2.0	>2.0	
	Sodicity (ESP)	%	<10	10-15	>15	
Erosion hazard	Slope	%	<3	3-5	5-10	

Source: NBSS and LUP (1994)

Appendix IX: 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	
	Texture-subsurface		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; 5.5-5.9	>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	<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: NBSS and LUP (1994)

Appendix X: 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	<1.0	1-2	2 to 4	>4
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	<3	3.5	5-8	>8

Source: NBSS and LUP (1994)

Appendix XI: 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; 4.5-5.4	>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	<1.0	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 (2002)

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

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	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	>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
	Stonnes	%	<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	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: NBSS and LUP (1994)

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

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	26-29 35-38	25-20 39-40	<20 >40	
	Mean min. temp. in growing season	°C	10-20	21-30	9-5	<5	
	Mean RH in	Growing season		70-85	60-70/85-90	60-50/>90	<50
		Ripening stage		55-76	75-90	<55/>90	-
Land quality	Land characteristics						
Oxygen availability to roots	Soil drainage	Class	Well drained	Mod./ imperfectly drained	Poorly drained	V. poorly/ excessively drained	
	Depth of water	M	>1.0	1.0-0.5	<0.5		
Nutrient availability	Texture	Class	l, cl, sil, sicl, sc, scl	C(m/k), sl	c+(ss)		
	pH	1:2.5	7.0-8.0	6.0-6.9 8.1-9.0	4.0-5.9/ 9.1-9.5	<4.0/>9.5	
	CEC	C mol (p+)/kg	>20	10-20	10-50	<5	
Rooting conditions	Effective soil depth	cm	>100	100-75	75-50	<50	
	Stonnes	%	<15	15-35	35-50	>50	
Soil toxicity	Salinity (EC saturation extract)	dS/m	<2.0	2.0-4.0	4.0-9.0	>9	
	Sodicity (ESP)	%	<10	10-15	15-25	>25	
Erosion hazard	Slope	%	<3	3-5	5-8	>8	

Clay (m/k) = mixed/kaolinitic; Clay(ss) = Shrink-swell clays
Source: Naidu (1999)

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

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	15-25	26-30	31-35 10.14	>35 <10
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	ls, sic, sicl, sc, c(m/k)	c (ss)	s
	pH	1:2.5	6.0-7.5	5.0-5.9; 7.6-8.5	<5; >8.5	
	CEC	C mol (P+)/kg	>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	
	Coarse fragments	%	<15	15-35	>35	
Soil toxicity	Salinity (EC saturation extract)	dS/m	Non-saline	Slight	Strongly	
	Sodicity (ESP)	%	Non-sodic	Slight	Strongly	
Erosion hazard	Slope	%	1-3	3-5	5-10	>10

Appendix XV: 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; 5.0-5.9	>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	Non saline	1-2	2-4	<4
	Sodicity (ESP)	%	Non sodic	5-10	10-15	
Erosion hazard	Slope	%	<3	3-5	5-10	

Mineralogy: C(m/k) = clayey (mixed/kaolinitic); C(ss) = Shrink-swell clay

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

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	16-25	26-30 13-15	31-32 10-12	>35 <10
Land quality	Land characteristics					
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately/imperfectly	Poorly drained	Very poorly drained
Nutrient availability	Texture-surface	Class	sl, l, ls	s, scl	sil, cl	Heavy c
	Sub-surface texture	Class	scl, sil	s, sil	s	Heavy c
	pH	1:2.5	5.5-6.5	6.6-8.2 5.0-5.4	>8.5 <5.0	
	CEC	C mol (p+)/kg	>16	<16	<5	
	OC	%	High	Medium	Low	
Rooting conditions	Effective soil depth	cm	75-100	50-75	25-50	<25
	Stonnes	%	0-10	10-15	15-35	>35
Soil toxicity	Salinity (EC saturation extract)	dS/m	>15	<16		
	Sodicity (ESP)	%	Non Sodic	10-15	>15	
Erosion hazard	Slope	Hills %	<5	5-10	10-15	>15
		Plains %	<3	3-5	5-8	>8

Source: Reddy and Shivaprasad (1999)

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

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	25-28	29-32 20-24	15-19 33-36	<15 >36
	Total rainfall	mm	600-750	500-600 750-1000	400-500 >1000	
	Rainfall in growing season	mm	>150	120-150	90-120	
Land quality	Land characteristics					
Moisture availability	Length of growing period	Days	>150	10-150	90-120	
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderate	Imperfect	Poor
Nutrient availability	Texture	Class	l, sl, cl, scl,	sic, sicl, sc, c(m/k)	c(ss)	ls, s
	pH	1:2.5	6.0-7.0	5.0-5.9; 7.1-8.5	<5; >8.5	
	CEC	C mol (P+)/kg	>15	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	15-35	>35
Soil toxicity	Salinity (EC saturation extract)	dS/m	Non-saline	Slight	Strongly	
	Sodicity (ESP)	%	Non-sodic	Slight	Strongly	
Erosion hazard	Slope	%	1-3	3-5	5-10	>10

Appendix XVIII: 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	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	

Note: Clay (m/k) = Mixed/kaolinitic; Clay (s) = Swell-shrink; ESP-Exchangeable sodium percent

Appendix XIX: 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	<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

Protective irrigations are desirable in drought years; Clay (m/k) = mixed kaolinitic; Clay (s) = Sell-shrink; Clay (<60) soils with clay content less than 60 per cent, clay (>60%) soils with more than 60% clay

Appendix XX: Soil site suitability criteria (crop requirements) for sapota

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 18-23	>42 <18
Land quality	Land characteristics					
Moisture availability	Length of growing period	Days	>150	120-150	90-120	<120
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately well drained	Imperfectly drained	Poorly drained
Nutrient availability	Texture	Class	scl, l, sil, cl	sl, sc, sicl, c(m/k)	c (s>60)	ls, s, c (s>60)
	pH	1:2.5	6.0-7.5	7.6-8.0 5.0-5.9	8.1-9.0 4.5-4.9	>9.0 <4.5
	Available nutrient status (NPK)	Fertility rating class	High	Medium	Low	
Rooting conditions	Effective soil depth	cm	>150	75-150	50-75	<50
	Presence of gravel	%	Non gravelly	<15	15-35	<35
Soil toxicity	Salinity (EC saturation extract)	dS/m	Non saline	Upto 1.0	1.0-2.0	2.0-4.0
	Sodicity (ESP)	%	Non sodic	10-15	15-25	>25
Erosion hazard	Slope	%	<3	3-5	5-10	

Protective irrigations in drought period is desirable; clay (m/k) = mixed/kaolinitic; clay(s) = swell-shrink; clay (<60) soils with clay content less than 60 per cent, clay (>60%) soils with more than 60% clay

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

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	26-29	23-25 30-32	20-22 33-34	
	Total rainfall	mm	1500-2500	1000-150	500-1000	<500
	Dry months (months with <50 mm rainfall)	Months	>3	4-5	6-7	-
Land quality	Land characteristics					
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately well drained	Imperfectly drained, excessively drained	Poorly drained
	Depth of water table	m	2-3	1 to 2	0.5 to 1	
Nutrient availability	Texture	Class	cl, scl, sc, sicl, sil	sl, c (non-swelling), sic	c (swelling), ls, s	
	pH	1:2.5	5.1-6.5	6.6-7.5; 4.5-5.0	7.6-8.5; 4.0-4.4	-
Rooting conditions	Effective soil depth	cm	>100	75-100	50-75	<50
	Coarse fragments	Vol %	<15	15 to 35	35 to 50	>50
Erosion hazard	Slope	%	<8	8 to 15	15 to 30	

Source: Naidu *et al.* (1997)

Appendix XXII: 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	>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	Non-saline	Slight	Strongly	
	Sodicity (ESP)	%	Non-sodic	Slight	Strongly	
Erosion hazard	Slope	%	1-5	5-10	10-20	>20

Appendix XXIII: 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	>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	Non-saline	Slight	Strongly	
	Sodicity (ESP)	%	Non-sodic	Slight	Strongly	
Erosion hazard	Slope	%	1-3	3-5	5-10	>10

CHARACTERIZATION AND CLASSIFICATION OF SOILS OF A MICROWATERSHED ON BASALT PARENT ROCK IN NORTHERN TRANSITION ZONE OF KARNATAKA

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ABSTRACT

A study was undertaken to characterize and classify soils of a microwatershed in northern transition zone of Karnataka to assess land capability and soil-site suitability for irrigation and crops with special objective to study fertility constraints by GIS techniques.

The microwatershed has topographic variations with slope ranging from 1 to 15%. Ten pedons representing the microwatershed were characterized, classified and assessed for land capability and suitability for crops. Soils were shallow to deep, dark reddish brown to very dark greyish brown, granular to sub-angular blocky in structure, excessive to poorly drained, slightly acidic to slightly alkaline (pH, 6.22- 8.42), non-saline (EC, 0.20-1.03 dS m⁻¹), low to high in organic carbon (1.3 -11.5 g kg⁻¹) and low to moderate in CEC (5.12-66.31 cmol (p+) kg⁻¹) with wide textural variations (extremely gravelly sand to clay) with depth. Argillic horizon and slickensides were prevalent in pedons of red and black soils, respectively. According to Soil Taxonomy, out of ten pedons, three were Lithic Ustorthents, Typic Haplustepts and Typic Haplustalfs while others were Typic Haplusterts at sub-group level. Five soil series were identified and mapped into ten mapping units which were evaluated for land capability, irrigability and soil-site suitability for crops. Land capability subclasses in the study area were III, IV and VII with limitations of texture, drainage, fertility and topography. Land irrigability classes were currently unsuitable to marginally suitable with limitations of topography and texture. No land was highly suitable for crops. Majority of the crops were moderately to marginally suitable and few were currently and potentially unsuitable.

Assessment of soil fertility status revealed that, major area was high in organic carbon and available nitrogen. Available P ranged from low to medium in status. The microwatershed was rich in available potassium except hill-tops. Entire area was high in Cu, Fe and Mn but low in available S and Zn.