EVALUATION AND CHARACTERISATION OF TUNGI WATERSHED OF BY USING REMOTE SENSING AND GIS TECHNIQUES.

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B.Sc. (Agri.)

DISSERTATION

SUBMITTED TO THE
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2015

CANDIDATE'S DECLARATION

I HEREBY DECLARE THAT THE DISSERTATION

OR PART THEREOF, HAS NOT BEEN

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ANY UNIVERSITY

PLACE: LATUR

DATE : REG. NO.: 2013A/42ML

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This is to certify that the dissertation entitled **"EVALUATION AND CHARACTERISATION OF TUNGI WATERSHED BY USING REMOTE SENSING AND GIS TECHNIQUES"** submitted by **MAHADEV TUKARAM SAYAMBAR** to the Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (Agriculture)** in the subject of **SOIL SCIENCE AND AGRICULTURAL CHEMISTRY** is a record of original and bonafide research work carried out by him under my guidance and supervision. It is of sufficiently high standard to warrant its presentation for the award of the said degree.

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Place : **Latur**

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This is to certify that the dissertation entitled **"EVALUATION AND CHARACTERISATION OF TUNGI WATERSHED BY USING REMOTE SENSING AND GIS TECHNIQUES"** submitted by **MAHADEV TUKARAM SAYAMBAR** to the Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (Agriculture)** in the subject of **SOIL SCIENCE AND AGRICULTURAL CHEMISTRY** has been approved by the student's advisory committee after viva-voce examination in collaboration with the external examiner.

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PLACE: LATUR

DATE: 30/05/2015.

(SAYAMBAR M. T.)

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Abrriviations

%	Per cent
<	Less than
>	Greater than
^0C	Degree celcious
BSP	Base saturation percentage
CEC	Cation exchange capacity
Cm	Centimeter (s)
Cmol $(P^+)kg^{-1}$	Centi mol per kilogram
dSm^{-1}	decisimen per meter
DTPA	Diethyline Triamine Penta Acetic acid
E	East
et al.	et alia *(and others)*
Fig	Figure
Ha	Hectare
i.e.	that is
Kg ha^{-1}	Kilogram per hectare
M	Meter
me l^{-1}	milli equivalent per liter
mg kg^{-1}	milligram per kilogram
Mg m^{-3}	mega gram per meter(s)
Mm	Milli meter(s)
mm hos/cm	mili mohs per centimeter
$mmol^{-1}$	Milli mol per liter
MSL	Mean sea level
N	North
NBSS and LUP	National Bureau of Soil Survey and Land Use Planning
NIV	Nutrient index value
Pp	pages
USDA	United State Department of Agriculture

Introduction

CHAPTER-I

INTRODUCTION

Land resources particularly soil; water and vegetation are the most important natural resources, which are interdependent that one cannot be managed efficiently without the other two. Sustainable utilization of these resources involves potential and limitations of these available resources. Watershed has been recognized as a hydrological unit for better management and rational utilization of the land and water resources for optimum and sustained production with minimum hazards to natural management.

The pressure on land in our country is constantly surmounting due to the rapidly increasing needs for providing food, fiber and fuel to the fast growing population and demand for urban development, industries etc. Owing to the limited scope for exploitation of the hitherto unused land for agriculture, there is an imperative need for conservation of soil and land resources. Precise scientific information on characteristics, potential, limitations and management need of different soil is therefore, indispensable for planned development of these resources. To maintain present level of soil productivity and to meet the demand of future, management of natural resources on scientific principles is very important. Therefore, increased emphasis is being laid on characterization of soil, their evaluation and accurate mapping using remote sensing and geographical information system.

The importance of soil survey and mapping for preparing an inventory of a region, the soil properties are used for evaluation of soil for different crop. The value of soil resource inventory for increasing food production and conservation of natural resources has been receiving significant importance not only for soil resource database generated but also for its quality (Eswaran and Gathrie, 1982).

Various systems of land evaluation are in vogue viz. storie index, requier index. The parametric approach method developed by Sys (1985) and FAO (1976) framework are good methods for land evaluation. The FAO (1976) framework provides a set of principles from which land evaluation can in established to suit local condition. The USDA capability classification, land suitability classification are used to evaluate the soil for different crops and optimal use of available natural resources.

Satellite remote sensing has emerged as powerful and efficient tools for mapping and monitoring of natural resources of earth surface environment. The synoptic coverage, multispectral and multi-temporal sensing capabilities offered by space borne sensor are well suited to inventorying natural resources. Several workers have utilized this technology for soil mapping on different terrain condition at different scales. (Shrivastava and Saxèna 2004; Velmurugan *et al.* (2009) and on watershed basis. (Solanke *et al.* 2005; Shukla *et al.* 2009; Kashiwar *et al.* 2009 and Patil *et.al.* 2010).

A geographical information system (GIS) has become efficient inevitable platform for mapping evaluation, monitoring and management of natural resources (Burrough 1986, and Maji *et al.* 1998). It is designed for storing, querying, analyzing as well as displaying spatial and non-spatially referenced data.

Precise scientific information on characteristics, potential, limitations and management needs of different soils is indispensable for planned development of these resources to maintain the present level of soil productivity and to meet the demands of the future. Soil resource inventory provides an insight into the potentialities and limitations of soils for its efficient use. It also provides adequate information in terms of landform, terrain, vegetation as well as characteristics of soils, which can be utilized for land resources management and development (Manchanda *et al.* 2002). Rational utilization of land resources can be achieved by optimizing its use, which demands evaluation of land for alternative land use, ensuring its judicious use. Tungi watershed in Ausa tehsil in Latur district of Marathwada region of Maharashtra were selected for this study, as it has wide variety of soils. The catchment area of the watershed is an undulating terrain; it is quite likely that the land is subjected to different degrees of erosion resulting in varied depth of soil. The suitability of soils and economic viability are the two important aspects, which can guide the farmers in proper site selection and management of different sets of crops. The yield potential and quality also differ from place to place. Hence, in depth study with regards to climate and soil site suitability, land capability, land irritability and land productivity evaluation for commonly grown crops in this watershed is essential in order to guide the farmers in proper site selection, and obtaining the sustainable potential yield and easy to understand production potential. With this view the present investigation were carried out with following objectives.

Objective:

1. To interpret the satellite remote sensing data for preparation of the physiographic and land use/land cover map of the study area.
2. To characterize and classify the soils occurring on different physiographic unit of the Tungi watershed.
3. To evaluate the land resource for preparation of land capability, land irrigability, Soil site suitability, and productivity maps by using GIS technique.
4. To suggest the suitable action plan for land resource management of the study area.

Review of Literature

Chapter II

REVIEW OF LITERATURE

A brief review of the literature related to the present investigation has been grouped under following heads.

2.1 Land Use/ Land Cover Mapping

2.2 Physiography/Soil mapping

2.3 Soil-Site Characteristics

2.3.1 Soil characteristics

2.3.2 Morphological properties

2.3.3 Physical properties

2.3.4 Chemical properties

2.4 Land Evaluation

2.4.1 Land Capability

2.4.2 Land Irrigability

2.4.3 Soil Productivity

2.4.4 Soil-site Suitability

2.1 Land use/land cover

Saxena *et al.* (2000) used FCC of IRS-1B LISS-II and IRS-1C LISS-III at 1:50,000 scale to prepare land use/land cover map of Gondkhairi watershed in Kalmeshwar tehsil of Nagpur district, Maharashtra. They have mapped land use/land cover as single crop (28.8% of TGA), double crop (14.3%), scrubland (43.1%), degraded notified/open forest (7.2%), rock outcrop (3.8%) and water bodies (2.8%).

Lingade (2001) used IRS-1C LISS-III PAN merged data to prepare the land use/land cover map of Mangli village, Nagpur district of Maharashtra state. He has identified land use/land cover classes as agricultural land (single crop and double crop, orchard, fallow land), scrubland and wasteland, habitation, streams/nala and roads.

Srivastava *et al.* (2001) visually interpreted IRS-1C PAN merged LISS-III data to derive information on land use/ land cover of Junewani village of Nagpur district in Maharashtra for village level agricultural resource planning. They have reported that nearly 68 per cent area of the village is under agriculture, 13 per cent under forest, 14 per cent under wasteland and the remaining 5 per cent under miscellaneous category (habitation, road and streams).

Gawande *et al.* (2001) prepared land use/land cover map of Kamthi area, Nagpur district, Maharashtra using IRS LISS-III, FCC of bands 2, 3 and 4 (1:250,000) and reported that major part of the area was covered by agricultural land followed by built up and waste land.

Bodhankar *et al.* (2002) studied the land use/land cover of Devadkasha watershed of Nagpur district, Maharashtra based on data of two seasons (*kharif*and *rabi*) of IRS-1C LISS-III (1:50,000 scale) and reported that agriculture land occupied nearly 33 per cent area of watershed whereas, forest, scrub/wastelands occupied 43 and 22 per cent, respectively and the remaining 2 per cent under water body and habitation.

Potdar *et al.* (2003) prepared land use/land cover map on 1:50,000 scale using IRS-1C LISS-III data of two seasons (March 2000 and November 2000) of Nanda-Khairi watershed of Nagpur district, Maharashtra. They identified and mapped three categories of agriculture land as single crop, double crop, and fallow land and three categories of forest land *viz.* moderately dense, thin and degraded and two categories of wastelands (with scrub and without scrub).

Durbude and Venkatesh (2004) prepared land use/land cover map on 1:50,000 scale for Hire watershed in Koppal district of Karnataka using IRS-1C LISS-III in conjunction with SOI toposheet. They categorized land use/land cover in five classes *viz.* agriculture, built-up land, scrub land, waste land and water body.

Solanke *et al.* (2005) characterized the land resources of Ganeshpur micro-watershed near Nagpur; Maharashtra using IRS-1C PAN merged LISS-III data of March 2002 and December 2002 in conjunction with Survey of India toposheet. They classified land use/land cover in eight classes'*viz.* agricultural land (single and double crop), notified forest (moderately dense and degraded forest), wastelands (with scrub and without scrub), and habitation and water body.

Shamsudheen *et al.* (2005) used IRS-1D LISS-III data to prepare land use/land cover map of Kumta tehsil of Uttar Kannada district of Karnataka. Their study indicated that majority of the land was under agriculture (groundnut, paddy, pulses, sugarcane and plantation crop), wasteland, forest plantation, forest, degraded forest and water bodies.

Shetty *et al.* (2005) prepared land use/land cover map of Yennehole river basin of Karnataka state using IRS-1C and IRS-1D LISS-III data on 1:50,000 scale. They delineated land use/land cover units as rock outcrop, fallow, rubber, casuarina, coconut, areca nut, building, road, water, paddy, barren land and forest.

Martin and Saha (2007) mapped land use/land cover in Ason river watershed, a part of Doon valley of Dehradun district of Uttarakhand and delineated the area under forest, forest with dense bamboo and reeds, forest with less dense bamboo and reeds, forest with bush type tree and grassland, grassland with or without tree, swamp, barren land/rock out crop.

Sharma and Chaudhary (2007) prepared land use map on 1:12,500 scale of Shiwalik hills of Solan district in Himachal Pradesh. They classified land use as mixed dense forest, sparse/open forest, agriculture, scrubland, grassland and agricultural plantations.

Bandopadhyay *et al.* (2009) prepared land use/land cover map using IRS-1D LISS-III data of Feb. 2004 at 1:50,000 scale in conjunction with SOI toposheet of Hisarghatta watershed, Karnataka. They classified land use/ land cover as double crop (*kharif* crops, *rabbi* crops with fallow land), plantation crops, forest, grasslands, scrubs, rocky area, settlement and water body.

Kashiwar *et al.* (2009) characterized the land resources of Salai watershed near Nagpur, Maharashtra using IRS-1D LISS-III and PAN sharpened LISS-III data. They delineated and mapped land use/land cover classes as single crop, double crop, scrubland and moderately dense forest.

Naidu *et al.* (2009) prepared the land use/land cover map of different forest types in Karnataka using IRS 1C/1D LISS-III + PAN merged data. The land cover/land use identified are Evergreen/semi evergreen forest, moist/dry deciduous forest, scrub/degraded forest. Soils of moderately deep to very deep with moderate dry period of 6-7 months supported moist/dry deciduous forest. Longer dry period (>8 months) supports scrub/degraded type of forest vegetation irrespective of soil conditions.

Shukla *et al.* (2009) studied the land resources of Dhamni micro-watershed in Chandrapur district of Maharashtra and reported that 84.2 per cent of watershed was under cultivation. Forest comprises 4.5 per cent (mainly degraded) and wasteland with scrub covering 9.4 per cent area of the watershed.

Ardak *et al.* (2010) prepared land use/land cover map of Khapri village of Nagpur district of Maharashtra on 1:12,500 scale based on IRS-P6 LISS-IV and IRS-1D PAN merged LISS-III data. They identified and mapped land use/land cover classes as agriculture (single crop and double crop), degraded forest and wasteland with scrub.

Patil *et al.* (2010)[a] used IRS-1D LISS-III data of Nov. and Feb. 2004 to prepare land use/land cover map of Lendi watershed of Chandrapur district of Maharashtra. They identified major land use/land cover classes as cultivated land (62.8%) of which 43.3 per cent was under single and 19.5 per cent under double crop, forest (14.9%), wasteland with scrub (18.9%), rock outcrop (0.73%) and water body (2.67 %).

Patil *et al.* (2010)[b] prepared land use/land cover map of Longadga watershed of Chandrapur district of Maharashtra using IRS-1D LISS-III and Landsat-7 TM data. They classified land use/land cover into cultivated land, wasteland with scrub, water body and habitation.

Bante *et al.* (2012) visually interpreted IRS-1D LISS III and LISS IV data of Taroda watershed of Vidharbha region of Maharashtra for land use/land cover which indicated that 54.8 per cent of TGA was under cultivation, 22.7 per cent under wasteland with scrub and 21.1 per cent was under degraded forest.

Deshmukh (2012) studied the land use/land cover of Tandulwani watershed of Nagpur district, Maharashtra using Geocoded FCC of IRS-P6 LISS-IV imagery and SOI toposheet (1:50,000) and found nearly 42.8 % of the area is crop land, 37.5 % notified forest, 19.4 % wasteland and the remaining 0.3 % habitation.

Das *et al.* (2013) studied nine villages of Doomdoma sub division of Tinsukia district of Assam using IRS-P6 LISS-IV, Cartosat 1and LISS-IV + Cartosat-1merged and, LISS-III image and classified land use and land cover as agriculture (field crops and tea garden), wastelands (scrubland), built up forest plantations and water body where in 81% area of the study area was under agriculture use that includes kharif crop (mostly winter rice called Sail rice in Assam), double crop (i.e. kharif and rabbi) and tea gardens. Area under tea gardens was the highest and occupies 1173.34ha area which is 50% of the total study area and 62% of agricultural land.

Nasre *et al.* (2013) prepared land use/land cover map of Karanji watershed of Yavatamal district of Maharashtra using IRS-P6 LISS-III and LISS-IV remote sensing data and digital elevation model (DEM) classified mapped and assessed for their sustainable use.

Raju *et al.* (2013) used remote sensing and Geographic Information System to classify land use/land cover of Vizianagaram district of Andhra Pradesh and identified the agriculture land, built-up land, forest and wasteland and water bodies. About 68% of the total geographical area of the district is covered by agricultural land followed by forest land (15% of TGA) and waste land (10% of TGA), while built up land area covered for 1 per cent of total geographical area.

Bhandari *et al.* (2014) studied watershed of Tons river in Dehradun using LISS-III remote data. They identified the five LULC classes out of which, forest had the maximum cover of 60%, followed by agriculture (28.9%), waterbed (4.74%), flood plains (4.38%) and scrub (1.04%), using a combination of two approaches, visual image interpretation and digital image classification of FCC (geocorrected at 1:50,000 Scale).

Rane and Bhushan (2014) visually interpreted IRS P6 LISS-III data to derive information on land use and land cover of Jalgaon district in Maharashtra. They have reported that agriculture remains the major land use class comprising about 65.81% of the total geographical area followed by barren land (21.05%), forest cover (8.44%), water body (2.75%), built-up area (1.5%) and agriculture within the forest (0.55%).

2.2 Physiography/Soil Mapping

Saxena *et al.* (2000) used IRS-1C LISS-III (1:50,000 Scale) to prepare physiography map of Gondkhairi watershed in Kalmeshwar taluka of Nagpur district. They identified and mapped six physiographic units' *viz.* Table and top, subdued Plateau, escarpment, pediment, upper and lower valley.

Arunkumar *et al.* (2002) prepared the soil map of Lower Palar Manimuthar watershed, Tamil Nadu using IRS-1B LISS-III data. Ten soil series viz. Neman series (P1), Pillamangalam series (P2), Sirukadalpatti series (P3), Nedumaram series (P4), Vengalur series (P5), Kunnakudi series (P6), Puthirapatti series (P7), Kandavirayanpatti series (P8), Naduvakottai series (P9) and Melkudi series (P10) were identified and mapped.

Bodhankar *et al.* (2002) prepared physiography-soil map of Dewadkasha watershed in Nagpur district, Maharashtra using geo-coded false colour composite (FCC) of IRS-1C. Physiographically, the area was characterized into hills and ridges, plateau top, escarpment, pediment and buried pediment, which were further sub-divided based on slope and image characteristics. Twelve soil series were tentatively identified in the area on different physiographic units.

Potdar *et al.* (2003) prepared physiography map of Nanda-Khairi watershed of Nagpur district, Maharashtra using geocoded false colour composite of IRS-1C.They identified and delineated major physiographic units viz. plateau/summits, escarpments, upper foot slope, lower foot slope, upper alluvial plain and lower alluvial plain.

Obi-Reddy and Maji (2003) delineated and characterized different geomorphic units of Tundiya river catchment, north eastern part of Nagpur district, Maharashtra using IRS-ID LISS-III satellite data (bands 2, 3 and 4). They delineated geomorphological units as table top summits, structural hills, subdued plateau, linear ridges, shallow, moderate and deeply buried foot slopes, shallow valley fills and deep valley fills.

Reddy *et al.* (2004) characterized the land resources around Mohgaon and Degma villages in Hingna tehsil, Nagpur district and reported extremely shallow and well drained soils (Lithic Ustorthents) on plateau summits and isolated mounds and deep soils (Vertic Haplustepts) in the main valley floor.

Srivastava and Saxena (2004) prepared the soil map of Junewani village on 1:12,500 scale using IRS-1C PAN merged LISS-III data of two seasons. They visually interpreted the remote sensing data to prepare the physiography-land use (PLU) map. The PLU–soil relationship was established based on ground truth and soil map depicting phases of soil series of the village was prepared.

Maji *et al.* (2005) prepared landform map of Ringnabody watershed of Nagpur district, Maharashtra using IRS-1C LISS-III data. They classified the watershed into summit crest, escarpment, isolated mounds, denuded plateau, foot slopes, upper piedmont, lower piedmont and narrow valley as dominant landforms.

Thangasamy *et al.* (2005) studied the morphological, physical and physico-chemical characteristics of soils in Sivagiri micro-watershed of Chittoor district in Andhra Pradesh. The soils were classified as Aquic Ustorthents, Typic Ustipsamments, Typic Ustifluvents, Typic Haplustepts, Vertic Haplustepts, Typic Haplustalfs and Typic Rhodustalfs.

Solanke *et al.* (2005) prepared physiography map of Ganeshpur micro-watershed of Nagpur district, Maharashtra based on PAN+LISS-III merged data of April, 2002. They identified four major physiography units in the watershed *viz.* plateau, escarpment, pediments and valleys.

Sarkar *et al.* (2006) used IRS-1D LISS-III fused with PAN data on 1:12,500 scales in Patloinala micro-watershed of Purulia district, West Bengal to prepare the physiography map of the area. They delineated micro-watershed as upland (Tanr), medium land (Baid) and low land (Bahal and Kanali) based on image characteristics.

Martin and Saha (2007) used remote sensing and GIS techniques for the preparation of physiography map of Ason river watershed using LANDSAT TM data in conjunction with SOI toposheet (1:50000 scale) and delineated physiographic units as hills, piedmont, valley, side slope and alluvial plain.

Rao *et al.* (2008) characterized and classified the soils on different landforms in Ramachandrapuram Mandal of Chittoor district of Andhra Pradesh. They classified Pedons 1, 2 and 3, occupying plains, as Vertic Haplustepts, Typic Ustipsamment and Typic Haplustepts respectively. Pedon 4 and pedon 5 occurring on upland was classified as Typic Haplustalf and Typic Ustifluvents, respectively. Pedon 4 was classified as Typic Haplustalf due to the presence of argillic (Bt) sub-surface diagnostic horizon. The pedons 6 and 7 located on hill slope were classified as Typic Ustorthents.

Shamsudheen *et al.* (2008) studied the soils of Kumtataluka of Uttarkannada Dist. of Karnataka and identified eight physiograpic units viz. hills, plateau, escarpments, pediments, valley, recent alluvial plain, old alluvial plain and coastal alluvial plain. The soils of hill, pediment and valley were classified as Ustalfs. Hill soils were classified at subgroup level as Typic Kanhaplustalfs whereas valley soils were classified as Ultic Haplustalfs. The soils of alluvial plain and coastal alluvial plain were classified as Typic Ustifluvents and Oxyaquic Ustifluvents, respectively.

Kashiwar *et al.* (2009) prepared physiography map of Salai watershed of Nagpur district, Maharashtra based on IRS-1D LISS-III and PAN sharpened LISS-III and divided the watershed as subdued table land, upper valley and isolated mound with pediments.

Ardak *et al.* (2010) prepared physiography map of Khapri village of Nagpur district of Maharashtra on 1:12,500 scale using IRS-P6 LISS-IV and IRS-1D PAN sharpened LISS-III. They identified six major landforms viz. isolated hillocks, plateau top, escarpment, pediment, upland and valley plain.

Patil *et al.* (2010) [a] studied the physiography of Lendi watershed of Chandrapur district of Maharashtra using IRS-1D LISS-III data. They classified the watershed into five major physiographic units'*viz.* isolated mounds, subdued plateau, uplands (upper reaches), midlands (interfluves) and lowland (stream channel) and prepared soil map of study area. Eleven soil series viz. Salori-1, Salori-2, Salori-3, Kutbala-1, Kutbala-2, Mowada, Shegaon-1, Shegaon-2, and Bandra were identified and mapped

Patil *et al.* (2010) [b] used IRS LISS-III and Landsat TM data to derive spatial information on physiography of Longadga watershed of Chandrapur district of Maharashtra. They divided the watershed into five major physiographic units, *viz.* subdued plateau, pediment, buried pediment, alluvial plain and valley fills. Based on ground truth physiography-soil relationship was established and soil map of area was prepared an association of soil series.

Nasre *et al*., (2013) interpreted IRS-P6 LISS IV and LISS-III (1:50,000 scale) satellite data of two seasons to prepare physiography and soil map of Karanji watershed of Yavatmal district, Maharashtra. They identified seven major physiographic units viz. plateau top, escarpment, isolated hillocks, foot slope, undulating land, alluvial plain and valley. The soils of very gently sloping plateau top were very shallow, clayey and classified as Typic/Lithic Ustorthents whereas, soils occurring on undulating land, foot slope, alluvial plain and valley having very gentle slopes, were moderately deep to very deep, clayey in texture and were classified as Typic/Vertic Haplustepts and Sodic Haplusterts. The soils of escarpments and isolated hillocks on moderately to moderately steeply sloping lands were very shallow, loamy and classified as Typic/Lithic Ustorthents.

Bhandari *et al.* (2014) studied watershed of Tons river in Dehradun. They divided study area into three major landforms (hilly, piedmont plains and flood plains) and further divided into 10 physiographic soil units. Most part of the study was covered by Himalayan Mountains and piedmont plains.

Singh (2014) interpreted IRS -1C LISS – III data of Mohan Rao watershed which exists between two states Haridwar district of Uttarakhand and Saharanpur district of Uttar Pradesh at the scale of 1:50,000. They delineated different physiographic unit'sviz. Siwalik hills, Piedmont plain, alluvial plain, Residual hills.

2.3 Soil-Site Characteristics

2.3.1 Soil characteristics:

The important soil characteristics which directly or indirectly effect on crop growth and soil characteristics are described as below.

Walkar *et al.* (1968) reported that landform parameter such as slope, length and direction, curvation, distance from the hill slope summit and its relative elevation influence the soil profile development. They also observed the influence the slope, length and its direction on horizon development.

Landey *et al.* (1982) reported that black soil and associated soil were found on various micro–land form units both erosional and depositional. The depositional features are generally residual hill ranges directed means of butte, escarpment and pediments while the depositional features are visible in the piedmont plain margin gradually with the valley floor. He was also observed that the texture of black soil were usually fine and varied from clay loam, silty clay to clay. The clay content varies from 35 to 60 percent. They also observed that the bulk density was normally high in black soils and the normal range estimated with dry clod method ranged between 1.5 to 1.8 M gm^{-3}.

Mungare and Pharande (1982) reported that soil texture is the main factor of soil moisture. They established highly significant correlation between clay content and clay plus silt content with sand content.

Vadivelu *et al.* (1983) and Bhattacharyya *et al.* (1989) reported that soil–site and climatic characteristics. changes with geomorphic unit which is turn influence on land use pattern, they observed that hill ridges with shallow soil were mostly under forest with patches of rainfed crops. The pediments surface with shallow to deep soils were cultivated to sorghum and soybean and pearl millet, while the soils occurring on pediment plain and flood plains were very deep and cultivated to sorghum, pigeon pea, safflower under rainfed condition.

Bharambe and Ghonsikar (1985) studied the soils in Jayakwadi command area and reported that calcium carbonate content in these soils ranged from 1.12 - 16.81per cent, pH of the very deep soil, deep soil and medium soils were neutral to alkaline in nature and varied from 7.19 to 9.30, 7.85 to 9.12 and 7.33 to 9.20 respectively and bulk density of very deep soil, deep soil, medium soil and shallow soils are 1.18 to 1.52, 1.23 to 1.50, 1.20 to 1.50 and 1.20 to 1.61 Mg m^{-3} respectively. Total porosity of very deep soil, deep soil, medium soil and shallow soil ranged from 37 to 58, 43 to 54 and 38 to 53 percent respectively.

Pal and Deshpande (1987) reported that basalt rocks reality weathers to fine clay and this could be the reason for high clay and low content of sand in deep black soil.

Ahuja *et al.* (1988) studied soil properties of 21 sites and observed that depth ranging from 15 to 135 cm and found that bulk density and clay content was increased with increasing depth while silt and organic matter content decreased with depth.

Srivastava *et al.* (1991) studied the soils of Ujjain district of Madhya Pradesh and observed that the soils on hill and ridges were shallow, excessively drained with problem of severe erosion soils on gently sloppy to undulating lands were as deep to very deep, well drained and were suitable for arable crops if irrigation was provided. Soil on gentle sloping land was very deep, moderately well drained calcareous and were under cultivation.

Sharma *et al.* (1996) reported that the soil at elevated topography were shallow to moderately deep, clayey to loamy skeletal and yellowish brown, while the soils at lower topography were deep to very deep, fine to fine loamy and grayish. The influence of topography was marked on soil properties such as pH, $CaCO_3$, clay content, Vertic properties and exchangeable Cations.

Chinchmalatpure *et al.* (1998) observed that Entisols are the dominant soils on hill top and have erosional surface, Vertisols are the dominant soils, occurring on concave slope of basaltic transect.

Kadu *et al.* (2003) reported that evaluation of Vertisols for deep rooted crops on the basis of hydraulic conductivity alone my help in planning and management of Vertisols under semi-arid climate in India.

Dhale and Jagdish Prasad (2009) studied soils and productivity of sweet orange, in Jalna district of Maharashtra and reported that the soils are shallow to very deep and grouped into Typic Haplusterts to Liptic Haplusterts. The different soil site attribute responsible for yield of sweet orange.

Ashok kumar and Jagdish Prasad (2010) studied typical sugarcane growing soils of Ahmadnagar district of Maharashtra for their characterization and classification. He was reported that the soils under sugarcane are Vertic Haplustepts, Lithic Ustorthent and sodic Haplusterts.

Patil *et al.* (2013) studied on soils of Osmanabad district and reported that these soils are classified as Lithic Ustorthent, Typic Ustochrepts and Typic Haplusterts. The morphological, chemical and physical properties of soil are differing in relation to topographic position of soil profile. The different soil site attribute responsible for yield difference in soybean and pigeon pea are PAWC, clay content, soil depth, CEC and stoniness.

2.3.2 Morphological properties:

Soils developed from variety of parent material occurring on varies land form unit widely distributed through out of the country and have wide difference in their morphological characteristics.

Mehta and Shankaranaryana (1961) found that stones and gravels to the extent of more than 10-20 percent by volume on the surface adversely affect the root growth and water retention

Sehgal (1991) reported that soil depth is an important criteria for land evaluation. Most of the crop produce excellent yield with an effective soil depth of 90 to 100 cm. (Sys, 1985).

Dipaksarkar *et al.* (1997) reported that the soils of the hilly terrain are very shallow to shallow, yellowish red to dark reddish brown, gravelly sandy loam to sandy clay loam in texture with A-C and A-B-C horizon sequence are classified as, Lithic Ustorthents and Lithic Ustochrepts.

Gabhane *et al.* (2006) studied on Belura watershed Akola district, Maharashtra and reported that the soils are grouped under Typic Haplusterts and Vertic Haplusterts. The Vertisols soils showed well developed slickensides. This slickensides zone and well developed wedge shaped structural aggregates and angular blocky structure. This may be due to the swell-shrink phenomenon of smectite clay (Ahmand, 1983).

Patil *et al.* (2008) studied on soils at college of Agriculture farm Pune, Maharashtra and reported that the soil colour varies from brown (10YR 4/4) to dark brown (10YR 3/3), clay in texture and medium moderate sub angular blocky in structure.

Dhale and Jagdish Prasad (2009) reported that the soils of Jalna district, Maharashtra under sweet orange were 10YR 7.5 and 5YR with value 3 to 4 and chroma 1 to 4. Sub angular blocky to angular blocky structure.

Leelavati *et al.* (2009) studied the soil depth varies from deep to very deep and the soil colour on very gentle slopping land varies from yellowish brown (10YR 5/6) to dark red (2.5 YR 3/6) and in flat land soils showed very pale brown (10 YR 7/3) to reddish grey (5YR 5/2) colour.

Ashok kumar and Jagdish Prasad (2010) studied typical sugarcane growing soils of Ahmadnagar district of Maharashtra were characterized and reported that the soils were very shallow to very deep and have their Munsell colour notation in 10YR/7.5YR hue with value 3 to 4 and chroma 1 to 4. The dominant structure is moderate, medium, sub-angular blocky type, but angular blocky structure is a common feature in slickenside zone of Vertisols.

Kharche and Pharande (2010) studies on Mula command area, Ahamadnagar district, Maharashtra and reported that the soils of command area rich in ferromagnesium minerals that weathered into dark coloured soils. The texture of the soils varies from clay to clay loam because of fine grained basaltic parent material.

Likhar and Jagdish Prasad (2011) reported that the soil of Nagpur district the soil colour various from black (10YR 2.5/2) to redish brown (5YR 4/4). The dominant structure was moderate medium sub angular blocky in structure.

Meena *et al.* (2011) studies on Wardha Command area Maharashtra and reported that the soil colour varies from dark brown (10YR 3/3) to very dark grey (10YR 3/1) colour. Sub angular to angular blocky in structure and clayey in texture.

Patil (2011) reported that the soil of Osmanabad tahsil were yellowish brown (10YR 5/6) to black (10YR 2.5/1) in colour, very shallow to very deep in depth, granular to angular blocky in structure sandy clay loam to clay in texture.

Mane (2013) reported that the soils of Osmanabad district were very black (10 YR 2.5/1) to dark yellowish brown (10 YR 6/4) in colour, clay to sandy loam in texture; granular to angular blocky in structure.

Pawar (2013) reported that the soils of Osmanabad district were very dark grayish brown (10 YR 3/2) to light yellowish brown (10 YR 6/4) in colour, loam to clayey in texture, granular to sub angular blocky in structure, friable non sticky non plastic to firm very sticky very plastic consistency.

Vaidya *et al.* (2014) reported that the soils at farm college of Agriculture, Osmanabad were the pedon situated on elevated position are redish brown (5YR 5/4) to yellowish red (5YR 5/6) and the pedon situated on lower topography the soil colour varies from dark brown to (10YR 4/3) to yellowish brown (10YR 5/8). The soil structure is granular to sub angular blocky and soil texture sandy to clayey.

2.3.3 Physical properties:

Bharambe *et al.* (1986) reported that higher value of saturated hydraulic conductivity (6 to 39 mm hr^{-1}) for shallow soils and lower values (2 to 30 mm hr^{-1}) for deep black soils of the Jayakwadi and Purna command area.

Kanwar and Virmani (1986) and Vaidya and Pal (2002) obtained significant positive correlation between clay content and water holding capacity in Vertisol.

Yule (1986) the bulk density of swell shrink soils has been observed to change with moisture content.

Bharambe *et al.* (1987) reported that moisture retention under shallow soil at 33kPa and 1500 kPa tension is 28 to 34 and 15 to16 per cent respectively.

Nimkar (1990) reported that water retention at 33 kPa and 1500 kPa ranging from 36.6 to46.6 and 22.0 to 22.4 per cent respectively in black soils of Purna valley in Vidhrbha region.

Biswas and Mukherjee (1994) the retention and release of water in soils is a direct function of soil agreement and their porosity.

Gabhane (1995) reported that the water content both at 33kPa and 1500 kPa tension increases with increase in the silt and clay content individually and also in combination.

Walia and Rao (1997) revealed that clay content in khraund and Bharatkup soils varies from 15.4 to 39.8 per cent and such variation could be due to change in depositional pattern as indicated by abrupt change in sand / silt ratio and the bulk density varies from 1.46 to 1.96 Mg m^{-3} and increase with depth.

Shrivastava *et al.* (1998) observed that water retention in different horizons varied from 19.56 to 50.22 at 33 kPa and 9.81 to 30.34 at 1500 kPa. Silt content was significantly correlated with water content at 33 kPa whereas clay and silt plus clay showed significant positive relationship with the same at 33 and 1500 kPa.

Thangasamy *et al.* (2005) observed that the clay content varied from 2.50 to 58.30 per cent and silt content of all the profiles exhibited an irregular trend with depth. Coarse fraction (sand) constitutes the bulk of mechanical fraction, which could be attributed to the dominance of alluvial sandy parent material and he was also reported that the bulk density varied from 1.32 to1.90 Mg m^{-3} and increased with depth which might be due to more compaction in deeper layer caused by over-head weight of the surface soil.

Gabhane *et al.* (2006) studies on soils of Belura watershed Akola district reported that the soils were clay in texture with clay content ranging from 34.4 to 73.4 per cent and which was increased with depth.

Patil *et al.* (2008) studied on soils of college of Agriculture Pune and reported that the soils are gravelly sand clay loam to clays in texture and high bulk density 1.83 Mg m^{-3}.

Leelavathi *et al.* (2009) revealed that the clay content varied from 2.13 to 55.32% and the silt content in all pedons exhibited an irregular trend with depth and sand constituted the bulk of mechanical fractions, which could be attributed to the dominance and alluvial sandy parent material and the bulk density and different pedons, varied from 1.15 to 1.61 Mg m^{-3} and showed an increasing trend with depth which might be due to more compaction, low organic matter and less aggregation.

Kharche and Pharande (2010) studied on soils of Mula command area Ahamadnagar district Maharashtra and reported that the clay content in different horizons varies from 36.2 to 57.2 per cent. Bulk density of soil varied from 1.32 to 1.65 Mg m^{-3}.

Vaidya and Dhawan (2010) reported that the soils of Kini farm college of Agriculture, Osmanabad were clay loam to sandy clay loam in texture and its bulk density (1.67 to 2.11 Mg m^{-3}) varied with slope.

Patil *et al.* (2013) studies on soils of Osmanabad district, Marathwada region Maharashtra and reported that the soils are sandy clay loam to clayey in texture. The AWC of soils varies from 7.5 to 20.8 per cent and the PAWC of the soils are varies from 59 to 259 mm.

Vaidya *et al.* (2014) studied on soils of college of Agriculture, Osmanabad and reported that the soils are high coarse fragment varies from 7.83 to 93.6 per cent. The sand is the dominant fraction in pedon located in elevated position. The clay is dominant fraction in pedon located at depress position. The available water capacity ranged from 7.5 to 15.8 per cent this variation attributed to textural difference.

2.3.4 Chemical properties:

Kadam *et al.* (1983) reported that there was increase in EC of sugarcane soils which were varied from 0.10 to 0.40 dSm^{-1}. Increase in EC due to the excessive irrigation, fertilization and accumulation of salts in root zone and reported that slight increase in organic carbon from 0.42 to 0.56 per cent in sugarcane soils of MalshirasTaluka in Solapur district. This increase in organic carbon was attributed to application of FYM and addition of sugarcane trash, root biomass and their subsequent decomposition might have also increased the organic carbon status of soil.

Bharambe and Ghonsikar (1985) studied the soils in Jayakwadi command area and reported that calcium carbonate content in these soils ranged from 1.12 to16.81 per cent, pH of the very deep soil, deep soil and medium soil varied from neutral to highly alkaline ranges from 7.19 to 9.30, 7.85 to 9.12 and 7.33 to 9.20 respectively.

Venkatasubbian *et al.* (1986) reported that Vertisols with clay 55 to 63 percent and pH greater than 8 were associated with cation exchange capacity of 50 to 60 cmol (P^{+}) kg^{-1} of soil.

Tan (1988) stated that base saturation was closely related to cation exchange capacity and positive correlation exists between percent base saturation was frequently consider to be an indication for soil fertility.

Salunke (1990) analyzed the sugarcane growing soils of Nanded and Parbhani districts and reported that EC of these soils varied from 0.30 to 0.71 dSm^{-1}.

Sehgal (1991) observed that nodular form of $CaCO_3$ up to 20 percent also support good crop of cotton in black soils. Solid–Phase calcium carbonate governed the P reaction and related to carbonate particle size distribution.

Coulumbe *et al.* (1991) observed that the neutral Vertisols exchange sites were occupied mainly by Ca and Mg and to a lesser extent by K and Na.

Gajbhiye and Deshmukh (1992) correlated the yield with individual soil parameter and observed that the soil depth, clay content, $CaCO_3$ and pH, were the most important factor influencing the crop.

Prasad and Srivastava (1993) studied the physiography and soils of Dewas district, Madhya Pradesh and reported that hill slops and undulating plateau were dominantly under dry deciduous forest and shallow and coarse textured soils with swell-shrink potential and mostly cultivated to rain fed crops like soybean, sorghum fallowed by wheat and gram soils of gently to moderately sloping plain were moderately deep to deep, calcareous with Vertic properties and cultivated to cotton and pigeon pea.

Khadse (1993) studied the organic carbon status of Nagpur district and stated that the organic carbon of the soil varied from 0.11 to 0.76 per cent. He was further reported that the soil depth increased, organic carbon contain decreased. This is due to sieving effect and adsorption of fine organic particles and soluble organic matter respectively by the soil particles.

Bhosle (1994) analyzed soils from Beed district and reported that EC of these soils varied between 0.11 to 0.64 dSm^{-1}.

Patil and Sonar (1994) studied the swell-shrink soils of Maharashtra and reported that the per cent organic carbon were varied between 0.37 to 0.72, the calcium carbonate content were ranged from 0.2 to 14.4 per cent, available N content were ranged from 115 to 225 kg ha^{-1} with a mean value of 205 kg^{-1} in available N and available K content was varied from 224 to 909 kg ha^{-1}.

Ambulgekar (1995) studied the fertility status of soils of Latur and Osmanabad districts and reported that N content in deep black and medium black soils were varied between 160 to 311 and 123 to 231 kg ha^{-1} with average values of 201 and 188 kg ha^{-1} respectively.

Malewar (1995) reported that the soils of Marathwada region of Maharashtra state contained the calcium carbonate from 0.00 to 11.5 per cent with an average value of 6.25 per cent.

Coulambe *et al.* (1991) soil pH is mostly related to the nature of the parent material, climate and topographic situation which determine the composition of soil. However alkali soil condition pH more than 8.3 may destabilize structural peds lead to very slow permeability. Which are not desirable for agricultural purpose.

Pharande *et al.* (1996) studied Vertisols of Maharashtra and reported that DTPA-Zn content was ranged between 0.21 to 3.94 mg kg^{-1} with a mean value of 1.57 mg kg^{-1}.

Sharma *et al.* (1996) reported that the soil properties such as pH, $CaCO_3$ clay content, Vertic properties, CEC and exchangeable cation were markedly influenced by the topography of the land scape.

Balpande *et al.* (1996) while studying the grape cultivated soil of Nashik district observed that the DTPA extractable Cu ranged from 1.16 to 22.0 mg kg^{-1}, Fe 2.52 to9.22 mg kg^{-1}, Zn 0.06 to 3.06 mg kg^{-1} and Mn 3.44 to 32.1 mg kg^{-1} in different horizon.

Malewar *et al.* (1998) studied the soils of semi-arid area of Northern Marathwada and reported that the $CaCO_3$ content in these soils were ranged from 37.50 to 114.0 g kg^{-1} and available K_2O content in the semi-arid soils of Northern Marathwada were ranged from 318.0 to 616.0 kg ha^{-1} respectively.

Jagdish Prasad and Gajbhiye (1999) reported the antagonistic effect of $CaCO_3$ and micronutrient cations.

Sarkar and Sahoo (2000) found that there is tendency for pH to increase with depth, possibly due to leaching of bases in vertisols.

Sharma and Bali (2000) reported that organic carbon content increased significantly in cultivated soils over uncultivated soils and reported that organic carbon content was higher in surface soil as compared to subsurface soils.

Jagdish Prasad *et al.* (2001) studied the Characteristics and classification of some orange growing soils in Nagpur district of Maharashtra and found that exchangeable Mg^{++} ranged from 8.6 to 14.2 cmol (p^+) kg^{-1}, and exchangeable calcium ranged from 24.1 to 42.5 cmol (P^+) kg^{-1}.

Kulkarni (2001) reported that continuous cropping of sugarcane had significantly affected the physico-chemical properties of soils. An affect was more when crop was growing continuously for more than twenty years. The pH of the soils was recorded from 8.33 to 7.75; organic carbon content ranging from 0.66 to 0.94 percent and the $CaCO_3$ content was decreased from 3.63 to 3.39 percent. This was due to the organic matter accumulation from the plant residues (sugarcane trash) left out in the fields after sugarcane harvesting due to continuous cropping. It was also attributed to addition of organic manures in cultivated soil.

Mali and Raut (2001) analyzed one hundred fifty eight surface soil samples (0-30 cm depth) of oilseed growing area of Latur district and revealed that these soils contained the $CaCO_3$ 3.1, 3.75 and 3.70 per cent in Vertisols, Inceptisols and Entisols respectively.

Dube (2002) reported that soils from continuous sugarcane growing area increased their EC from 0.41 to 0.48 dSm^{-1} due to the continuous use of irrigation for sugarcane cultivation and use of excess water by farmer for sugarcane cropping for obtaining the maximum yield.

Ghuge (2002) studied sugarcane growing soils under BalaghatShetkari Co-operative sugar factory, Jalna and reported that the EC of Vertisols, Inceptisols and Entisols were ranged from 0.17 to 0.48, 0.19 to 0.40 and 0.20 to 0.48 dSm^{-1} respectively and indicated that the organic carbon content were ranged between 0.40 to 1.01, 0.27 to 0.93 and 0.19 to 0.74 per cent with the mean value of 0.72, 0.61 and 0.48 per cent respectively.

Jagtap (2002) studied continuous cropping of sugarcane soil from Purna sugar factory area of Parbhani district and reported that available nitrogen content was varied from 172.41 to 197.31kg ha^{-1}.

Padole and Mahajan (2003) reported that the pH varied between 7.2 to 8.9 and K content of swell-shrink soils of Vidarbha region of Maharashtra state ranged from 118 to 257 kg ha^{-1} respectively.

Waikar *et al.* (2004) analyzed the soils from Marathwada and found that the EC of these soils were ranged from 0.12 to 0.86 dSm^{-1}, and the available phosphorus content in these soils ranged from 10.0 to 19.1 kg ha^{-1}.

Gabhane *et al.* (2006) reported that the studies of Belura watershed Akola district is neutral to moderately alkaline in reaction (PH 7.5 to 8.03) in general pH of the soil increased with depth. The organic carbon content of the soils varies from 0.32 to 0.72 per cent and it was decreased with depth. The CEC of soil varied from 51.1 to 62.9 cmol (p^{+}) Kg^{-1}.

Nayak *et al.* (2006) studied swell and shrink soils of Vertisols order and found that exchangeable calcium were ranged from 10.1 to 30.5 cmol(p^{+}) kg^{-1}.

Balpande *et al.* (2007) studied that the pH ranged from 7.2 to 8.9 (neutral to strongly alkaline) with a tendency to increase with depth. The relatively higher pH of the soil may be due to the calcareous nature of parent material, free $CaCO_3$ and high amount of alkaline earth metal (Bharambe and Ghonsikar 1985).

Indulkar *et al.* (2007) reported that the pH of Udgir and Deonitahsils of Latur district ranged from 7.00 to 8.79 and 7.00 to 8.91 and the DTPA- Mn content of soils were ranged from 0.14 to 21.30 mg kg^{-1} and 0.32 to 17.5 mg kg^{1},and the DTPA- Cu content of soils were ranged from 0.98 to 7.66 mg kg^{-1} and 0.74 to 9.42 mg kg^{-1} respectively.

Waghmare and Takankhar (2007) studied the chemical properties and micronutrient status of some soils of Ausa and Nilangatahsils of Latur district in Maharashtra and reported that the available Pcontent of these soils were ranged from 4.22 to 24.98 kg ha^{-1} and 4.22 to 28.13 kg ha^{-1} respectively.

Patil *et al.* (2008) reported that the soils of college of Agriculture Pune farm are moderately alkaline in reaction (pH 8.0 to 8.7) low to medium organic carbon (0.14 to 0.42%). The soil is moderately calcareous in nature. The $CaCO_3$ content increased with increasing depth.

Ravte (2008) analyzed the soils of Ausa and Nilangatahsils of Latur district and reported that the Ca^{++} content in these soils were ranged from 11.05 to 50.7 cmol kg^{-1}, and the Mg^{++} content in these soils were ranged from 20.6to 28.9 cmol (p^+) kg^{-1} respectively.

Vaidya and Mali (2008) reported that the soils of Kini farm College of Agriculture Osmanabad are low to moderate in organic carbon, neutral to alkaline (6.8 to 7.2) in reaction and calcareous in nature (<5%).

Jibhakate *et al.* (2009) studied the physico-chemical status of soils of Katol tahasil in Nagpur district and showed that the values of pH of these soils ranged from 7.1 to 8.2 indicating neutral to alkaline reaction.

Kharche and Pharande (2010) the soils of Mula command area in Ahamadnagar district are moderately to slightly alkaline in nature (8.2 to 9.5).The EC of saturation extract 0.70 to 6.52 dSm^{-1}. The soils with high Na^+ on exchange compound (ESP>10) and high CEC ranged from 21.3 to 64.8 cmol (p^+) kg^{-1}.

Meena *et al.* (2011) studied on Wardha command area Maharashtra reported that the soils are moderately alkaline to strongly alkaline in reaction (pH 7.3 to 8.6). The electrical conductivity value ranged from 0.12 to 0.68 dSm^{-1}.

Patil *et al.* (2013) studied on soils of Osmanabad district, Maharashtra and reported that the soils are slightly acidic to moderately alkaline in nature. The CEC varies from 23.19 to 44.8 Cmol (P^+) kg^{-1}. Low to moderately high in organic carbon. The base saturation per cent is greater than 90 per cent.

Vaidya *et al.* (2014) studied on soils of College of Agriculture, Osmanabad and reported that the soils are neutral to alkaline in nature (6.9 to 7.4 pH).

The soluble salt concentration low <1 dSm^{-1}. The organic carbon content is low to high (0.3 to 1.1%) The cation exchange capacity varies from 17.1 to 48.21 cmol (p^{+}) kg^{-1}. The exchangeable complex dominated by ca^{++} followed by mg^{++}, k^{+} and Na^{++}.

2.4 Land Evaluation

2.4.1 Land capability and Irrigability

Solanke *et al.* (2005) prepared land capability map of Ganeshpur micro-watershed of Nagpur district, Maharashtra. The land capability sub-classes identified in the area are *IIs, IIIs, IIIes, IVes* and *VIes.*

Thangasamy *et al.* (2005) evaluated the soils of Sivagiri micro-watershed of Chittoor district in Andhra Pradesh and group the soils into *IIs, IIIes, IIIw* and *IVs* sub-classes.

Tripathi *et al.* (2006) worked in Kiar-Nagali micro-watershed in North-West Himalaya and grouped the soils into *VIIIe, VIIes, IIIes* and *IIe* land capability sub-classes and 2t, 3t and 6t land irrigability sub-classes.

Gabhane *et al.* (2006) evaluated the land for land use planning of micro-watershed in Vidarbha region of Maharashtra. The study area was classified into land capability classes *II, III, IV* and *VI.*

Sarkar *et al.* (2006) grouped soils into four land capability classes viz., *II, III, IV* and *VI* in Patloinala micro-watershed of Puruliya district, West Bengal.

Mini *et al.* (2007) evaluated the soils of Mirjan village of coastal agro-ecology of Karnataka and grouped the soils into *IIIs, IVs* and *Vs* sub-classes.

Rao *et al.* (2008) evaluated the soils of Chittoor district in Andhra Pradesh and soils were grouped under sub-classes viz., *IIs, IIIs, IIIes* and *IVes.*

Kashiwar *et al.* (2009) evaluated the soils of Salai watershed in Nagpur district of Maharashtra and grouped the soils into five land capability sub-classes *IIIs, IIIes, IVs, IVes* and *VIs* and three land irrigability sub-classes 2d, 4s and 4st.

Patil *et al.* (2010) [b] evaluated the soils in Longadga watershed of Chandrapur district, Maharastra. They grouped land units into *IIs* and *IIIs* land capability subclasses

Panhalkar and Sachin (2011) evaluated the soils of Dudhganga basin of Southern Maharashtra and grouped the soils in to class *II, III, IV* and *VI* using RS and

GIS tools. The class II is much suitable for agriculture accounts 16.30 per cent. Class *IV* is a dominating class as far as the areal extent is concerned with 34.05 per cent. The class *VI* is most susceptible to land degradation which accounts for 28.61 per cent.

Deshmukh (2012) classified the land of Tandulawni watershed of Nagpur district, Maharashtra in to land capability sub classes IIs, Ives and VIs.

Bhandari *et al.* (2014) classified the area in the watershed of Tons river in Dehradun into land capability classes *II, III, IV* and *VI* using RS and GIS. The very steep slopes were founded under *IV* and *VI*. Most of the gentle slopes and piedmont plains came under classes *II* and *III*. Class *VI* covered mainly forests and class *III* covered mainly agricultural land whereas flood plains came under class *IV*.

Singh (2014) interpreted IRS-1C LISS–II data of Mohan Rao watershed which exists in Haridwar district of Uttarakhand and Saharanpur district of Uttar Pradesh at 1:50,000 scale. They grouped study area into six irrigability sub classes viz. *Is, IIs, IIIs, IVs, Vs* and *Vis.*

2.4.2 Soil productivity evaluation

Tripathi *et al.* (2006) evaluated the productivity potentials of Kiar-Nagali micro-watershed in North-West Himalayas and reported that Nagali-II and Kundla soils have good productivity potential whereas, Nagali-I soils are unsuitable for cultivation.

Chaudhary and Singh (2007) evaluated the productivity potential of soils developed on varying physiographic positions of Solan district of Himachal Pradesh and reported that soils developed on very steep hill slopes (Loamy-skeletal TypicUdifluvents) are extremely poor to nil, Fine-loamy TypicEutrudepts are poor, Fine DystricEutrudepts are average and Fine- loamy TypicEutrudepts soils are good in actual productivity potential.

Shukla *et al.* (2009) evaluated the productivity potentials of Dhamni micro-watershed of Chandrapur district of Maharashtra and reported that soils of Dhamni-3, Dhamni-5, Bijoni-1 and Bijoni-3 were good in productivity with moderate limitations of soil moisture, organic matter, soil texture, structure and mineral reserve and soils of Dhamni-1, Dhamni-2, Dhamni-4, Dhamni-6 and Bijoni-2 were average in productivity due to severe limitations of soil moisture, texture, structure and soluble salts.

Kashiwar *et al.* (2009) evaluated the soil productivity of Salai watershed of Nagpur district, Maharashtra and reported that the soils of Khursapar-5 were good in soil productivity; soils of Khursapar-4 are average whereas, soils of Khursapar-1, Khursapar-2, Khursapar-3, Junapani-1, Junapani-2 and Salai were extremely poor to poor in soil productivity.

Ardak *et al.* (2010) evaluated the productivity potentials of Khapri village of Nagpur district of Maharashtra and reported that soils of Khapri-7 and k hapri-8 were good in productivity, Khapri-2, Khapri-3, Khapri-4 Khapri-5 and Khapri-6 were poor in productivity and soils of Khapri-1 are extremely poor in productivity.

Patil *et al.* (2010) [b] evaluated the soil productivity potentials of Longadga watershed of Chandrapur district, Maharashtra and reported that all the soils except Kharwad-1 are good in productivity.

Nasre *et al.* (2013) evaluated the soils of Karanji watershed in Yavatmal district in Maharashtra for soil productivity and grouped the soils into extremely poor to poor at upper elevation and good at lower elevation.

2.4.3 Soil - site suitability evaluation

Reddy *et al.* (2004) evaluated the soils of Mohgaon and Degma villages of Hingna tehsil, Nagpur district of Maharashtra for cotton suitability and reported that Mohgaon-8 (Typic Haplusterts) and Mohgaon-10 (Vertic Haplustepts) were highly suitable; Mohgaon-5 (Typic Ustorthents), Mohgaon-9 (Typic Haplustepts) were moderately suitable, Mohgaon-1, 2 and 7 (Lithic Haplustepts) and Mohgaon-6 (Typic Ustorthents) were marginally suitable, whereas, Mohgaon-3 and 4 (Typic Ustorthents) were permanently not suitable for cotton.

Shukla *et al.* (2009) worked out the soil suitability for pigeonpea and soybean in Dhamni micro-watershed in Chandrapur district of Maharashtra and reported that the soils are moderately to marginally suitable to pigeonpea and moderately suitable to soybean cultivation.

Kashiwar *et al.* (2009) reported that the soils of Salai watershed of Nagpur district of Maharashtra are moderately to marginally suitable for sorghum and moderately to not suitable for cotton cultivation.

Bandyopadyay *et al.* (2009) assessed the land suitability potentials for agriculture in Hisarghatta watershed in Bangalore Urban and Rural district of Karnataka and categorized the agricultural lands into good, fair, moderate, average, poor and not suitable.

Ardak *et al.* (2010) worked out the soil suitability for cotton and soybean in khapri village of Nagpur district of Maharashtra and reported that Khapri-1 (Lithic Ustorthents) and Khapri-2, 3, 5 and 6 (Typic Ustorthents) were not suitable, Khapri-4 (Typic Ustorthents) are marginally suitable, Khapri-7 (Vertic Haplustepts) and Khapri-8 (Typic Haplusterts) were moderately suitable for cotton and soybean.

Patil *et al.* (2010) [a] reported that the soils of Lendi watershed of Chandrapur district of Maharashtra are moderately to marginally suitable for cotton, pigeonpea and soybean whereas, soils of isolated mounds are not suitable.

Patil *et al.* (2010) [b] evaluated the soils of Longadga watershed of Chandrapur district, Maharashtra for major crops *viz.* cotton, pigeonpea and soybean and reported that the soils of subdued plateau, pediment, buried pediment, alluvial plain and valley fills are moderately suitable and soils of subdued plateau are marginally suitable for growing cotton and pigeonpea whereas, soils of subdued plateau, pediment, buried pediment and alluvial plain are moderately suitable and soils of subdued plateau and valley fills are marginally suitable for growing soybean.

Niranjan *et al.* (2011) studied six pedons from banana –growing tracts in Pulivendla area of Kadapa district, Andhra Pradesh and evaluated their suitability. They reported that the pedons P2, P3 and P6 are moderately suitable, where as P1, P4 and P5 are marginally suitable for Banana cultivation.

Nasre *et al.* (2013) evaluated soil site suitability of major crops in Karanji watershed, Yavatmal District of Maharashtra. They reported that the soils in upper reaches are marginally to moderate suitable for major crops and soils of middle and lower reaches are moderately to highly suitable for major crops.

Material and Methods

Chapter – III

MATERIAL AND METHODS

In this chapter, details regarding the location of Tungi watershed, site selection of the typifying pedons, horizon wise sample collection and characterization of the same for morphological, physical and chemical properties of soil.

The material used and procedure followed during this investigation are described under the following heads.

3.1 General description of the study area

3.2 Remote sensing and collateral data

3.3 Remote sensing data interpretation

3.4 Ground truth collection and methods of soil analysis

3.5 Land evaluation

3.6 Generation of thematic maps

3.1 General description of the study area

3.1.1 Location

Geographically, the Tungi watershed is located between 76°24’28’’ to 76°37’02’’ E longitudes and 18°14’31’’ to 18°19’36’’ N latitudes in Ausa tehsil of Latur district, Maharashtra. The total area of Tungi watershed in Latur distrct is 24777.91 ha. The study area falls in the SOI toposheet No. 56 B/8 and 56B/12 on 1:50,000 scale. The location map of the study area is given in fig.3.1

3.1.2 Physiography, Relief and Drainage

The area is covered by the basaltic lava – flows. Same layer of the lava-flow are hard and compact while other are soft. These basalt flows are the result of intense volcanic activity during Cretaceous Eocene period (almost seventy million year ago). When the lava flows were ejected through long narrow fissures on the earth surface. This area has shallow cover of gravelly sediments over a hard basaltic contact within 50 cm of the surface.

The general elevation of the area ranges from 620 to 660 m above mean sea level (MSL). The area is associated with very gently sloping (1-3%), and gently sloping (3-8%) lands. The drainage is, essentially, dendritic in nature.

Climate

The climate of the study area was characterized by hot sub-humid and has good distribution of rains during the monsoon season. The winter season commences from November and last up to the end of February followed by summer season which continuous up to May. While June to October was the rainy season. The climate of the area is hot, dry and sub-humid with annual rainfall of 794 mm at which nearly 85 per cent is received during June to September (table 3.1). The mean maximum and minimum temperature are 32.7^{0}C and 18.1^{0}C respectively. April and May have high temperature (38.8^{0}C and 39.4^{0}C mean temperature), December and January coolest month (29.3^{0}C and 30.41^{0}C mean temperature). The length of growing period 149 days and humid period 104 days soils has Ustic moisture regime and Hyperthermic temperature regime.

3.1.3 Natural vegetation and present land use

The most of the area is under soybean (*Glycine max)*, Pigeonpea *(Cajanus cajan),* sorghum (*Sorghum bicolar)* and sugarcane (*Saccharum officinarum)* in *kharif* season where as sorghum (*Sorghum bicolar*), wheat *(Triticum austivum)* and gram *(Cicer arietinum*) in the *rabi* season. Field bunds and banks of nalas are covered under dry deciduous plant species and grasses. Commonly occurring species of tree and grasses are Babul *(Acacia arabica)* Ber *(Zizyphus jujuba)* Neem (*Azardirecta indica*), Palas (*Butea monosperma*), Mango *(Mangifera indica*), Hariyally (*Cynodon dactylon*) and kans *(Succharum spontaneum*).

3.2 Remote Sensing and Collateral Data

3.2.1 Remote Sensing Data

Digital data of IRS-LISS-III with bands 2, 3 and 4(Jun, 2013) was used in the present study: The standard false colour composite (FCC) was generated with the combination of green, red and infrared bands. Satellite image of the study area is shown in fig. 3.2

3.2.2 Collateral Data

Survey of India (SOI) toposheet No. 56 B/8 and 56B/12 (1:50,000 scale) was used to collect topographic and location information. The toposheet was used to prepare base map for different landforms, generation of slope and drainage for planning the traverse route for ground truth collection.

Table-3.1 Climatological data (Average 10 years) of Latur district.

Month	Rainfall (mm)	Temperature(°C)		Relative Humidity (%)
		Maximum	Minimum	
January	6	30.41	12.5	60
February	5.2	32.08	14.08	60.2
March	9.02	35.94	17.81	54.7
April	16.86	38.81	21.38	49.92
May	18.51	39.46	22.83	50.9
June	103.03	34.22	21.66	70.3
July	162.48	31.61	21.07	80.4
August	188.46	29.75	20.17	83.2
September	206.57	30.07	21.22	83.2
October	69.07	31.07	18.7	74.6
November	9.4	30.00	14.09	66.4
December	0.2	29.3	11.9	65.7

Source: Oilseed Research Station Latur, V.N.M.K.V. Parbhani.

3.3 Remote Sensing Data Interpretation

The methodology followed for the interpretation of the IRS-1D data is essentially the standard visual interpretation technique based on the tone, texture, pattern, shape, size, association etc. The other ancillary data such as toposheet and other available information (reports, maps etc.) were used for preparation of land use/land cover and physiography maps. Screen digitization was done to prepare various thematic maps. The interpretation methodology comprised of following steps.

- Geo-referencing of imagery with reference to SOI toposheet using ArcGIS software.
- Systematic interpretation of false colour composite (FCC) using image characteristics *viz.* tone/ colour, texture, shape, pattern and size for identification of different landforms, land use/ land cover and to generate pre-field image interpreted base map.
- For physiographic delineation, contours were digitized from SOI toposheet and transferred as layer on satellite image. Satellite data was interpreted and physiographic units *viz.* plateau, escarpment, and pediment, alluvial plain and narrow valley were delineated. Through ground truth, each image interpretation unit *viz.* landform, slope and land use/land cover were verified.
- Satellite data was interpreted for various land-use/land cover classes like agricultural land, waste land, and forest land habitation and water bodies. Further subdivision of agricultural land into single crop, double crop was based on image characteristics of satellite data
- Slope map of the watershed was prepared based on contour information available on SOI toposheet and ground truth data.
- Correlation of image interpretation units with the ground truth observations.
- Random field checks to verify and validate the soil, land use and their boundaries.
- Finalization of physiography, soil and land use/land cover maps with necessary changes after field verification.
- The final output of land use/land cover, slope, physiography and soil were generated using Arc GIS software.

- The land capability, land irrigability, soil productivity and suitability maps were prepared from soil-site characteristics and other data.

3.4 Ground Truth Collection and Methods of Soil Analysis

3.4.1 Ground Truth Collection

Using the interpreted maps (physiography and land use/land cover maps prepared from toposheet and satellite data), the area was traversed to verify different landform units and present land use/land cover classes. To understand the soil variability in the watershed, nine (9) soil profiles and twenty one (21) water samples were studied. Site and soil characteristics like slope, stoniness, erosion, colour, texture, structure etc. were recorded as per Soil Survey Division Staff (2000) and soils were classified as per Keys to Soil Taxonomy (Soil Survey Staff, 2003). Nearly 1.0 kg of representative soil sample from each horizon of all the representative profiles and1 liter representative water sample were collected for laboratory studies.

3.4.2 Soil Analysis

The soil samples collected during the field work were initially air dried in laboratory at room temperature, ground using wooden mortar and pestle, screened through 2 mm sieve, properly labeled and stored in polythene bags for laboratory analysis. For certain soil characteristics like organic carbon, samples were further ground and screened through 80 mesh sieve. The following determinations were made on processed samples by adopting the standard procedures (Jackson 1967, Black *et al.* 1965).

A brief description of standard procedures followed for various morphological, physical and chemical characteristics of soil sample were given below.

3.4.2.1 Morphological properties

Morphological properties of soil were studied in the field and profile description was done as per the procedure suggested by USDA and Soil Survey Staff (1975).

3.4.2.2 Physical properties of soil

1. **Particle size distribution analysis:** The particle size distribution analysis was carried out as per the international pipette method (Jackson, 1979).
2. **Bulk Density:** The bulk density was determined by clod coating method (Piper, 1966).

3. **Hydraulic conductivity:** Disturbed soil sample was fully saturated and then leached with deionized water and hydraulic conductivity of soil was determined by constant head method as described by Richard (1954).

4. **Soil moisture retention:** The moisture retention and release behavior within the available range of 33 kPa to 1500 kPa were based on less than 2 mm sample using pressure plate and membrane apparatus (Richards, 1954).

5. **Available water capacity:** Available water capacity (AWC) and plant available water capacity (PAWC) were determined using the expression suggested by Gardner *et al.* (1984) and latter modified by Coughlam *et al.* (1986).

3.4.2.3 Chemical properties of soil

1. **Soil reaction:** pH of 1:2.5Soils: water suspension was determined electrometrically using pH meter as per method described by Jackson (1979).

2. **Electrical conductivity:** 1:2.5 soil: water suspension as per the method described by Jackson (1979).

3. **Calcium carbonate:** The calcium carbonate was estimated by rapid titration method as described by Piper (1950).

4. **Organic carbon**: Modified Walkley and Black's rapid titration procedure was followed for estimating the organic carbon content (Jackson, 1958).

5. **Cation exchange capacity:** It was estimated by soil screened through 2 mm sieve was saturated with 1N sodium acetate (pH 8.2). After removal of excess sodium acetate by washing with alcohol, the adsorbed sodium was extracted by washing with 1N ammonium acetate (pH 7.0) and the leachate was made up to known volume. Na^+ present in the leachate was determined with a flame emission spectrophotometer (Richards, 1954).

6. **Exchangeable cations:** Exchangeable calcium and magnesium were determined on less than 2 mm samples by leaching with 1N NaCl solution (Piper, 1966) and titrating the leachate with standard EDTA solution as per the method of Richards (1954). Exchangeable sodium and potassium were determined on less than 2 mm soil by leaching with 1N ammonium acetate (pH 7.0) solution. Na and K from the leachates were estimated by flame emission spectrophotometer (Jackson, 1958).

7. **Available nitrogen:** This was determined by alkaline permanganate method by using Kel-plus distillation unit (Subbiah and Asija, 1956).

8. **Available phosphorus:** Available phosphorus was determined by Olsen's method, reading was recorded using spectrophotometer (Jackson, 1967).

9. **Available potassium:** Available potassium was determined by flame photometer using 1N Neutral ammonium acetate (pH 7.0) solution as an extractant as described by (Jackson, 1967).

10. **Available micronutrients:** DTPA (0.005 M) extractable Fe, Mn, Zn and Cu was determined as the procedure outlined by Lindsay and Norvell (1978) using atomic absorption spectrophotometer.

3.4.3 Analysis of water sample

The fresh water samples are collected from the well and tube well in plastic bottles for laboratory analysis. A brief description of standard procedures followed for various chemical characterization of water sample is given below.

1. **Water reaction (pH)**: The pH of water sample was determined by using glass electrode pH meter (Jackson, 1973).

2. **Electrical conductivity (EC)**: Electrical conductivity of water sample was determined by using EC meter (Jackson, 1973) and irrigation water samples were categorized as per the classification of the irrigation water based on salinity hazard (Richards, 1954).

3. **Soluble Cations**

3.1 **Sodium and Potassium (Na^+ and K^+):** Sodium and potassium content in water samples were determined by using flame photometer (Jackson, 1973).

3.2 **Calcium and Magnesium (Ca^{++} and Mg^{++}):** These were estimated by Versenate (EDTA) titration method given by Richards, 1954.

4. **Soluble anions**

4.1 **Carbonates and Bicarbonates (CO_3^{--} and HCO_3^-)**: The carbonates and bicarbonates from water samples were determined by titrimetric method given by Richards, 1954.

4.2 **Chlorides and Sulphate (Cl^- and SO_4^{--}):** Chlorides and sulphates were determined by the Mohr's titration method (Richards, 1954).

5. **Sodium Adsorption Ratio (SAR):** It was computed by the formula (Richards, 1954) as given below.

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

Where, all Cations are expressed in me L^{-1}

6. **Residual Sodium Carbonate (RSC):** RSC was calculated by the following formula given by Eaton (1950)

$$RSC\ (me\ L^{-1}) = (CO_3^{-} + HCO_3^{-}) - (Ca^{++} + Mg^{++})$$

Where, all Cations and anions are expressed in me L^{-1}

7. **Kelley's Ratio**: The ratio of monovalent to divalent cations (Kelley's ratio) is calculated by using the following formula,

Kelley's ratio= Monovalent cations/ Divalent cations.

3.5 Land Evaluation

Land evaluation is the process of assessing the potential of land for alternative uses. There are several methods available for qualitative and quantitative evaluation. Among the various methods, the land capability classification (Klingebiel and Montgomery, 1961), land irrigability classification (AIS&LUS, 1971), land productivity (Riquier *et al.*, 1970) and land suitability classification (Sys, 1971 and FAO, 1976) were used.

3.5.1 Land Capability Classification

The land capability classification given by Klingebiel and Montgomery (1961) as modified by AIS & LUS (1971) was adopted for grouping the soils in different land capability subclasses.

The land capability classification is a broad grouping of soils based on their limitations and is designed to emphasize the hazards in different kinds of soils. Soils are grouped according to their potential and limitations for sustained production. Land suited for cultivation is grouped in class *I* to class *IV* according to the degree of limitations. Lands in class *V* to class *VII* are suited for silviculture, pasture and forestry.

Class *VIII* land is neither suited to agriculture nor forestry but suitable for recreational use.

Land capability classes are divided into subclasses that represent groups of soils having the same kind of dominant limitation for agricultural use. Four kinds of limitation are recognized at subclass level, 'e' for slope, water or wind erosion, 'w' for drainage problems, wetness or overflow, 's' for soil limitations affecting the plant growth and 'c' for limitation due to climate.

3.5.2 Land Irrigability Classification

Land irrigability classification of soils was done as per the procedure outlined in Soil Survey Manual (AIS & LUS, 1971).

The land irrigability grouping of soil and land conditions is concerned primarily with predicting the behavior of soils under the greatly altered moisture regime brought about by introduction of irrigation. According to this, land is grouped into six land irrigability classes. Lands of class 1 to 4 are generally irrigable but limitations in their use for sustained irrigation increase from 1 to 4. However, special and detailed investigations are necessary to assign irrigability class 5 lands on permanent basis. Class 6 lands are not suited to sustained use under irrigation. Land irrigability sub-classes are assigned based on the dominant limitations for sustained use under irrigation. The sub-classes recognized relate to soil deficiencies (s), topography (t) and drainage (d).

3.5.3 Soil Productivity Classification

Soil productivity was evaluated as per procedure outlined by Riquier *et al.* (1970).

Requier *et al.* (1970) proposed a parametric method for land evaluation. This system suggests the calculation of productivity index considering the nine factors as determining soil productivity *viz.* moisture (H), drainage (D), effective depth (P), texture/structure (T), base saturation (N), soluble salt concentration (S), organic matter content (O), mineral exchange capacity/nature of clay (A) and mineral reserve (M). Each factor is rated on a scale from 0-100, the actual percentages being multiplied by each other. The resultant index of productivity, also lying between 0 and 100, is set against a scale placing the soil in one of five productivity classes (excellent, good, average, poor and extremely poor to nil).

3.5.4 Soil-site Suitability Classification

The soil-site suitability for major crops (soybean and pigeonpea) grown in the study area was worked out as per the methodology given in the FAO framework on land evaluation (FAO, 1976) and modified by Sys *et al.,* (1991). Land suitability refers to the fitness of a given type of land for a defined use. Sys *et al.* (1991), described suitability class levels *i.e.* S_1- highly suitable, S_2- moderately suitable, S_3- marginally suitable, N_1- presently unsuitable but suitable after correction, N_2- permanently unsuitable. The suitability units differ in management requirement. The soil-site suitability criteria as suggested by Naidu *et al.*, (2006) have been used for evaluating the suitability of soils for soybean and pigeonpea.

3.6 Generation of Thematic Maps

In the present study, ArcGIS ver. 10.1software was used for spatial and attribute database generation, GIS analysis and generation of various thematic maps. The steps followed are given below

- The line maps of physiography, land use/land cover and field boundaries were created through screen digitization using ArcMap editor by keeping the georeferenced raster maps (satellite data) and toposheet in the background.
- The line map of physiography and land use/land cover were checked for digitization and topological errors and polygonised to generate polygon maps.
- Attributes for physiography, land use/land cover, soils, slope, land capability, land irrigability, soil productivity and soil-site suitability for soybean and pigeonpea crops were added in the attribute table.
- Various thematic maps were generated linking the spatial data with attribute data.

Results and Discussion

CHAPTER-IV

RESULTS AND DISCUSSION

The results of the field and laboratory investigation carried out on soil samples collected from methodically identified soil site in Tungi watershed of Latur district have been presented and discussed in this chapter under following heads.

4.1 Interpretation of satellite data for resource characterization

4.1.1 Land use/ land cover

4.1.2 Physiography mapping

4.2 Soil site characteristics

4.2.1 Morphological properties of soil

4.2.2 Physical properties of soil

4.2.3 Chemical properties of soil

4.3 Quality of Irrigation water

4.4 Soil classification

4.5 Fertility Status of Soil

4.5.1 Available macronutrients

4.5.2 Available micronutrients

4.6 Land evaluation

4.6.1 Land Capability

4.6.2 Land Irrigability

4.6.3 Soil Productivity

4.6.4 Soil-site Suitability

4.7. Land resources development and conservation

4.1 Interpretation of satellite data for resource characterization

Different thematic maps *viz.* land use/land cover, physiography and soil were prepared using IRS-P6 LISS-III (June 2013) data on 1:50,000 scale in combination with SOI toposheet (1:50,000 scale) and verified in field during ground truth. The characterization of different land resources is discussed below.

4.1.1 Land use/land cover

The visual interpretation of IRS LISS-III FCC led to the identification and delineation of different land use/land cover categories such as single crop (kharif and

Rabi crop), double crop, scrubland (Dense and open), water body and built-up area (Habitation) (fig. 4.2). The area under different land use/land cover classes with image characteristics are given in table 4.1. The study indicates that 92.89 per cent area of the watershed is under cultivation like single and double crop. The wasteland, habitation and water body constitute 2.72, 2.38 and 1.71 per cent of the total area, respectively.

4.1.1.1 Single crop

Single crop mainly occurs on very gentle slopes of plateau, and pediment. The single cropland exhibits greenish blue with diffuse checkerboard pattern on satellite data and occupies an area of 17099.27 ha representing 68.66 per cent of the total geographic area (TGA) of the watershed.

4.1.1.2 Double crop

Double crop mainly occurs on very gently sloping pediment and alluvial plain of the watershed and exhibits dark red and brown, bold checker board pattern on IRS LISS-III FCC of Jun 2013. The double cropland occupies an area of 6077.06 ha representing 24.23 per cent of the total geographic area (TGA) of the watershed.

4.1.1.3 Scrubland

Wasteland occurs on plateau, pediment, escarpment and valley and could be delineated and mapped using satellite data as it exhibits very light blue with medium texture, very light blue with pink tone, medium texture and dark brown with medium texture in different physiographic units. Wasteland occupies an area of 473.54 ha representing about 2.72 per cent of the total geographic area (TGA) of the watershed.

4.1.1.4 Waterbody

The water body exhibits dark blue with smooth texture on the satellite data and covers an area of 423.11 ha representing 1.71 per cent of the total geographical area of the watershed.

4.1.4 Physiographic mapping

Based on visual interpretation of IRS LISS-III data along with SOI toposheet and subsequent ground truth verification, three major physiographic unit's *viz.* pediplain (P), Pediments (D) and pediplain- Pediment complex (C) were identified. These physiographic units were further sub-divided based on slope, land use/land cover and

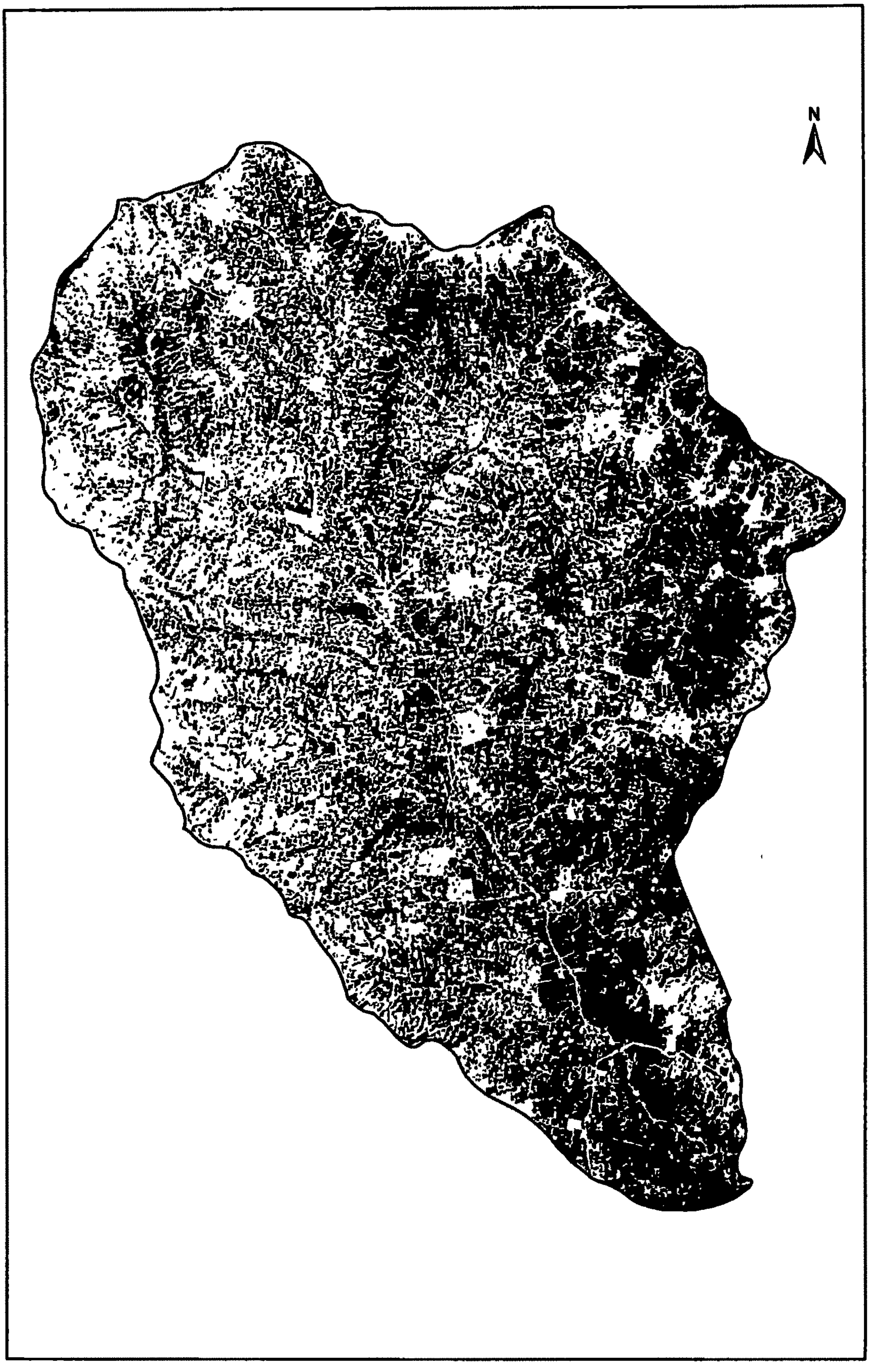

Fig-4.1 Satellite data of Tungi water shed IRS-III, Date: 01 Jun 2013 (23m Resolution)

image characteristics. The physiographic map with three mapping units is presented in fig. 4.3 and physiographic legend and the extent of area is presented in table 4.2.

Table 4.1. Land use/land cover classes of Tungi watershed

Land use class	Image Characteristics	Area	
		Hectares (ha)	% of TGA
Single crop			
Kharif	Greenish blue with diffuse checker board pattern	15905.97	64.21
Rabi		1103.30	04.45
Double crop	Dark red and brown, bold checker board pattern	6077.06	24.23
Build-up area	Red and brown tone with medium texture	588.92	2.38
Scrubland			
Dense	Light pink and bluish pink tone	347.17	01.40
Open		126.37	01.32
Water body	Dark blue, smooth texture	423.11	1.71
Total		**24771.90**	**100**

4.1.4.1 Pediment

The pediment occurs on moderately elevated area (640m above MSL) in the watershed with very gentle slope and occupies an area of 3797.47 ha representing 15.32 per cent of the total area of watershed. This physiographic unit was further sub-divided into very gently sloping pediment, under single crop and wasteland.

4.1.4.3 Pediplain

The plateau is located in the upper reaches of the watershed with elevation ranging from 620 m above mean sea level (MSL) with very gentle slopes (1-3%). It occupies an area of 8414.17 ha 33.96 per cent of the total area of watershed. This physiographic unit was further sub-divided into very gently sloping single crop land and very gently sloping wasteland.

4.1.4.2 Pediplain- Pediment complex

The moderately sloping (3-8%) occurs at an elevation ranging from 600 m above MSL and occupies 12560.28 ha representing 50.70 per cent of total geographic area of the watershed.

4.2.1 Morphological properties of soil

The morphological characteristics of different pedons studied during present investigation and presented in (Table 4.3 and 4.4).

Soil morphology is the study of soil and their characteristics under field condition. Soils are studied only in the field and can be best evaluated in situ examination of soil profile. However, in laboratory soil samples are analyzed for further interpretation. Soil description is based on classifying soil in defined categories in the profile. Various soil horizons were studied. Each horizon was observed and described in respect of various characteristics such as depth, color, texture, consistency etc.

Salient morphological characteristics of the typifying pedon are described as under:

Pedon -1 (P_1)

Location	:	Borphal, Tal. Ausa, Dist. Latur (76^{0}28'24''E to 18^{0}12'51''N)
Land form and slope	:	5-8%, gently to moderately sloping, undulating plain
Drainage	:	Well drained
Vegetation	:	Neem, Nilgiri, Mango and Babul
Parent material	:	Basalt
Climate	:	Hot sub-humid

Table 4.2 Physiography legend of Tungi watershed

Physiography	Slope (%)	Image characteristic	Profile association	Soil characteristic	Soil Taxonomy
Pediment	1-8	Light green and light pink plane with checkerboard	P_1	Very shallow soil, light brownish gray colour (10 YR 6/2) with severe erosion.	Typic Ustorthents
Pediplain	1-3	Dark green, dark pink tone	P_4, P_5 and P_6.	Very deep soil (>150cm), black in colour (10 YR 2.5/1) with nil to moderate erosion.	Typic Haplusterts
Pediment-Pediplain complex	3-8	Dark and light green, dark pink tone	P_2, P_3, P_7, P_8 and P_9.	Moderately deep to shallow soil, light brownish gray (10 YR 6/2), very dark grayish brown (10 YR 3/2) and dark brown (10 YR 3/3) in colour, with moderate erosion	Typic Haplustepts and Typic Haplusterts

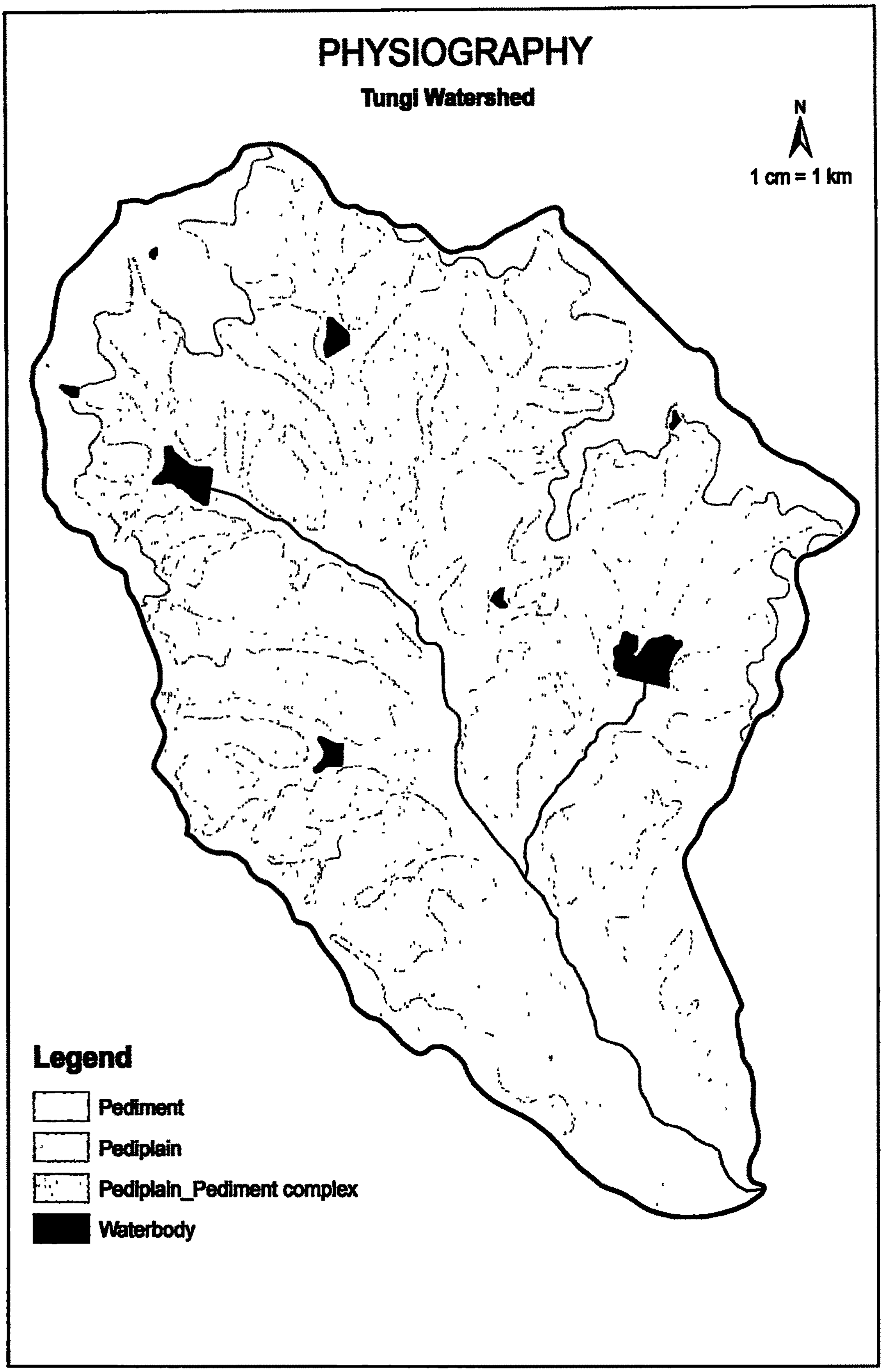

Fig4.3: Physiographic map of Tungi watershed

Classification	:	Typic Ustorthents

Horizon	**Description**
Ap	0-21 cm,---Very Dark grayish brown (10 YR 3/2 D); silty clay loam; medium weak, sub angular blocky structure; soft, friable, slightly sticky, slightly plastic; very fine few, many fine, many pores; very fine many, few many roots; violent effervescence; moderately alkaline (pH 8.07); clear smooth boundary.
M	21-41 cm, ---Light brownish gray (10 YR 6/2 D); silty loam; medium weak, granular structure; soft, friable, non-sticky, non-plastic; coarse few, fine many pores; fine few, coarse few roots; strong effervescence; moderately alkaline (pH 8.07).

Plate No 4.1- Show overall view of the pedon No-1

Plate No 4.11- Show land use and land form around pedon No-1

Pedon- 2 (P_2)

Location	:	Tungi, Tal. Ausa, Dist. Latur ($76^0$28'35" E to $18^0$09'81" N)
Land form and Slope	:	1-3%, moderately sloping, nearly level plain
Drainage	:	Moderately drained
Vegetation	:	Neem, Mango and Jambul
Parent material	:	Basalt
Climate	:	Hot sub-humid
Classification	:	Typic Haplusterts

Horizon	**Description**
Ap	0-20 cm, --- Very dark grayish brown (10 YR 3/2 D); silty clay; medium, moderate, sub angular blocky structure; soft, very sticky , very plastic; very fine many, fine many pores; very fine many, fine many roots; violent effervescence; moderately alkaline (pH 8.00); clear smooth boundary.

Bw_1 20-34 cm,--- Very dark grey (10 YR 3/1 D); silty clay; medium, moderate, sub angular blocky structure; hard, very sticky very plastic; very fine many, fine many pores; vary fine many, fine many, coarse many roots; violent effervescence; moderately alkaline (pH 8.27); clear smooth boundary.

Bw_2 34-43 cm, --- Very dark grey (10 YR 3/1 D); silty clay; medium, moderate, sub angular blocky structure; hard, very sticky very plastic; very fine few, few many pores; fine few, coarse few roots; violent effervescence; moderately alkaline (pH 8.38); diffuse irregular boundary.

Ck 43-64 cm,---Light brownish gray (10 YR 6/2M); silty clay; medium, weak, sub angular blocky structure; soft slightly sticky, slightly plastic; vary fine few, few many pores; fine few, coarse few roots; violent effervescence; moderately alkaline (pH 8.40); diffuse irregular boundary.

Sm 64-115 cm, ---Dark gray (10 YR 4/1 M); silty clay; medium, weak, sub angular blocky structure; friable, non-sticky non-plastic; coarse many pores; fine few, coarse few roots; violent effervescence; moderately alkaline (pH 8.31).

Plate No 4.2- Show overall view of the pedon No-2

Pedon- 3 (P_3)

Location	:	Masalga, Tal. Ausa, Dist. Latur ($76^0$27'17''E to $18^0$08'13''N)
Land form and Slope	:	3-8%, gently to moderately sloping, undulating plain
Drainage	:	Well drained
Vegetation	:	Babul, Neem, Caster and Mango
Parent material	:	Basalt
Climate	:	Hot sub-humid
Classification	:	Typic Haplusterts

Horizon **Description**

Ap 0-18 cm, ---Dark brown (10 YR 3/3 D); silty clay ; medium, moderate, sub angular blocky structure; slightly hard, very sticky, very plastic; very fine many,

Table 4.3 Soil sites land form characteristics of Tungi watershed.

Location	Land form	Parent materials	Slope %	Runoff	Drainage	Erosion
Pedon 1 Borphal	Gently to moderately sloping undulating plain	Basaltic	3-8	Server	Well	Server
Pedon 2 Tungi	Moderately sloping nearly level plain	Basaltic	5-3	Medium	Moderately Well	Moderate
Pedon 3 Masalga	moderately sloping moderatelyplain plain	Basaltic	3-5	Medium	Well drained	Moderate
Pedon 4 Haregoan	Moderately sloping nearly level plain	Basaltic	1-3	Very Slow	Imperfect	Very slow
Pedon 5 Limbala	Moderately sloping nearly level plain	Basaltic	1-3	Slow	Imperfect	Very slow
Pedon 6 Talni	Moderately sloping nearly level plain	Basaltic	1-3	Medium	Imperfect	Moderate
Pedon 7 Dapegoan	Gently to moderately sloping undulating plain	Basaltic	3-8	Server	Well drained	Server
Pedon 8 Fattepur	Level plain	Basaltic	3-5	Medium	Moderately Well	Moderate
Pedon 9 Chincholi Tapse	gentelysloping nearly undulating	Basaltic	1-3	Server	Well drained	Server

Table-4.4 Morphological characteristics of Tungi watershed

Horizon	Depth (Cm)	Course Fragment (%)	Boundary	Matrix Colour	Texture	Structure	Consistancy	Pores	Roots	Efferveces
Pedon 1 Borphal, Tal- Ausa, Dist- Latur (Typic Ustorthents).										
Ap	0-21	7.03	cs	10 YR 3/2	c	m1 sbk	s, fr, ss, sp	vff, mf, m	vfm, fm,	ev
M	21-40	17.70	-	10 YR 6/2	s	m1gr	s, fr, ns, np	cf, fm	ff, cfc	2ev
Pedon 2 Tungi Tal- Ausa, Dist- Latur (Typic Haplustepts).										
Ap	0-20	8.83	cs	10 YR 3/2	sic	m2 sbk	s, vs, vp	vfm, fm	vfm, fm	ev
Bw1	20-34	12.50	cs	10 YR 3/1	sic	m2 sbk	h, vs, vp	vfm, fm	vfm,fm,cm	ev
Bw2	34-43	12.04	di	10 YR 3/1	sic	m2 sbk	h, vs, vp	vff, fm	ff, cf	ev
Ck	43-64	17.38	di	10 YR 6/2	sic	m1 sbk	s, ss, sp	vff, fm	ff, cf	ev
Sm	64-115	4.79	-	10 YR 4/1	s	m1 sbk	fr, ns, np	cm	ff, cf	ev
Pedon 3 Masalga Tal- Ausa, Dist- Latur (Typic Haplustepts).										
Ap	0-18	3.66	cs	10 YR 3/3	sic	m1 sbk	sh, vs, vp	vfm, fm	vf, mf, mcf	ev
Bw1	18-39	43.80	cs	10 YR 3/2	sic	M2 sbk	h, vs, vp	vfm, fm	vf, mf, mcf	ev
Ac	39-50	43.83	cs	10 YR 4/5	si,c,l	m1 gr	s, ns, np	cm	cf	ev
M	50-75	61.88	-	10 YR 5/4	s	gr	s, ns, np	cm	cf	ev
Pedon 4 Haregoan Tal- Ausa, Dist- Latur (Typic Haplusterts).										
Ap	0-18	4.46	cs	10 YR 3/1	sic	m1 sbk	sh, vs, vp	sh	vf , mf,cf	e
Bw1	18-42	5.87	cs	10 YR 2.5/1	sic	m2 sbk	h, vs, vp	vf, mff	vf , mf,cf	e
Bss1	42-66	2.85	cs	10 YR 2.5/1	sic	m3 abk	h, vs, vp	vf, mff	fm, cf	e
Bss2	66-90	4.90	cs	10 YR 2.5/1	sic	m3 abk	h, vs, vp	vf, mff	fm, cf	e
Bss3	90-150	-	-	10 YR 2.5/1	sic	-	h, vs, vp	vf, mff	fm, cf	e
Pedon 5 Limbala Tal- Ausa, Dist- Latur (Typic Haplusterts).										
Ap	0-19	1.82	cs	10 YR 2.5/1	sic	m1 sbk	sh, vs, vp	sh	vf , mf,cf	ev
Bw1	19-38	1.49	cs	10 YR 2.5/1	sic	m2 abk	h, vs, vp	vf, mff	vf , mf,cf	ev
Bw2	38-67	3.35	cs	10 YR 2.5/1	sic	m3 abk	h, vs, vp	vf, mff	fm, cf	ev
Bss1	67-96	5.17	cs	10 YR 2.5/1	sic	m3 abk	h, vs, vp	vf, mff	fm, cf	ev
Bss2	96-145	2.69	-	10 YR 2.5/1	sic	m3 abk	h, vs, vp	vf, mff	fm, cf	ev

Horizon	Depth (Cm)	Course Fragment (%)	Boundary	Matrix Colour	Texture	Structure	Consistancy	Pores	Roots	Effervecces
Pedon 6 Talani Tal- Ausa, Dist- Latur (Typic Haplusterts).										
Ap	0-16	14.81	cs	10 YR 3/1	sic	m1s sbk	sh,vs, vp	vfm, fm, cf	vf , mf,cf	ev
Bw1	16-31	10.75	cs	10 YR 3/1	sic	m2 sbk	sh,vs, vp	vfm, fm, cf	vf , mf,cf	ev
Bw2	31-59	9.16	cs	10 YR 3/2	sic	m2 abk	h, vs,vp	vff, fm	fm, cf	ev
Bss1	59-87	6.49	cs	10 YR 3/2	sic	m2 abk	h, vs,vp	vff, fm	fm, cf	ev
Bss2	87-113	10.91	cs	10 YR 3/3	sic	m2 abk	h, vs,vp	vff, fm	fm, cf	ev
Bss3	113-150	8.06	-	10 YR 4/4	sic	m2 abk	h, vs,vp	vff, fm	fm, cf	ev
Pedon 7 Dapegoan Tal- Ausa, Dist- Latur (Typic Ustorthents).										
Ap	0-28	20.98	cs	10 YR 4/4	sic	m1, sbk	sh, vs, vp	vfm,fm	vfm,fm	e
Ac	28-40	10.88	cs	10 YR 4/3	sic	m1, sbk	sh, vs, vp	vfm,fm	vfm,fm	e
M	40-50	22.17	-	10 YR 5/3	s	gr	fr, ns, np	cf	cf	-
Pedon 8 Fattepur Tal- Ausa, Dist- Latur (Typic Haplustepts).										
Ap	0-18	6.36	cs	10 YR 3/2	sic	m1, sbk	sh, vs, vp	vfm,fm	vfm,fm	e
Ac	18-41	27.15	cs	10 YR 3/2	sic	m1, sbk	sh, vs, vp	vfm,fm	vfm,fm	
M	41-60	52.32	-	10 YR 5/3	s	gr	fr, ns, np	cf	cf	e
Pedon 9 Chincholi Tapse Tal- Ausa, Dist- Latur (Typic Ustorthents).										
Ap	0-18	7.83	cs	10 YR 3/3	sic	m1, sbk	ns, np	vfm,fm	vfm,fm	e
Ac	18-31	22.97	cs	10 YR 4/3	sic	m1, sbk	ns, np	vfm,fm	vfm,fm	e
M	31-45	71.33	-	10 YR 5/3	s	gr	fr, ns, np	cf	cf	e

few many pores; very fine many, fine many, coarse many roots; violent effervescence; moderately alkaline (7.90); clear smooth boundary.

Bw1 18-39 cm, ---Very dark grayish brown (10 YR 3/2 D); silty clay; medium, moderate, sub angular blocky structure; hard, very sticky, very plastic; very fine many, few many pores; very fine many, fine many, coarse few roots; violent effervescence; moderately alkaline (pH 7.90); clear smooth boundary.

Ac 39-50 cm, --- Yellowish brown (10 YR5/4 D); silty clay loam; medium, weak, granular structure; soft, non-sticky, non-plastic; coarse many pores; coarse few roots; violent effervescence; moderately alkaline (pH 8.16); clear smooth boundary.

M 50-75 cm, ---Yellowish brown (10 YR 5/4 D).

Plate No 4.3- Show overall view of the pedon No-3

Plate No 4.12- Show land use and land form around pedon No-3

Pedon- 4 (P_4)

Location	:	Haregoan, Tal. Ausa, Dist. Latur ($76^0$29'57" E to $18^0$06'24" N)
Land form and Slope	:	1-3%, moderately sloping, nearly level plain
Drainage	:	Imperfect drained
Vegetation	:	Babul, Neem, Sindi, Pimple, Ber, Umber and Mango
Parent material	:	Basalt
Climate	:	Hot sub-humid
Classification	:	Typic Haplusterts

Horizon Description

Ap 0-18 cm,---Very dark gray (10 YR 3/1 D); silty clay; medium, weak, sub-angular blocky structure; slightly hard, very sticky, very plastic; very fine many, fine many pores; very fine, many fine, coarse fine roots; slight effervescence; moderately alkaline (pH 8.37); clear smooth boundary.

Bw_1 18-42 cm,---Black (10 YR 2.5/1 D); silty clay; medium, moderate, sub-angular blocky structure; hard, very sticky, very plastic; very fine many, fine few pores; fine many coarse few roots; slight effervescence; strongly alkaline (pH 8.50); clear smooth boundary.

Bss_1 42-66 cm, ---Black (10 YR 2.5/1 D); silty clay; medium, strong, angular blocky structure; hard, very sticky, very plastic; very fine many, fine few pores; fine many, coarse few roots; slight effervescence; moderately alkaline (pH 8.30); clear smooth boundary.

Bss_2 66-90 cm, —Black (10 YR 2.5/1 D); silty clay; medium, strong, angular blocky structure; hard, very sticky, very plastic; very fine many, fine few pores; coarse fine roots; slight effervescence; neutral (pH 7.00); clear smooth boundary.

Bss_3 90-145 cm, --- Black (10 YR 2.5/1 D); silty clay; medium, strong, angular blocky structure; hard, very sticky, very plastic; very fine many, fine few pores; coarse fine roots; slight effervescence; slightly alkaline (pH 7.10); clear smooth boundary.

Plate No 4.4- Show overall view of the pedon No-4

Pedon- 5 (P_5)

Location	:	Limbala, Tal. Ausa, Dist. Latur (76^{0}31'00'' E to 18^{0}04'34''N)
Land form and Slope	:	1-3%, moderately sloping, nearly level plain,
Drainage	:	Imperfect drained
Vegetation	:	Babul, Neem, Sindi, Coconut and Mango
Parent material	:	Basalt
Climate	:	Hot sub-humid
Classification	:	Typic Haplusterts

Horizon **Description**

Ap 0-19 cm, --Black (10 YR 2.5/1 D); silty clay; medium, weak, sub angular blocky structure; slightly hard, very sticky, very plastic; very fine many, fine many pores; very fine many, fine coarse few roots; slight effervescence; slightly alkaline (pH 7.10); clear smooth boundary.

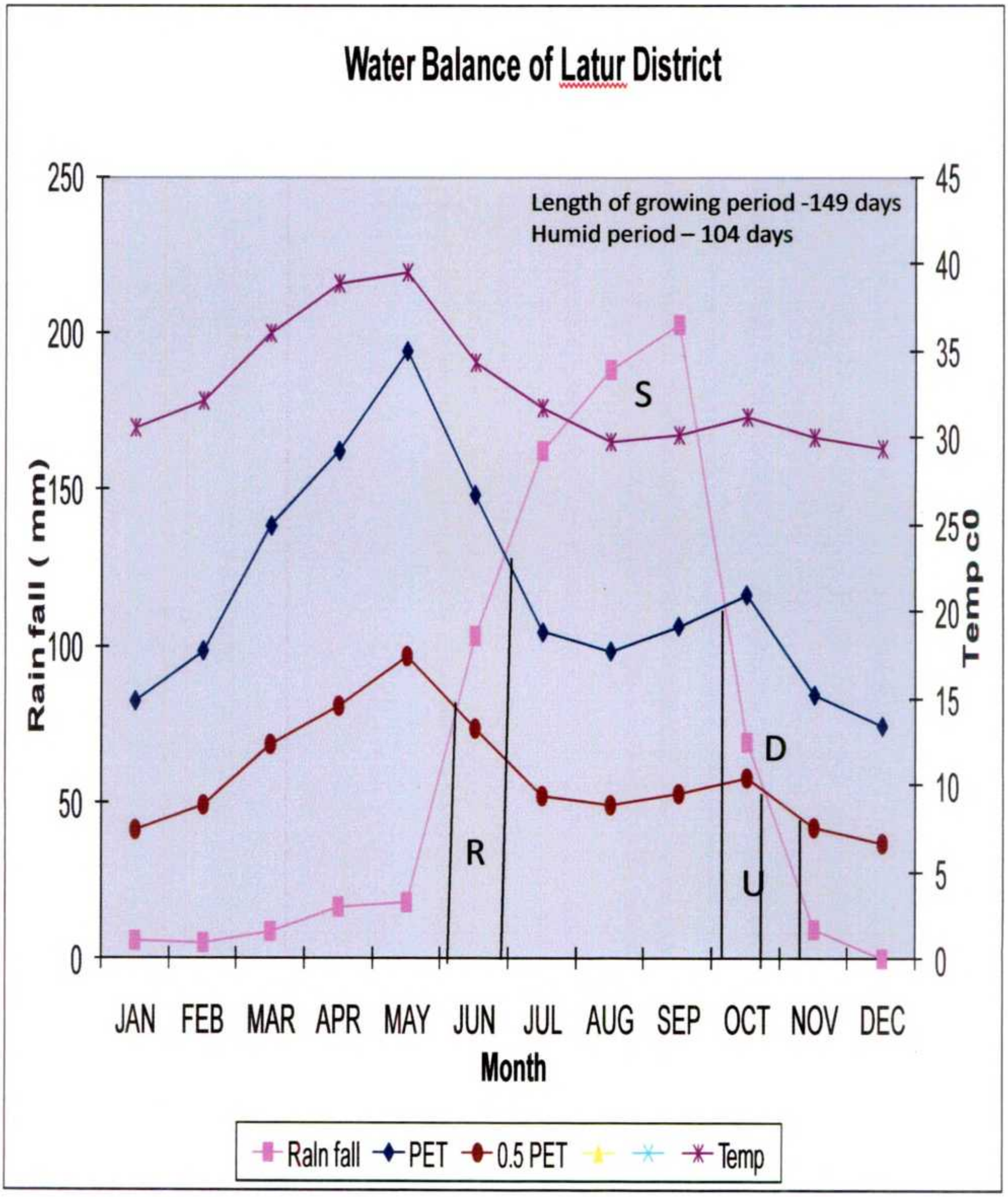

Fig 3.1 : Climatic data and water balance of Latur district.

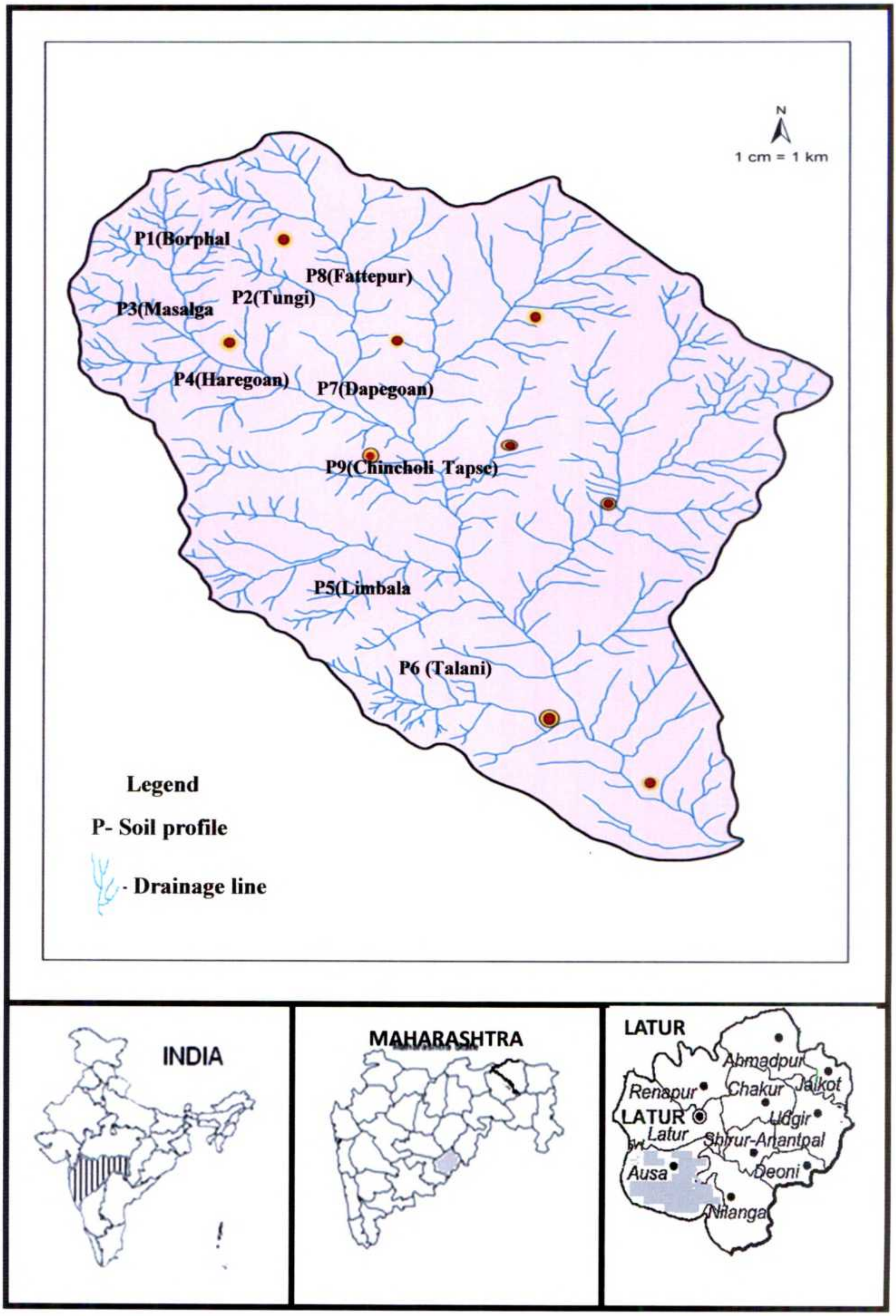

Fig-3.1 Profile location map of Tungi watershed in Latur District

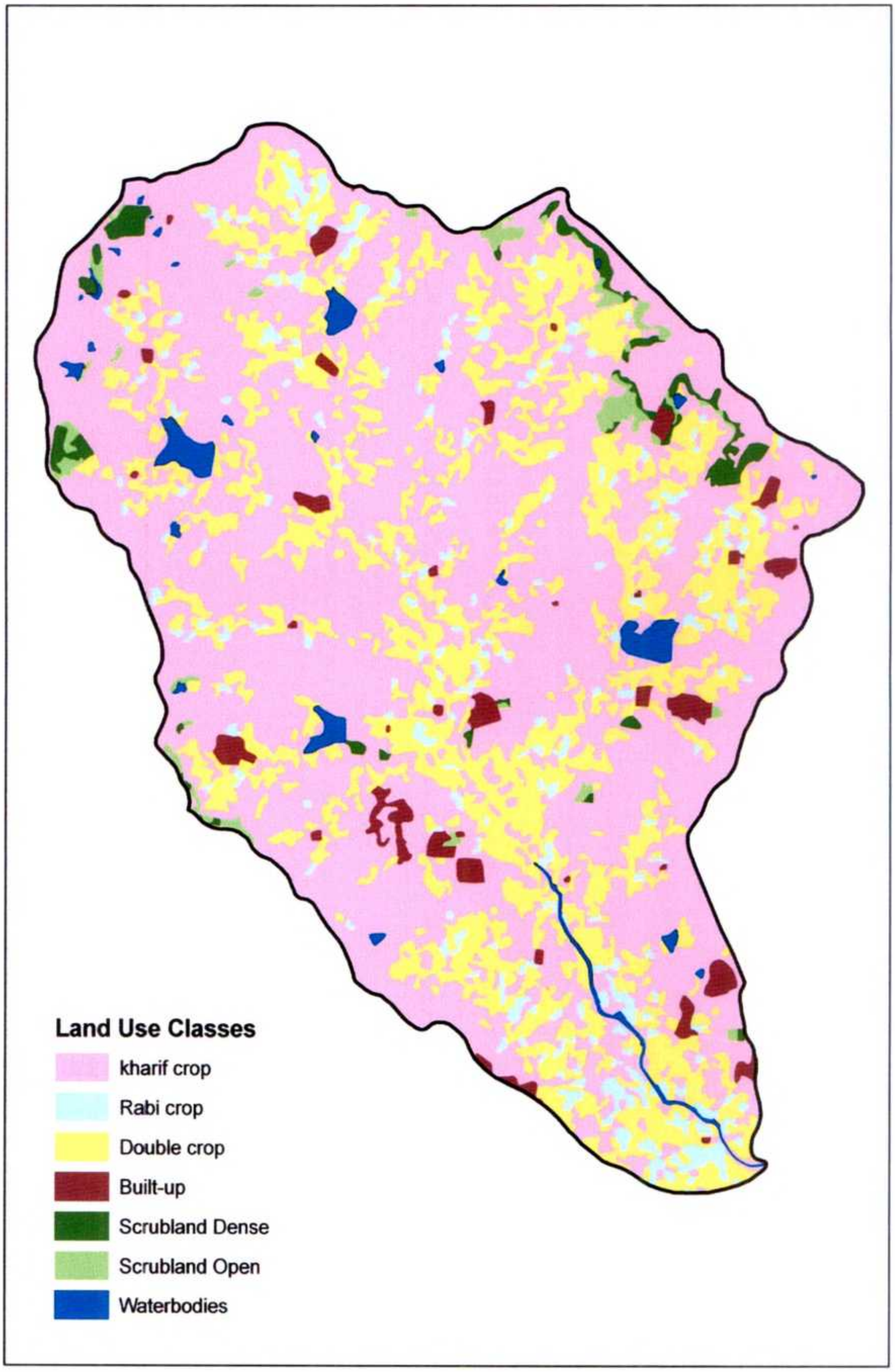

Fig: 4.2 Land use land /cover map of Tungi watershed

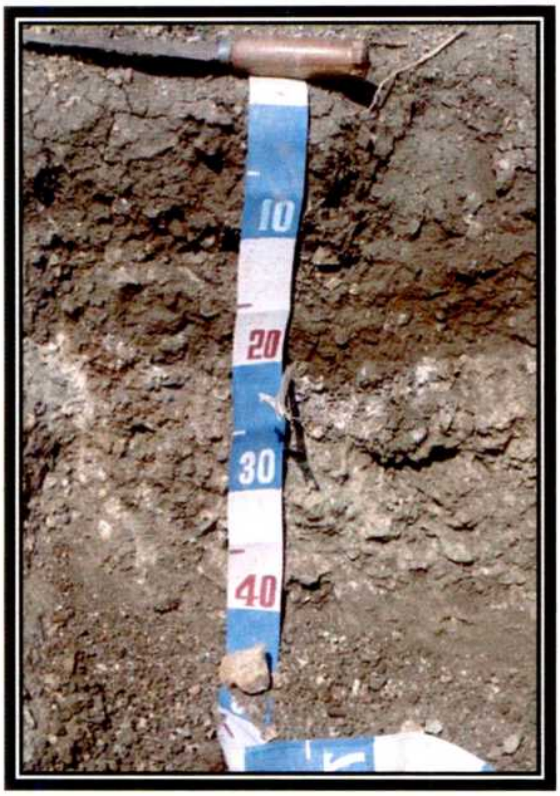

Plate 4.1:Show overall view of pedon-1

Plate 4.2:Show overall view of pedon-2

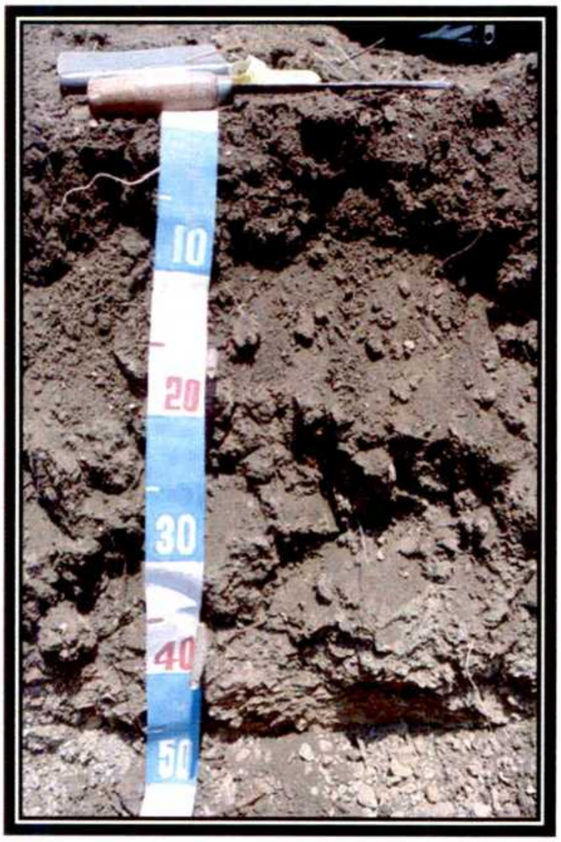

Plate 4.3:Show overall view of pedon-3

Plate 4.4:Show overall view of pedon-4

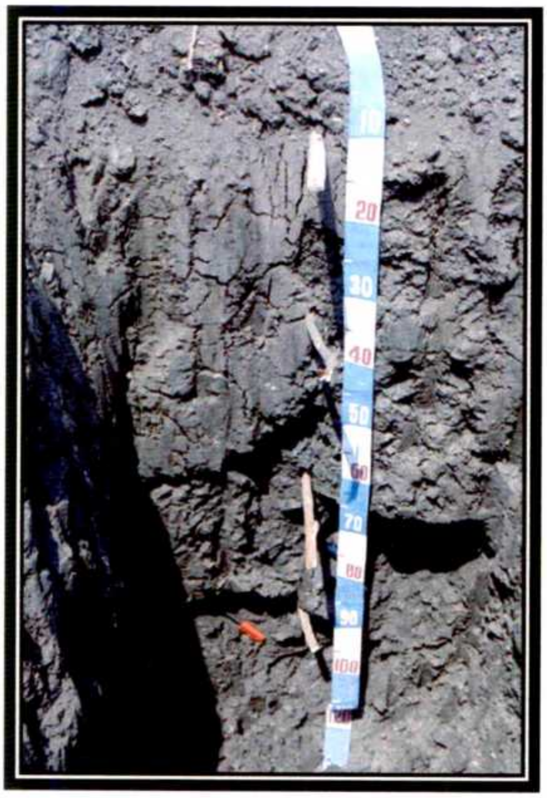

Plate 4.5:Show overall view of pedon-5

Plate 4.6:Show overall view of pedon-6

Fig-4.7 Show Well Developed slickenside in pedon 6

Plate 4.8:Show overall view of pedon-7

Plate 4.9:Show overall view of pedon-8

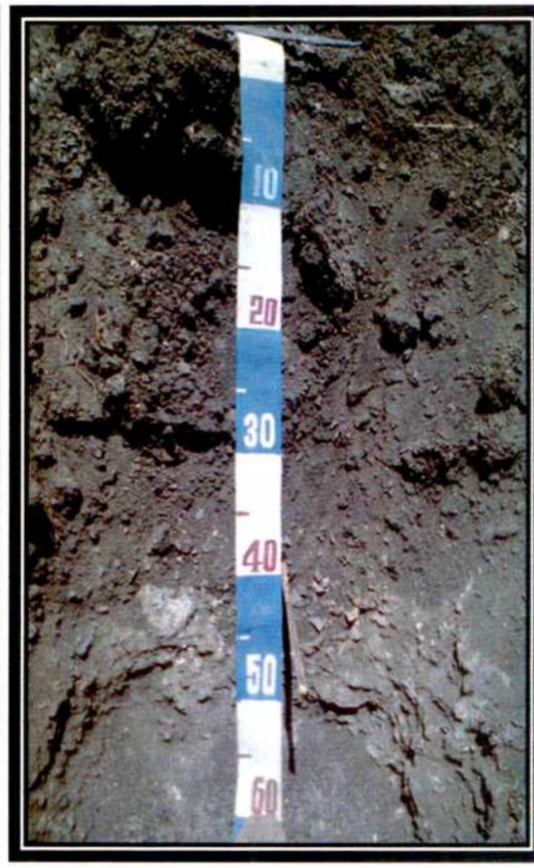

Plate 4.10:Show overall view of pedon 9

Plate 4.11Land use land form around Pedon-1

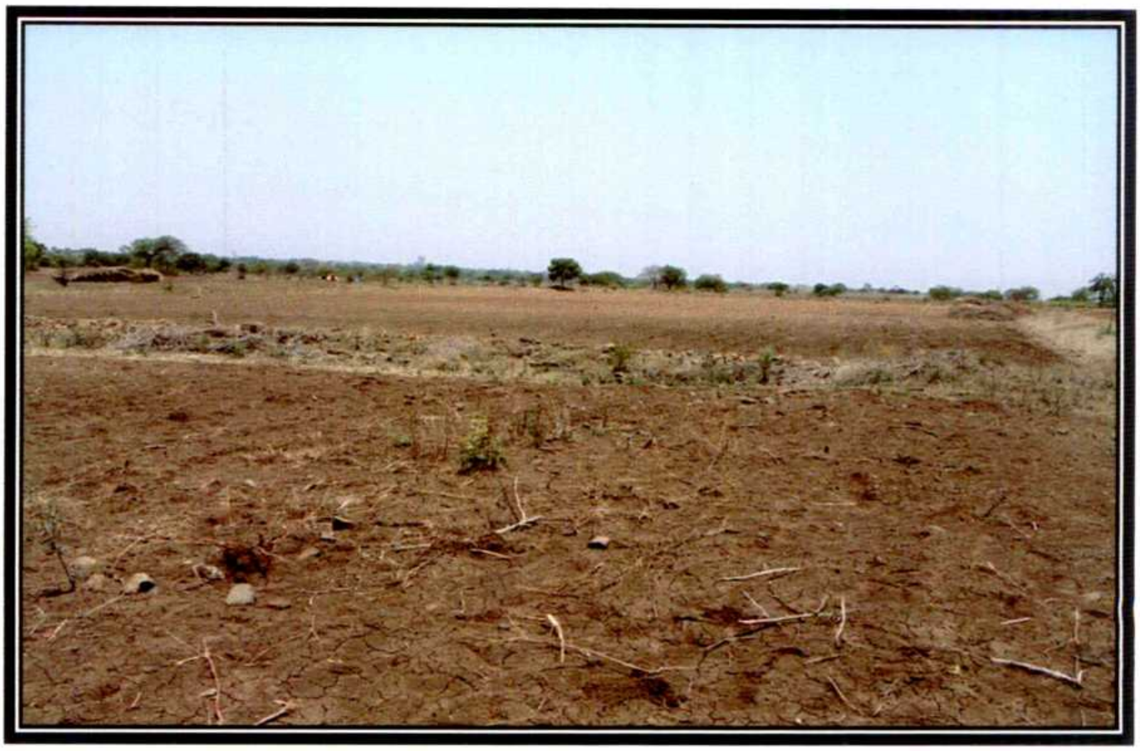

Plate 4.12 Land use land form around Pedon-3

Plate 4.13 Land use land form around Pedon-5

Plate 4.14 Land use land form around Pedon-6

Plate 4.15 Show overview of Well near pedon-1

Bw_1 19-38 cm,--- Black (10 YR 2.5/1 D); silty clay; medium, moderate, sub angular blocky structure; hard, very sticky, very plastic; very fine many, fine few pores; fine many, coarse few roots; slight effervescence; moderately alkaline (pH 7.60); clear smooth boundary.

Bw_2 38-67 cm, ---Black (10 YR 2.5/1 D); silty clay; medium, strong, angular blocky structure; hard, very sticky, very plastic; very fine many, fine few pores; fine many, coarse few roots; slightly effervescence; moderately alkaline (pH 8.00); clear smooth boundary.

Bss_1 67-96 cm,--- Black (10 YR 2.5/1 D); silty clay; medium, strong, angular blocky structure; hard, very sticky, very plastic; very fine many, fine few pores; coarse few roots; slightly effervescence; moderately alkaline (pH 8.00); clear smooth boundary.

Bss_2 96-145 cm, --- Black (10 YR 2.5/1 D); silty clay; medium, strong, angular blocky structure; hard, very sticky, very plastic; very fine many, fine few pores; coarse fine roots; slight effervescence; strongly alkaline (pH 8.87).

Plate No 4.5- Show overall view of the pedon No-5

Plate No 4.13- Show well developed slickenside in pedon No-5

Pedon -6 (P_6)

Location	:	Talni, Tal. Ausa, Dist. Latur (76^{0}31'00'' E to 18^{0}04'34'' N)
Landform and slope	:	1-3%, moderately sloping, nearly level plain
Drainage	:	Well drained
Vegetation	:	Babul, Neem, Nilgiri, Coconut, Palas and Mango
Parent material	:	Basalt
Climate	:	Hot sub-humid
Classification	:	Typic Haplusterts

Horizon **Description**

Ap 0-16 cm,---Very dark gray (10 YR 3/1 D); silty clay; medium, weak, sub angular blocky structure; slightly hard, very sticky, very plastic; very fine many, fine many, coarse fine pores; very fine many, few coarse fine roots; violent effervescences; moderately alkaline (pH 8.10); clear smooth boundary.

Bw_1 16-31 cm,--- Very dark gray (10 YR 3/1 D); silty clay; medium, weak, sub angular blocky structure; slightly hard, very sticky, very plastic; very fine many, fine many, coarse many pores; very fine many, few coarse fine roots; violent effervescence, moderately alkaline (pH 8.10); clear smooth boundary.

Bw_2 31-59 cm, ---Very dark grayish brown (10 YR 3/2 D); silty clay; ; moderate, medium angular blocky structure; hard, very sticky, very plastic; very fine many, fine many, pores; fine many, coarse fine roots; violent effervescence; moderately alkaline (pH 7.87), clear smooth boundary.

Bss_1 59-87cm, --- Very dark grayish brown (10 YR 3/2 D); silty clay; medium, moderate, angular blocky structure; hard, very sticky, very plastic; very fine few, fine many pores; coarse fine roots; violent effervescence; moderately alkaline (pH 8.11); clear smooth boundary.

Bss_2 87-113cm, --- Dark brown (10 YR 3/3 D); silty clay; medium, moderate, angular blocky structure; hard, very sticky, very plastic; very fine few, fine many pores; coarse fine roots; violent effervescence; moderately alkaline (pH 8.13); clear smooth boundary.

Bss_3 113-150 cm, --- Dark yellowish brown (10 YR 4/4 D); silty clay; medium, moderate, angular blocky structure; hard, very sticky, very plastic; very fine few, fine many pores; coarse fine roots, violent effervescence; moderately alkaline (pH 8.30).

Plate No 4.6- Show overall view of the pedon No-6

Plate No 4.14- Show overall view of the pedon No-6

Pedon- 7 (P_7)

Location	:	Dapegoan, Tal. Ausa, Dist. Latur ($76^0 29'60''$ E to $18^0 09'13''$ N)
Land form and Slope	:	3-8%, gently to moderately sloping, undulating plain
Drainage	:	Well drained

Vegetation	:	Neem, Babul and Mango
Parent material	:	Basalt
Climate	:	Hot sub-humid
Classification	:	Typic Ustorthents

Horizon **Description**

Ap 0-28 cm, --- Dark yellowish brown (10 YR 4/4); silty clay loam; soft angular blocky structure; soft, slightly sticky, slightly plastic; very fine many, fine many pores; very fine many, fine many roots; slight effervescences: moderately alkaline (pH 7.97); clear smooth boundary.

Ac 28-40 cm,--- Brown (10 YR 4/3); silty clay loam; soft angular blocky structure; soft, slightly sticky, slightly plastic; very fine many, fine many pores; very fine many, fine many roots; slight effervescences; moderately alkaline (pH 7.85); clear smooth boundary.

M 40-50 cm, --- Brown (10 YR 5/3); loam;

Plate 4.8- Show overall view of the pedon No-7

Pedon- 8 (P_8)

Location	:	Fattepur, Tal. Ausa, Dist. Latur ($76^0$31'54" E to $18^0$11'48"N)
Landform and Slope	:	1-3%, moderately sloping, nearly level plain
Drainage	:	moderately well drained
Vegetation	:	Chinch, Chandan, Jambhul, Neem and Mango
Parent material	:	Basalt
Climate	:	Hot sub-humid
Classification	:	Typic Haplusterts

Horizon **Description**

Ap 0-18 cm,--- Very dark grayish brown (10 YR 3/2); Silty clay; medium, weak, sub angular blocky structure; slightly hard very sticky, very plastic; very fine, many fine pores; very fine many, fine many roots; slight effervescences; strongly alkaline (pH 8.55); clear smooth boundary.

Ac 18-41 cm, --- Very dark grayish brown (10 YR 3/2); Silty clay; medium, weak, sub angular blocky structure; slightly hard, very sticky, very plastic; very fine, many fine pores; very fine many, fine many roots; slight effervescences; moderately alkaline (pH 8.00).

M 41-60cm--- Brown (10 YR 5/3);

Plate 4.9- Show overall view of the pedon No-8

Pedon -9 (P_9)

Location	:	Chincholi Tapse, Tal. Ausa, Dist. Latur ($76^0 32'32''$E to $18^0 07'43''$ N)
Land form and slope	:	3-8%, gently moderate sloping
Drainage	:	Well drained
Vegetation	:	Neem, Ber, Babul, sindi and Mango
Parent material	:	Basalt
Climate	:	Hot sub-humid
Classification	:	Typic Ustorthents

Horizon **Description**

Ap 0-18 cm,--- Dark brown (10 YR 3/3); Silty clay loam; medium, weak, sub angular blocky structure; slightly hard, non-sticky, non-plastic; very fine many, fine many pores; very fine many, fine many, coarse few roots; slight effervescences; moderately alkaline (pH 8.00); clear smooth boundary.

Ac 18-31cm,--- Brown (10 YR 4/3); Silty clay loam; medium, weak, sub angular blocky structure; slightly hard, non-sticky, non-plastic; very fine many, fine many pores; very fine many, fine many, coarse few roots; slight effervescences; moderately alkaline (pH 8.00); clear smooth boundary.

M 31-45 cm, --- Yellowish brown (10 YR 5/4).

Plate 4.10- Show overall view of the pedon No-9

4.2.1.1 Soil Depth

The soil depth is an important factor in the crop production which influences the crop yield in general, increases in yield with increases in soil depth (De La Rosa 1981; Bhaskar *et al.*1987). Soil depth is a central characteristic in land evaluation as it partly control the water storage, available water capacity, storage of nutrients and providing volume for the production of root biomass in the root zone. Soil depth data presented in (Table 4.4) indicated that soil depth varies between 30 to 38 cm in Typic Ustorthents (P_1, P_7 and P_9), moderately deep in Typic Haplustepts 40 to 100 cm (P_2 P_3 and P_8) and very deep in Typic Haplusterts > 150 cm (P4, P5 and P6). The variation in soil depth might be due to the landform setting, (Vadivelu *et al.* 1983, Sharma and Raychaudhary 1988).

4.2.1.2 Soil Colour

Soil colour is one of the important morphological characteristics used for soil identification in the field and it helps in soil classification. Although it has little bearing on the function of the soil, a number of important aspects like wetness, organic matter content and the relative age of the soils can be inferred from soil colour.

The black colour of soil usually indicates the presence of titaniferous magnetite and organic matter; red color indicates the presence of free iron oxides common in well-oxidized soils and commonly found in the humid tropical region.

The soils of the study area had colours in the hue ranging from 10 YR, values ranging from 2.5 to 6 and chroma of 1 to 5. The hue, value and chroma denote dominant spectral colour, lightness or darkness of a color and strength of colour respectively.

The low chroma indicates poor drainage of the soils and the dark colour of the soils may be due to high dark colored ferromagnesian minerals:

The data presented in table No.4.4 indicates that most soils of the study area were black (10 YR 2.5/1) to dark brown (10 YR 3/3) in colour. The pedon P_1 P_7 and P_9 (Typic Ustorthents) soils colour varies from 10 YR 3/2 to 10YR 6/2 corresponds to the very dark grayish brown to light brownish gray. The pedon P_2, P_3 and P_8 (Typic Haplustepts) soils colour varies from 10 YR 3/1 to 10YR 6/2 corresponds to the very dark grey to light brownish gray in colour. The pedon P_4 P_5 and P_6 (Typic Haplusterts) soils colour varies from black (10 YR 2.5/1) to dark yellowish brown (10YR 4/4).

4.2.1.3 Soil structure

The soil structure refers to aggregation of primary soil particles in to large units known as peds. In addition, it can be defined as the arrangement of primary soil particles into secondary units. The secondary units are characterized and classified based on shape, size and degree of distinctness into size, classes, types and grades respectively. The soils have structure varies from, medium strong, angular blocky to medium weak, sub angular blocky in structure in pedon P_4, P_5 and P_6 (Typic Haplusterts) showed well-developed intersecting slickenside and wedge shaped structural aggregates (Plate- 4.7). This may be due to swell shrink properties of Vertisols in such soils resulting in the development of slickenside's (Ahmad 1989).

In Typic Ustorthents (P_1, P_7 and P_9) and in Typic Haplustepts (P_2, P_3 and P_8) soils structure varies from medium weak sub angular blocky to granular soils structure.

4.2.1.4 Soil consistency

Consistency from table 4.3 shows that in pedon P_1, P_7 and P_9 (Typic Ustorthents) the soil consistency in wet condition varies from slightly hard, very sticky, very plastic to friable non-sticky, non-plastic. The pedon P_2, P_3, and P_8 (Typic Haplustepts) soil consistency varies from friable non sticky, non-plastic to hard, very sticky, very plastic in wet condition. While the pedon P_4, P_5 and P_6 (Typic Haplusterts) soils consistency varies from slightly hard, very sticky, very plastic to hard, very sticky, very plastic in wet condition.

4.2.2 Physical characteristics of the soil

4.2.2.1 Coarse fragments

The data in the table 4.4 and table 4.5 indicated that the coarse fragments of the soils at higher topographic position P_1, P_7 and P_9 (Typic Ustorthents) was higher ranged from 7.03 to 71.33 per cent as compare to soil at lower topographic position P_4, P_5 and P_6 (Typic Haplusterts) is varies from 1.49 to 14.81 per cent. It is further noticed that the presence of coarse fragments decrease down the slope. Therefore, it is obvious that the presence of coarse fragments is related with topographic situation.

Table-4.5 Physical characteristics of Tungi watershed

Horizons	Depth (cm)	Coarse fragment (%)	BD (Mg m^{-3})	HC (cm hr^{-1})	Partical size analysis (%)			Moisture retention (%)		AWC (%)	PAWC (mm)
					Sand	Silt	Clay	33 kPa	1500 kPa		
Pedon 1 Borphal, Tal- Ausa, Dist- Latur (Typic Ustorthents).											
Ap	0-21	07.03	1.60	10.60	20.96	48.87	30.17	24.6	11.9	12.7	62.67
M	21-40	17.70	1.30	17.10	31.33	45.78	22.89	18.4	10.3	8.1	
Pedon 2 Tungi Tal- Ausa, Dist- Latur (Typic Haplustepts).											
Ap	0-20	08.83	1.50	6.30	1.50	39.76	58.74	42.1	23.3	18.8	154.22
Bw1	20-34	12.50	1.60	30.00	1.70	39.97	58.33	42.2	24.4	17.9	
Bw2	34-43	12.04	1.60	7.00	6.47	33.34	60.19	40.1	21.0	19.1	
Ck	43-64	17.38	1.45	22.40	8.01	46.37	45.62	26.4	16.4	10.0	
Sm	64-115	04.79	1.55	22.30	10.12	42.45	47.43	20.7	15.4	05.3	
Pedon 3 Masalga Tal- Ausa, Dist- Latur (Typic Haplustepts).											
Ap	0-18	03.66	1.45	8.90	4.14	48.96	46.90	46.2	25.2	21.0	184.70
Bw1	18-39	43.80	1.49	8.7	4.05	48.91	47.04	47.7	25.4	22.3	
Ac	39-50	43.83	1.55	9.7	38.60	22.90	38.50	20.6	15.3	11.5	
M	50-75	61.88	1.40	11.2	48.75	13.25	38.00	20.6	09.2	11.4	
Pedon 4 Haregoan Tal- Ausa, Dist- Latur (Typic Haplusterts).											
Ap	0-18	04.46	1.70	3.40	8.70	29.30	62.00	36.7	19.6	17.1	278.56
Bw1	18-42	05.87	1.73	3.3	8.60	26.62	64.78	43.1	28.4	14.7	
Bss1	42-66	02.85	1.77	3.30	9.03	44.05	64.98	43.9	22.7	21.2	
Bss2	66-90	04.90	1.80	3.80	8.90	22.80	68.30	45.7	28.3	17.4	
Bss3	90-150	04.300	1.70	3.70	7.50	21.50	71.00	46.7	23.4	23.3	
Pedon 5 Limbala Tal- Ausa, Dist- Latur (Typic Haplusterts).											
Ap	0-19	01.82	1.62	4.10	0.84	44.03	55.13	42.4	23.3	19.1	281.55
Bw1	19-38	01.49	1.67	3.20	0.80	45.68	53.52	26.7	13.6	13.1	
Bw2	38-67	03.35	1.59	2.06	0.65	44.60	54.69	42.4	23.7	18.7	
Bss_1	67-96	05.17	1.60	2.30	0.70	42.42	56.88	44.3	24.3	20.0	
Bss_2	96-145	02.69	1.70	0.42	0.70	42.38	56.92	45.2	25.7	19.5	

Horizons	Depth (cm)	Coarse fragment (%)	BD ($Mg\ m^{-3}$)	HC ($cm\ hr^{-1}$)	Partical size analysis (%)			Moisture retention (%)		AWC (%)	PAWC (mm)
					Sand	Silt	Clay	33 kPa	1500 kPa		
Pedon 6 Talani Tal- Ausa, Dist- Latur (Typic Haplusterts).											
Ap	0-16	14.81	1.40	1.00	1.10	44.73	54.17	42.2	20.4	20.4	277.46
Bw1	16-31	10.75	1.90	1.82	0.29	45.81	53.90	47.7	27.2	20.5	
Bw2	31-59	09.16	1.80	8.67	0.25	43.63	56.12	47.9	30.2	17.2	
Bss1	59-87	06.49	1.78	3.03	0.10	43.03	56.87	48.1	29.6	18.3	
Bss2	87-113	10.91	1.90	11.95	0.55	40.36	59.09	47.1	26.8	20.3	
Bss3	113-150	08.06	1.92	9.89	0.31	37.50	62.19	47.6	27.4	20.2	
Pedon 7 Dapegoan Tal- Ausa, Dist- Latur (Typic Ustorthets).											
Ap	0-28	20.98	1.76	11.20	4.37	61.01	34.62	20.6	12.9	08.0	67.56
Ac	28-40	10.88	1.30	9.2	5.60	61.48	32.92	18.4	9.4	09.0	
M	40-50	37.17	1.30	22.30	30.67	19.14	50.19	15.4	3.4	12.0	
Pedon 8 Fattepur Tal- Ausa, Dist- Latur (Typic Haplustepts).											
Ap	0-18	06.36	1.54	8.2	14.40	65.02	50.62	27.6	17.2	09.5	127.8
Ac	18-41	19.10	1.40	10.4	22.17	22.11	55.72	28.4	16.4	18.3	
M	41-60	52.78	1.30	-	27.60	26.12	46.28	27.3	19.6	07.7	
Pedon 9 Chincholi Tapse Tal- Ausa, Dist- Latur (Typic Ustorthets).											
Ap	0-18	07.83	1.60	7.2	7.18	53.82	39.00	20.8	8.8	12.0	56.17
Ac	18-31	22.97	1.40	9.1	14.22	22.83	37.05	18.4	10.3	08.9	
M	31-45	71.33	1.5	24.1	22.96	36.79	40.25	17.4	9.9	07.5	

(BD- Bulk Density; HC- Hydraulic Conductivity; AWC- Available Water Content; PAWC- Plant Available Water Content).

4.2.2.2 Bulk density

Bulk density is the mass of soil per unit volume, including pore spaces (Hillel, 1980). As the bulk density relates to combined volume of the solids and pore spaces, it serves as a guide to assess the soil compaction and porosity. It can be used as an indicator for root penetration and soil aeration.

The bulk density of the soils of Tungi watershed varied from 1.30 to 1.92 Mg m^{-3}. The highest (1.92 Mg m^{-3}) bulk density was observed in Typic Haplusterts (pedon-P_6) as compared to Typic Ustorthents and Typic Haplustepts. The bulk density of Typic Ustorthents (P_1, P_7 and P_9) varies from 1.30 to 1.76 Mg m^{-3}, in Typic Haplustepts (P_2, P_3 and P_8) varies from 1.3 to 1.60 Mg m^{-3} and Typic Haplusterts (P_4, P_5 and P_6) are varies from 1.40 to 1.92 Mg m^{-3}.

In general, the bulk density increased with soil depth and with amount of clay. Surface soils showed lower bulk density as compared to subsurface soils. It may due to high organic carbon and disturbance due to intercultural operation. High value in subsurface layers may be due to smectitic clay and over burden leading to compaction, slickenside has, caused strong structural aggregate formation and high bulk density and root development have the inverse relationship. The bulk density of Typic Haplusterts increases with depth, which is highly co-related with clay content of soil (Ahuja *et al.* 1988).

4.2.2.3 Saturated hydraulic conductivity

The saturated hydraulic conductivity of the study area varies from 0.42 to 30.00 cm hr^{-1}. This variation attributed to textural difference. The saturated hydraulic conductivity of soils of Typic Ustorthents (P_1 P_7 and P_9) is ranged from 7.2 to 24.1 cm hr^{-1}, Typic Haplustepts (P_2, P_3 and P_8) varied from 6.30 to 30.0 cm hr^{-1} and Typic Haplusterts (P_4, P_5 and P_6) are ranged from 0.42 to 11.95 cm hr^{-1}. The hydraulic conductivity of surface soil is less as compared to subsurface in pedon P_4, P_5 and P_6. This variation attributed to application of irrigation water similar observation was reported by Nimkal *et al.* (1992) and Vaidya *et al.* (2007). The hydraulic conductivity of subsurface layer is high. This is due to presence of loose weathered murrum.

4.2.2.4 Particle size distribution

The data represented in table 4.5 indicated that the particle size distribution analysis indicates the general picture of physical nature of soil and also gives insight into its chemical and biological potentials. The particle size distribution related directly or indirectly to plant growth and provides understanding in respect of soil water retention, nutrient retention and their availability, workability, drainage condition and crop suitability.

The soils of the study area are developed on basaltic parent material and the soil developed on basalt produces high amount of clay on weathering (Eswaran *et al.* 1988).

From the data (Table 4.5), it is observed that the texture of all surface samples in the study area was silty clay in nature. The highest clay content was found in the pedon P_4 (71.00%). The soils at high topography Typic Ustorthents (P_1, P_7 and P_9) clay content varied from 22.89 to 50.19 per cent. The soils at sloping landscape Typic Haplustepts (P_2, P_3 and P_8) clay content ranged between 38.0 to 60.19 per cent were as at lower topographic position Typic Haplusterts (P_4, P_5 and P_6) clay content ranged between 53.52 to 71.00 per cent which correspond to clay texture. The data showed that soil developed on lower topographic position showed higher clay content as compared to soil developed on higher topographic position; topography and slope were found to affect the particle size distribution.

4.2.2.5 Moisture retention

The data represented in table 4.4 indicated that the moisture retention mainly dependent upon the amount and size of clay fraction and the type of clay minerals. The moisture retention increased with depth of the profile at 33 kPa as well as 1500 kPa. In general, deep soils Typic Haplusterts (P_4, P_5 and P_6) showed higher moisture retention which may be attributed to the increase in clay and the smectitic clay minerals that have large surface area to retain higher amount of water at high section (Ali and Biswas 1971).

The moisture retention in Typic Ustorthents (P_1, P_7 and P_9) soils varied from 17.4 to 24.6 at 33 kPa and 3.4 to 12.9 at 1500 kPa, in Typic Haplustepts (P_2, P_3 and P_8) soils varied from 20.6 to 46.2 at 33 kPa and 09.2 to 25.4 at 1500 kPa and in Typic

Haplusterts (P_4, P_5 and P_6) soils varied from 26.7 to 47.9 at 33 kPa and 13.6 to 30.2 at 1500 kPa suction respectively.

4.2.2.6 Plant available water capacity

The data represented in table 4.5 indicated that the available water capacity of the soils of Typic Ustorthents ranged from 07.5 to 12.7 per cent and PAWC value varies from 56.17 to 67.56 mm. The soils of Typic Haplustepts have AWC value ranged from 05.3 to 22.3 per cent and PAWC value varies from 127.08 to 184.7 mm. The available water capacity of soils of Typic Haplusterts ranged from 13.1 to 23.3 per cent and PAWC value varies from 277.86 to 281.55 mm. This indicated that the maximum available water content at soils of Typic Haplusterts followed by Typic Haplustepts and Typic Ustorthents. However, murrum layer recorded low PAWC compared to their respective soil. PAWC was found to increase with depth in soil. Gardner et al. (1984) that the plant available water capacity is limited by rooting depth have recorded it. The capacity of soil to store moisture for plant use is largely a function their clay content, depth of soil and mineralogy of soil. The correlation of soil depth with PAWC (r=0.949271) and clay content with PAWC (r=0.884944) were highly positive correlated obtained (Fig. 4.7& 4.8). This suggests that the soil depth, texture and PAWC are interrelated to each other and in turn control the crop yield.

4.2.3 Chemical properties

4.2.3.1 Soil reaction

The pH data presented in the table 4.6 indicated that the soils are slightly to strongly alkaline in reaction with pH ranged from 7.01 to 8.87. In Typic Ustorthents soils (P_1, P_7 and P_9) had pH value ranged from 7.80 to 8.07, Typic Haplustepts soils (P_2, P_3 and P_8) ranged from 7.90 to 8.55 and Typic Haplusterts (P_4, P_5 and P_6) soils have pH ranged from 7.00 to 8.87. The data shows that pH of soils decreasing with increasing altitude (Rajkumar *et al.* 1985).

4.2.3.2 Electrical conductivity

The data represented in table 4.6 indicated that the Electrical conductivity of the studied soil varies from 0.13 to 0.67 dSm^{-1}. Which is well within safe limit of electrical conductivity range, designated for normal soil (Richards, 1954) and all soils comes under non-saline class. The EC value of murrum layer as relatively less as compared to surface layer (0.13 to 0.28 dSm^{-1}).

4.2.3.3 Organic carbon

The data represented in table 4.6 indicated that the soil organic matter plays a very important role in maintenance and improvement of soil properties as well as nutrient status of soil. In addition to this, it also improves soil structure, infiltration rate, hydraulic conductivity, water and nutrient storage capacity and reduces soil erosion (Smith and Elliott 1990).The organic carbon content of Typic Ustorthents soil varied from 0.11 to 0.42 per cent, Typic Haplustepts soil varied from 0.04 to 0.61 and Typic Haplusterts soil varied from 0.07 to 0.81 per cent respectively. It was observed that as depth increases, percent organic carbon decreased. The soils were low to high in organic carbon content. The organic carbon content is low in murrum layer as compared to the overlying horizons.

4.2.3.4 Calcium carbonate

The data represented in table 4.6 indicated that the calcium carbonate content in soils of Typic Ustorthents was varied from 4.4 to 20.4 in Typic Haplustepts varies from (8.3 to 37.0) and Typic Haplusterts varies from (6.6 to 20.4). These soils contain low to high amount of $CaCO_3$. The high calcium carbonate in soil affects the available water capacity of soil, which has a great influence on crop production under rain fed conditions. High calcium carbonate affects the physical and chemical properties of soil and may prevent the root penetration (Sys 1985).

4.2.3.5 Cation exchange capacity

The data represented in table 4.9 indicated that the cation exchange capacity of Typic Ustorthents (P_1, P_7 and P_9) ranged from 27.50 to 44018 $cmol(p^+)kg^{-1}$, Typic Haplustepts (P2, P_3 and P_8) varied from 36.62 to 56.20 $cmol(p^+)kg^{-1}$ and Typic Haplusterts (P_4, P_5 and P_6) ranged from 48.52 to 63.58 $cmol(p^+)kg^{-1}$. The highest CEC was observed in Typic Haplusterts as compared to Typic Haplustepts and Typic Ustorthents. The high CEC is attributed to the high amount of clay. The relationship of cation exchange capacity and clay content in soil found to be significant positively correlated (r=0.982697) and which was increased with increasing clay content in soil (Fig. 4.7). Clay fraction of appears to influence largely the cation exchange capacity

Table-4.6Chemical characteristics of Tungi watershed

Horizons	Depth (cm)	pH	EC (dSm^{-1})	OC (%)	$CaCO_3$ (%)	CEC ($cmol(P^+)kg^{-1}$)	Cations ($cmol(P^+)kg^{-1}$)					Base saturation (%)
							Ca^{++}	Mg^{++}	K^+	Na^+	Sum of Cations ($cmol(P^+)kg^{-1}$)	
Pedon 1 Borphal, Tal- Ausa, Dist- Latur (Typic Ustorthents).												
Ap	Ap	8.07	0.18	0.42	19.6	33.51	18.0	08.8	1.09	2.19	30.08	89.79
M	M	8.07	0.13	0.19	20.4	27.50	17.6	06.8	0.26	2.28	26.94	97.96
Pedon 2 Tungi Tal- Ausa, Dist- Latur (Typic Haplustepts).												
Ap	Ap	8.00	0.13	0.58	20.0	56.20	34.0	14.0	0.62	2.08	50.70	90.21
Bw1	Bw1	8.27	0.12	0.40	26.9	50.92	32.8	12.8	0.52	2.32	48.44	95.12
Bw2	Bw2	8.38	0.50	0.07	27.0	48.90	32.4	10.4	0.49	1.92	45.21	92.45
Ck	Ck	8.40	0.18	0.07	37.0	41.34	24.8	09.6	0.28	3.29	37.97	91.84
Sm	Sm	8.31	0.13	0.04	36.9	48.20	19.4	22.2	0.25	4.19	46.04	95.51
Pedon 3 Masalga Tal- Ausa, Dist- Latur (Typic Haplustepts).												
Ap	Ap	7.90	0.16	0.12	09.3	50.20	44.8	09.6	0.49	2.05	56.94	113.42
Bw1	Bw1	7.90	0.13	0.45	08.3	47.30	41.6	06.8	0.34	2.17	44.79	94.69
Ac	Ac	8.16	0.19	0.39	13.7	36.62	24.8	06.4	0.24	1.56	33.00	90.11
M	M	8.00	0.13	0.28	14.5	36.70	22.4	09.2	0.31	1.26	33.17	90.38
Pedon 4 Haregoan Tal- Ausa, Dist- Latur (Typic Haplusterts).												
Ap	Ap	8.37	0.17	0.78	08.8	59.52	43.2	11.2	0.98	1.92	57.30	96.27
Bw1	Bw1	8.50	0.12	0.46	11.4	63.52	37.6	18.0	0.73	3.24	59.57	93.78
Bss1	Bss1	8.30	0.21	0.54	09.8	59.52	36.0	18.4	0.73	2.44	57.57	96.72
Bss2	Bss2	7.00	0.19	0.31	06.7	62.74	35.0	20.8	0.70	2.97	59.47	94.78
Bss3	Bss3	7.00	0.22	0.29	06.6	61.71	34.7	21.3	0.63	3.00	59.63	95.76
Pedon 5 Limbala Tal- Ausa, Dist- Latur (Typic Haplusterts).												
Ap	Ap	7.10	0.16	0.76	13.4	60.12	43.3	09.9	1.47	2.61	57.28	95.27
Bw1	Bw1	7.60	0.19	0.39	12.6	56.84	37.4	13.4	1.10	3.58	55.48	97.60
Bw2	Bw2	8.00	0.28	0.31	13.1	48.52	41.2	06.0	0.92	3.64	46.36	95.54
Bss1	Bss1	8.00	0.30	0.49	12.0	57.30	38.4	12.8	0.77	3.61	55.58	96.99
Bss2	Bss2	8.87	0.59	0.15	15.0	53.90	27.2	19.2	0.66	3.89	50.95	94.52

Horizons	Depth (cm)	pH	EC (dSm^{-1})	OC (%)	$CaCO_3$ (%)	CEC ($cmol(P^+)kg^{-1}$)	Cations ($cmol(P^+)kg^{-1}$)					Base saturation (%)
							Ca^{++}	Mg^{++}	K^+	Na^+	Sum of Cations ($cmol(P^+)kg^{-1}$)	
Pedon 6 Talani Tal- Ausa, Dist- Latur (Typic Haplusterts).												
Ap	Ap	8.10	0.26	0.81	16.6	52.14	35.6	10.4	2.37	3.19	51.56	98.88
Bw1	Bw1	8.10	0.24	0.42	20.5	50.36	36.4	10.0	1.23	3.48	51.11	101.48
Bw2	Bw2	7.87	0.37	0.10	19.3	59.26	37.2	14.4	0.78	2.70	55.08	92.94
Bss1	Bss1	8.11	0.53	0.07	14.9	58.60	32.8	19.2	0.80	2.74	55.54	94.77
Bss2	Bss2	8.13	0.59	0.43	19.0	60.04	31.2	20.8	0.90	2.88	55.78	92.90
Bss3	Bss3	8.30	0.67	0.30	12.0	61.14	26.8	22.0	1.04	4.11	53.95	88.82
Pedon 7 Dapegoan Tal- Ausa, Dist- Latur (Typic Ustorthets).												
Ap	Ap	7.97	0.36	0.25	04.4	32.92	22.0	06.8	1.26	0.99	31.05	94.37
Ac	Ac	7.85	0.16	0.18	14.6	34.62	17.6	14.4	0.66	0.97	33.63	97.14
M	M	7.80	0.15	0.11	15.1	29.40	14.4	10.9	0.70	0.87	26.87	89.86
Pedon 8.Fattepur Tal- Ausa, Dist- Latur (Typic Haplustepts).												
Ap	Ap	8.55	0.15	0.61	19.0	53.70	40.4	06.4	1.36	1.93	50.09	93.27
Ac	Ac	7.90	0.17	0.30	20.21	50.60	37.9	05.3	0.97	1.99	46.16	91.10Bw_1
M	M	8.00	0.20	0.16	29.3	46.12	36.0	05.2	0.45	2.00	43.62	94.97
Pedon 9 Chincholi Tapse Tal- Ausa, Dist- Latur (Typic Ustorthets).												
Ap	Ap	8.00	0.25	0.30	05.6	36.55	22.4	10.0	0.53	1.87	34.80	95.21
Ac	Ac	8.00	0.25	0.15	07.0	35.34	24.8	05.2	0.27	1.91	32.18	91.05
M	M	8.00	0.28	0.34	11.8	44.18	25.6	12.0	0.37	2.32	40.39	91.42

Table 4.7 Physical and chemical characteristics of typifying pedons and yield of Soybean and Pigeonpea (weighted means).

Pedon	Depth (cm)	Clay (%)	PAWC (mm)	pH	EC dSm-1	OC (%)	$CaCO_3$ (%)	CEC (cmol(P^+)kg-1)	Yield (q ha^{-1})	
									Soybean	Pigeonpea
P_1	40	30.40	62.67	8.0	0.15	0.31	09.98	30.65	07.9	06.50
P_2	115	51.48	154.22	8.2	0.16	0.18	31.98	48.72	21.5	15.75
P_3	75	44.61	184.7	7.9	0.14	0.30	11.39	42.89	18.8	11.25
P_4	150	67.52	278.56	7.6	0.19	0.41	08.16	61.55	23.5	17.20
P_5	145	55.78	281.55	8.1	0.36	0.36	13.49	54.70	21.5	18.75
P_6	150	57.84	277.46	8.1	0.48	0.23	16.45	58.08	20.8	18.25
P_7	50	37.32	67.54	7.9	0.27	0.20	8.98	32.61	15.7	10.00
P_8	60	51.20	127.80	8.1	0.17	0.34	22.63	50.11	18.8	12.50
P_9	45	38.82	56.17	8.0	0:26	0.26	07.93	38.57	07.9	06.50

Table 4.8 Correlation coefficients between soils attributes and yield of Soybean

Crop	Parameter X	Parameter Y	R
Soybean	Depth(cm)	PAWC (mm)	0.94*
	Clay (%)	CEC (cmol(P^+)kg^{-1})	0.69*
	Clay (%)	PAWC (mm)	0.69*
	Depth(cm)	Yield (q ha^{-1})	0.81*
	Clay (%)	Yield (q ha^{-1})	0.49
	PAWC (mm)	Yield (q ha^{-1})	0.82*
	OC (%)	Yield (q ha^{-1})	0.19
	$CaCO_3$ (%)	Yield (q ha^{-1})	0.41
	CEC (cmol(P^+)kg^{-1})	Yield q ha^{-1})	0.82

* Significant at 1 % **Significant at 5%

Table 4.9 Correlation coefficients between soils attributes and yield of Pigeonpea.

Crop	Parameter X	Parameter Y	R
Pigeonpea	Depth(cm)	PAWC (mm)	0.94*
	Clay (%)	CEC (cmol(P^+)kg^{-1})	0.69**
	Clay (%)	PAWC (mm)	0.69**
	Depth(cm)	Yield (t ha^{-1})	0.95*
	Clay (%)	Yield (t ha^{-1})	0.61
	PAWC (mm)	Yield (t ha^{-1})	0.92*
	OC (%)	Yield (t ha^{-1})	0.19
	$CaCO_3$ (%)	Yield (t ha^{-1})	0.37
	CEC (cmol(P^+)kg^{-1})	Yield (t ha^{-1})	0.90*

* Significant at 1 % **Significant at 5%

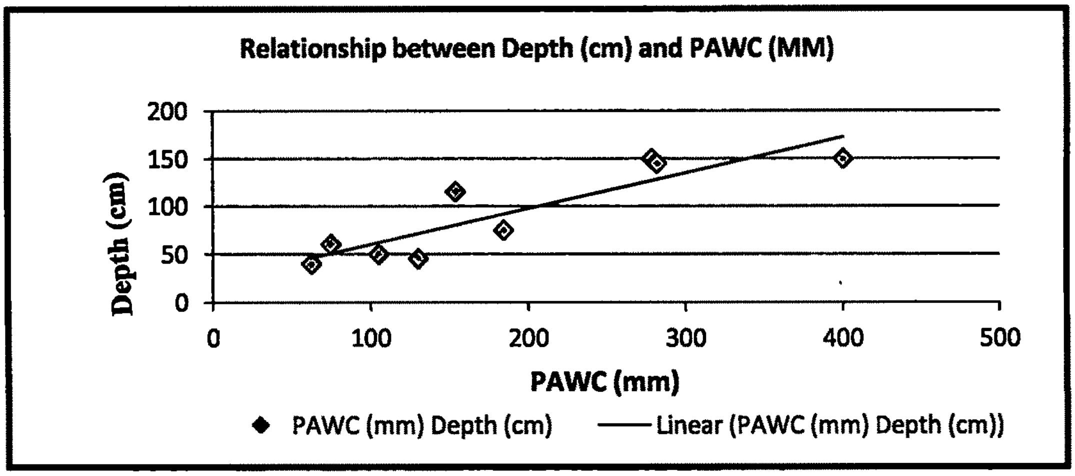

Fig-4.4Relationship between Depth (cm) and PAWC (mm) in Tungi watershed.

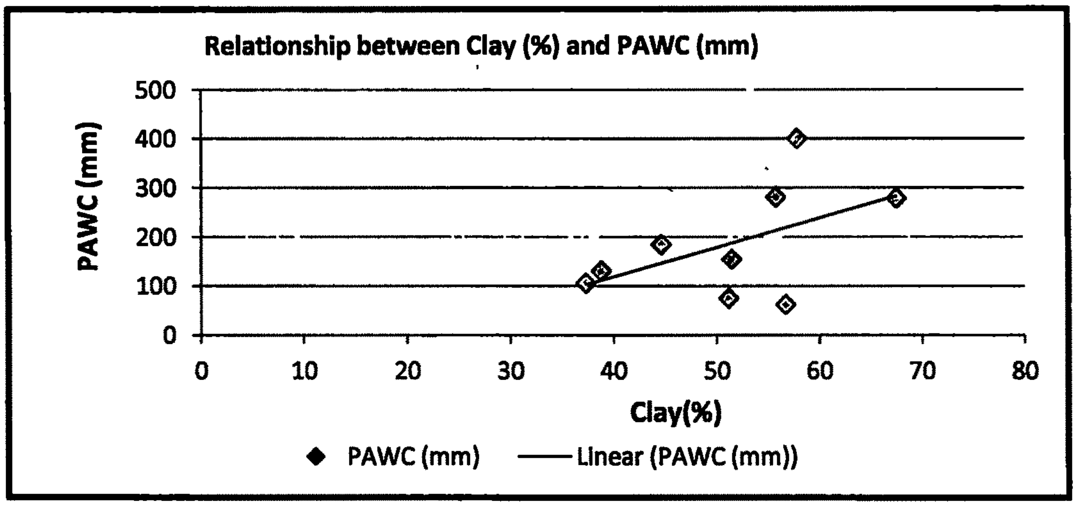

Fig-4.5 Relationship between Clay (%) and PAWC (mm) in Tungi watershed.

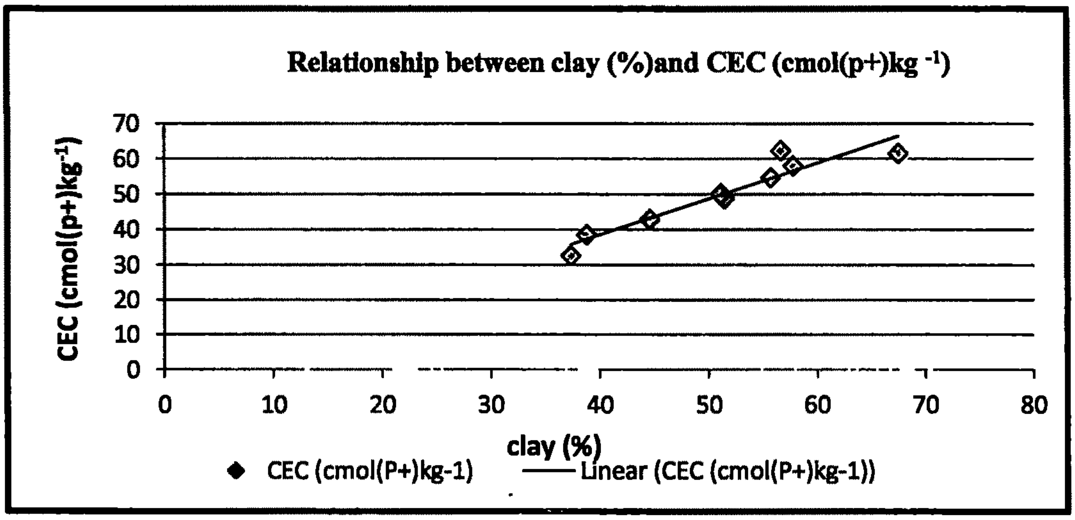

Fig-4.6 Relationship between clay (%)and CEC (cmol(p+)kg $^{-1}$) in Tungi watershed.

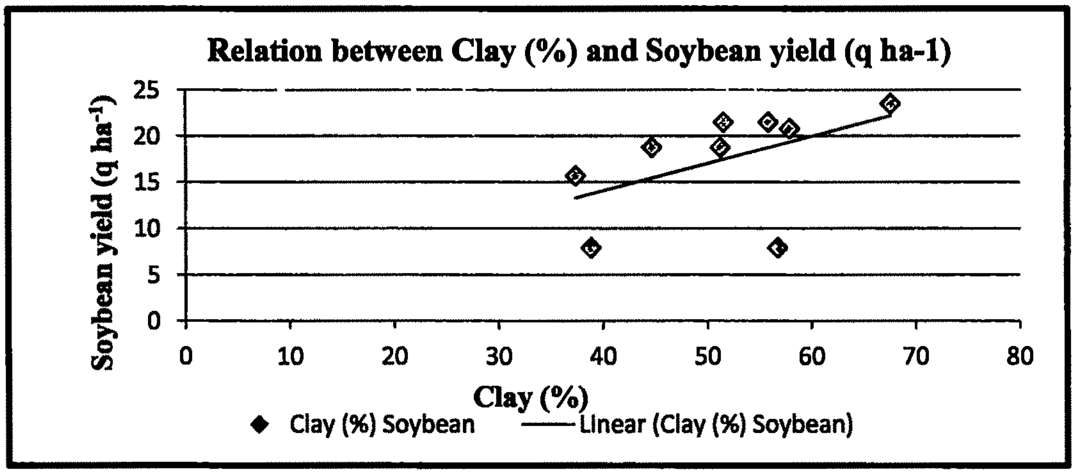

Fig-4.7 Relationship between Clay (%) and soybean yield (q ha^{-1}) in Tungi watershed

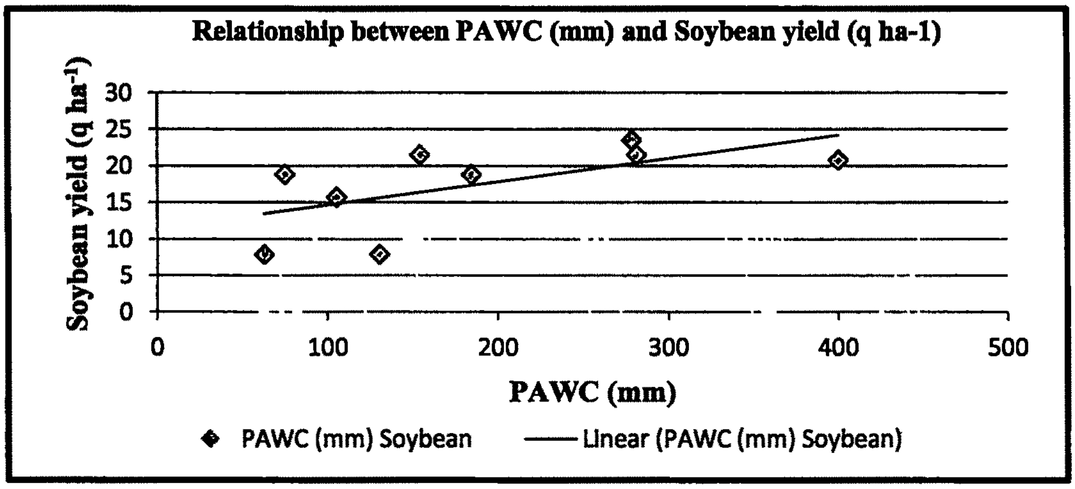

Fig-4.8 Relationship between PAWC (mm) and soybean yield (q ha^{-1}) in Tungi watershed

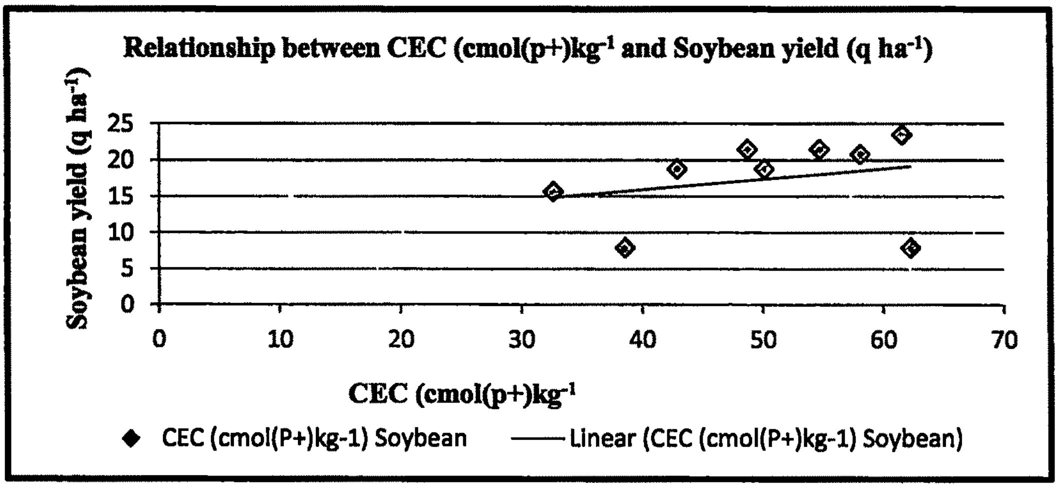

Fig-4.9 Relationship between CEC (cmol(p+)kg^{-1}andsyield (q ha^{-1}) in Tungi watershed

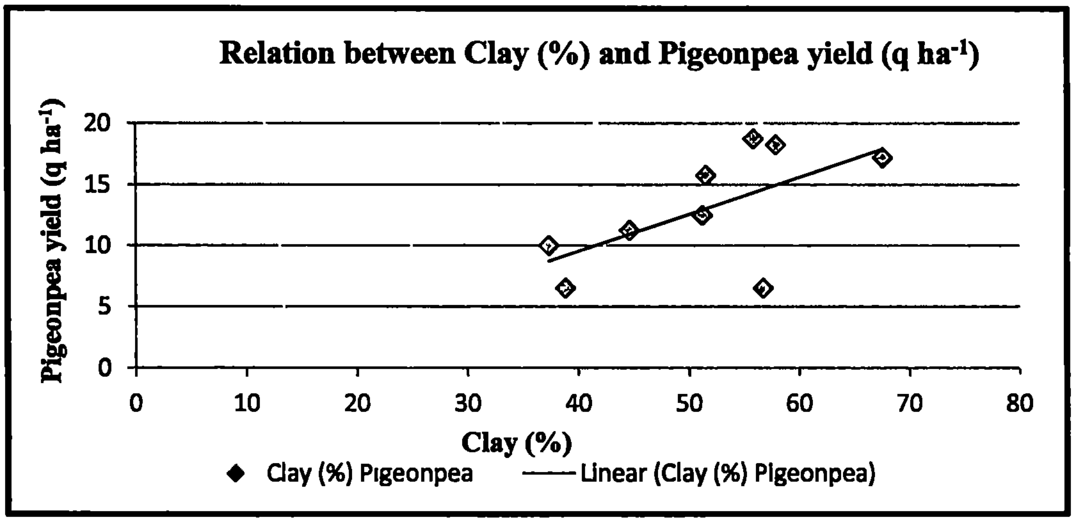

Fig-10 Relationship between Clay (%) and pigeonpea yield (q ha^{-1}) in Tungi watershed

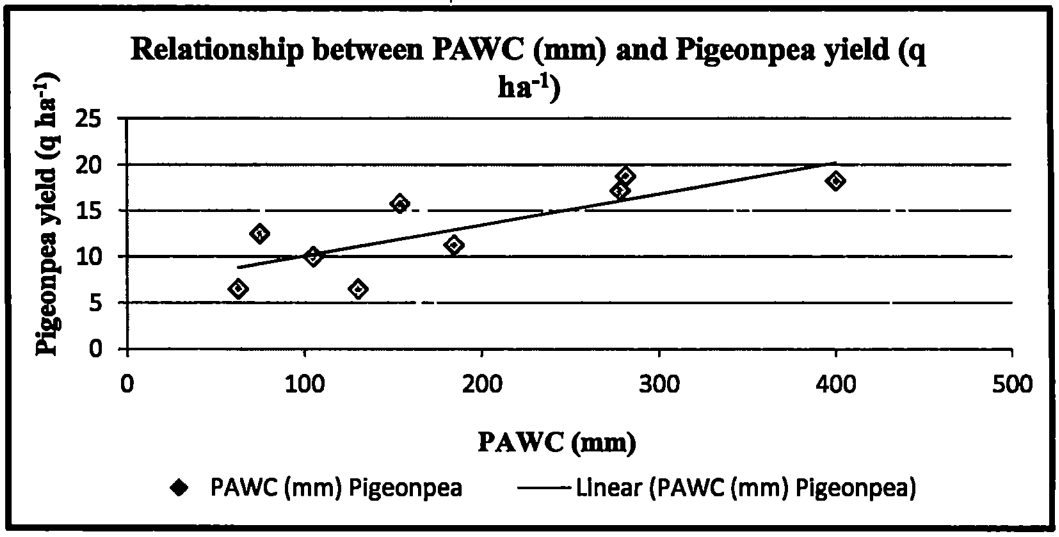

Fig-11 Relationship between PAWC (mm) and pigeonpea yield (q ha^{-1}) in Tungi watershed

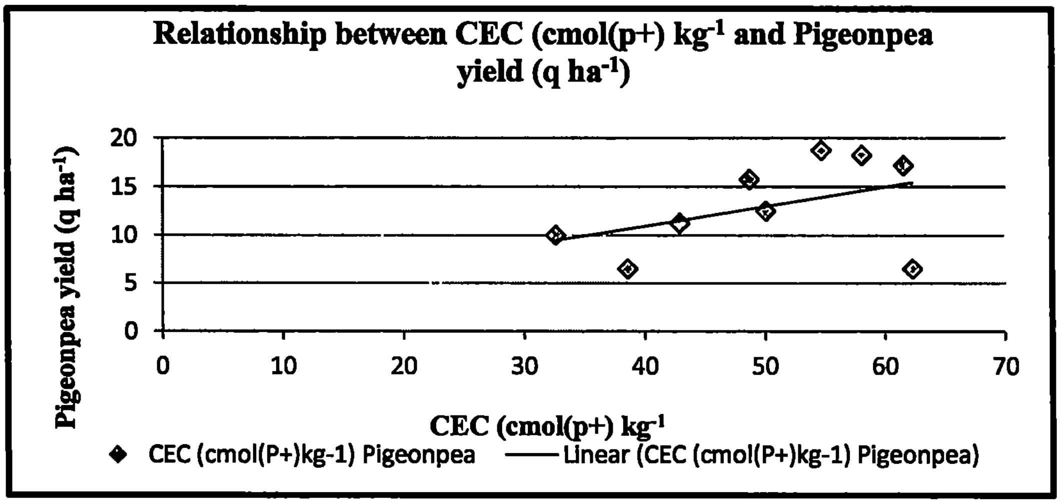

Fig-4.12 Relationship between CEC (cmol(P+) kg-1 and pigeonpea yield (qt ha-1) in Tungi watershed

values. The high cation exchange capacity of these black soils is attributed to its smectitic clay mineralogy (Pal and Deshpande 1987). Since the soils under study have low to moderate organic carbon status. Clay fraction appears to influence largely the cation exchange capacity values. The cation exchange capacity is the charge behavior of soils, whereas clay is the fundamental block contributing towards its cation exchanges, its relationship with clay rather than toposequential placement of the soils is appropriate (Ram and Gaikwad, 1985).

4.2.3.6 Exchangeable bases

The exchangeable bases (Table 4.6) indicated that the exchange site has the dominance of calcium followed by magnesium, sodium and potassium in all profiles. Typic Ustorthents (P_1, P_7 and P_9) have calcium ranged from 17.6 to 25.6 cmol(p^+)kg^{-1}, magnesium ranged from 6.8 to 14.4 cmol(p^+)kg^{-1} while sodium content ranged from 0.87 to 2.32 cmol(p^+)kg^{-1} and potassium content ranged from 0.25 to 1.26 cmol(p^+)kg^{-1}. In soils of Typic Haplustepts (P_2, P_3 and P_8) exchangeable calcium ranged from 19.4 to 44.8 cmol(p^+)kg^{-1} , magnesium 5.2 to 22.2 cmol(p^+)kg^{-1}, sodium 1.26 to 4.19 cmol(p^+)kg^{-1} and potassium content varies from 0.25 to 2.0 cmol(p^+)kg^{-1} respectively. In soils of Typic Haplusterts (P_4 P_5 and P_6) exchangeable calcium, magnesium sodium and potassium ranged from 26.8 to 63.52 cmol(p^+)kg^{-1}, 6.0 to 22.0 cmol(p^+)kg^{-1}, 1.92 to 4.11 cmol(p^+)kg^{-1} and 0.63 to 2.37 cmol(p^+)kg^{-1} respectively. In general these soils are saturated with bases especially calcium and magnesium where calcium is dominant cation over other cations suggesting the present of measurable calcium bearing minerals.

4.2.3.7 Base saturation

The data represented in table 4.6 indicated that the soil exhibit narrow variation in these percent base saturation among themselves. Base saturation varied from 88.82 to 113.42 per cent. The high base saturation of both soil and murrum was attributed to basaltic parent material, which is basic in nature and presence of free lime.

4.3 Chemical composition and quality of Irrigation water (Ground water)

Evaluation of the quality of the tube well and open well water resources in Tungi watershed is essential for better land used planning. The depth of well is 55 to 70 feet and depth of tube well is 560 to 750 feet below the ground level.

The data pertaining to the chemical analysis of well and tube well water and derived ratio for quality rating are given in (table 4.10) the ionic concentration and proportion of monovalent to divalent cations govern the behavior of waters. The ratio of monovalent to divalent cations (Kelley's ratio) is less than unity (0.23 to 1.43) indicating no sodiumfication of water in all well and tube well sample.

The carbonate and bicarbonate ranged from 0.4 to 2.0mmol^{-1} and 4.6 to 8.2mmol $^{-1}$ respectively. Residual alkalinity is a measure of hazard involved in the use of high bicarbonate containing waters. The well and tube well water had less than 1.25 mmol^{-1} of residual sodium carbonate. This suggests that this water is suitable for irrigation.

The well and tube well water sample were classified according to US salinity laboratory (Richards 1954). The water sample of Tungi watershed was medium Salinity low sodicity (C_2S_1) to high salinity low sodicity (C_3S_1).

The data of the water analysis (Table 4.10) suggested that the well and tube well water of Borphal, Tungi, Masalga, Haregaon, Limbala, Talani, Dapegaon, Fattepur and Nagarsoga are safe for irrigation under moderate leaching. The water sample of Chincholi Tapse and Jawalga are poor quality were, may cause accumulation of salt in the soil that would not only impair the drainage of these soil but also crop yield. This is the evidence in the reduction of HC in soils of the surface horizon (Table 4.5).

4.4 Soil classification

Based on field morphology and laboratory characterization the soils on various landforms have been classified according to U.S. comprehensive system of soil classification (Soil Survey Staff 1994 & 2006) and presented in (Table 4.11). The dominant soils of the study area belonging to three order viz. Entisols, Inceptisols and Vertisols.

4.4.1 Entisols

The soil developed on moderately sloping nearly level plain at elevated area of the Tungi watershed (P_1, P_7 and P_9) were lack of diagnostic subsurface horizons. They qualify for the order Entisols and due to presence of Ustic moisture regime; the soils are grouped into Ustorthents. At subgroup level, these soils classified as Typic Ustorthents because these soils do not key out for other subgroup.

Table 4.1[illegible] ...ngi watershed

Location		(Feet)	pH	Ec (dsm^{-1})	Cations (meq/lit.)				Anions (meq/lit.)				SAR	RSC	Salinity class	Kelley's Ratio
					Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{-}	HCO_3^{-}	SO_4^{--}	Cl^{-}				
Borphal	Well	55	7.4	0.84	2.7	3.4	3.0	2.57	-	7.8	0.67	1.2	2.40	1.70	C3S1	0.90
Borphal	T. well	750	8.3	0.53	2.9	2.6	3.0	0.72	-	4.6	0.76	0.8	2.56	0.91	C2S1	0.67
Tungi	T. well	600	7.6	0.68	2..4	3.7	4.7	0.57	-	7.1	1.22	1.2	3.82	1.00	C2S1	0.86
Tungi	well	600	7.4	0.91	2.6	2.8	4.8	0.69	-	6.7	0.92	2.4	4.13	1.30	C3S1	1.01
Masalga	Well	60	7.3	0.54	3.4	3.5	7.9	1.10	-	7.2	0.77	1.2	6.03	0.30	C2S1	1.20
Haregaon	T. well	600	7.8	0.72	2.9	3.9	4.6	0.67	-	7.8	0.88	1.6	3.53	1.00	C2S1	0.77
Haregaon	T. well	650	7.1	1.90	3.0	4.0	3.2	0.28	-	8.2	1.03	3.6	2.42	1.20	C3S1	0.49
Haregaon	Well	65	9.4	0.60	2.0	3.9	3.4	0.13	2.0	5.6	0.66	1.6	2.80	1.70	C2S1	0.59
Haregaon	Well.	65	8.9	0.50	3.0	3.7	3.1	0.10	0.4	7.6	1.18	1.2	2.40	1.30	C2S1	0.23
Limbala	T. well	450	7.6	1.16	1.9	4.1	4.5	1.00	-	7.3	1.05	0.4	3.68	1.30	C3S1	0.91
Limbala	T. well	650	8.2	0.47	2.7	3.0	2.9	0.25	-	6.6	0.67	1.2	2.43	0.90	C2S1	0.55
Talani	T. well	500	8.6	0.51	2.8	2.9	4.6	0.53	-	6.7	0.72	1.6	3.86	1.00	C2S1	0.90
Talani	T. well	600	8.4	0.68	2.6	2.7	4.2	0.54	-	6.8	0.77	1.6	3.65	1.50	C2S1	0.89
Dapegaon	T. well	650	7.9	0.67	2.8	4.2	4.0	1.08	-	7.9	0.80	0.8	3.03	1.00	C2S1	0.72
Fattepur	Well	65	7.8	0.53	3.0	3.6	3.7	0.90	-	7.9	0.68	1.6	2.89	1.30	C2S1	0.68
Fattepu	Well	70	8.3	0.45	2.0	3.7	3.2	0.60	-	6.9	0.65	0.8	2.68	1.20	C2S1	0.66
Fattepur	T. well	630	8.3	0.46	2.0	3.3	4.9	0.61	-	6.8	0.70	0.8	4.26	1.50	C2S1	1.03
Chincholi Tapse	T. Well	700	7.6	0.87	1.7	4.5	6.6	2.27	-	7.3	0.60	1.2	5.35	1.10	C3S1	1.43
Chincholi Tapse	T. Well	560	7.4	1.00	3.8	2.9	3.1	1.30	-	7.9	0.84	1.6	2.40	1.20	C3S1	0.65
Jawalga	T. Well	650	7.9	0.88	2.8	3.6	4.2	0.52	-	7.7	1.05	1.2	3.33	0.80	C3S1	0.73
Nagarsoga	T. well	650	8.7	0.41	1.9	4.3	3.7	0.28	-	7.8	0.76	2.4	3.24	1.60	C2S1	0.64

(SAR-Soddium Adsorption Ratio, RSC- Residual Sodium Carbonate)

Table-4.11 Soil classification of Tungi watershed

Sr. No.	Order	Suborder	Great group	Subgroup	Family
1.	Entisols	Orthents	Ustorthents	Typic Ustorthents	Silty clay, montmorilonitic, hyperthermic
2.	Inceptisols	Ustepts	Haplustepts	Typic Haplustepts	Silty clay, montmorilonitic, hyperthermic
3.	Inceptisols	Ustepts	Haplustepts	Typic Haplustepts	Clay loam, montmorilonitic, hyperthermic
4.	Vertisols	Usterts	Haplusterts	Typic Haplusterts	Clay, montmorilonitic, hyperthermic
5	Vertisols	Usterts	Haplusterts	Typic Haplusterts	Silty clay, montmorilonitic, hyperthermic
6.	Vertisols	Usterts	Haplusterts	Typic Haplusterts	Silty clay, montmorilonitic, hyperthermic
7.	Entisols	Orthents	Ustorthents	Typic Ustorthents	Silty clay, montmorilonitic, hyperthermic
8.	Inceptisols	Ustepts	Haplustepts	Typic Haplustepts	Silty clay, montmorilonitic, hyperthermic
9.	Entisols	Orthents	Ustorthents	Typic Ustorthents	Silty clay loam, montmorilonitic, hyperthermic

4.4.2 Inceptisols

The pedon P_2, P_3, and P_8 possess ochric epipedons followed by cambic subsurface diagnostic horizons and hence, grouped under Inceptisols. Due to ustic moisture regime, these pedons qualify for ustepts suborder. These pedons do not have duripan horizon and hence are classified under Haplustepts great group. At subgroup level these soil classified as Typic Haplustepts.

4.4.3 Vertisols

These soils were deep to very deep, black colored, clayey (>30 %) and characterized by deep and wide cracks, well developed slickenside and pressure faces. Thus these soils were classified under the order Vertisols and the subgroup level Typic Haplusterts and were observed at nearly level landform pedon P_4, P_5 and P_6.

4.5 Fertility status of soil

The data in respect of soil fertility status of selected pedons of Tungi watershed are presented in table 4.12 and 4.13, 4.14 and 4.16.

4.5.1 Available macronutrients.

4.5.1.1 Available nitrogen

The data represented in table 4.12 indicated that the available nitrogen content in soils of Tungi watershed varied from 102.72 to 291.91 kg ha^{-1} indicating that these soils were low in available nitrogen content. In general, the available nitrogen content of these soils was decreased with depth. The high amount of nitrogen content (weighted mean) was found in Typic Haplusterts (210.58 kg ha^{-1}) followed by Typic Haplustepts (pedon-P_3 185.22 kg ha^{-1}) and low amount in Typic Ustorthents (pedon-P_7 138.36 kg ha^{-1}). The surface soils were found to contain more nitrogen than sub surface soil. This may due to the application of nitrogenous fertilizers (Subramaniam & Kumarswami, 1989) and organic matter content. The presence of nitrogen in murrum layers of all soil profiles may be attributed to leaching of top soil nitrogen to the subsurface.

4.5.1.2 Available phosphorus

The data represented in table 4.12 indicated that the available phosphorus content in soils of Tungi watershed were found to be moderate varied from 11.20 to 28.00 kg ha^{-1} and it decreased with depth. The data presented in table 4.12 indicated that the high amount of available phosphorus content (weighted mean) was found in Typic Haplusterts (pedon-P_5 22.36 kg ha^{-1}) and low available phosphorus observed in Typic Haplustepts (pedon-P_2 11.69 kg ha^{-1}). Surface layer of soil found to be rich in phosphorus than sub surface layer, possibly due to fertilization. Deshmukh and Saxena (1982) and Vaidya et al. (2014) also reported Similar trained.

4.5.1.3 Available potassium

The data represented in table 41.2 indicated that the available potassium content in soils of study area ranged from 168.23 to 485.49 kg ha^{-1} (weighted mean) indicating that soils were medium to high in available potassium and it was decreased with depth. The maximum amount of available potassium content (604.08 kg ha^{-1}) was recorded in (pedon P_8) Typic Haplusterts.

The relationship between available N, P and K and CEC of soil was also positively correlated (r= -0.80147, r= 0.153085 & r= 0.265775 respectively). This indicated that the CEC increased with increases the availability of N, P and K in soils of Tungi watershed.

4.5.2 Available micronutrients

All crops require both major and minor nutrients for proper growth and development out of many micronutrients available Fe, Mn, Cu and Zn are the four important nutrients which are found to influence the growth and yield of the crops though iron is not a constituent of chlorophyll, it is essential for its synthesis. It acts as catalyst in enzyme action. Manganese is essential for chlorophyll synthesis. Copper is a constituent of several enzymes participation in the cellular oxidation-reduction processes while Zinc is involved in the biosynthesis of a plant hormone and a component of variety of enzymes. It also plays a vital role in nucleic acid, protein and chlorophyll synthesis.

The soils of Tungi watershed Fe, Mn, Zn and Cu varies from (weighted mean) 6.18 to 28.39, 6.20 to 30.77, 3.37 to 10.45 5.85 to 21.65 mg kg^{-1} respectively (Table 4.13). This indicated that the soils are high in Fe followed by Mn, Cu and Zn. The higher amount of Fe and Mn content in the soil may be due to the ferromagnesian parent material. The available micronutrient content in surface layer to be more than sub surface layers. This may be due to surface application of micronutrient.

Table-4.12 Available macronutrients of Tungi watershed

Horizons	Depth (cm)	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
Pedon 1 Borphal, Tal- Ausa, Dist- Latur (Typic Ustorthents).				
Ap	0-21	170.59	16.80	481.6
M	21-40	10528	16.80	123.2
Pedon 2 Tungi Tal- Ausa, Dist- Latur (Typic Haplustepts).				
Ap	0-20	227.94	13.44	280.0
Bw1	20-34	170.59	13.44	235.2
Bw2	34-43	105.28	12.32	224.0
Ck	43-64	105.28	12.32	134.4
Sm	64-115	103.97	12.80	123.2
Pedon 3 Masalga Tal- Ausa, Dist- Latur (Typic Haplustepts).				
Ap	0-18	249.26	16.80	221.7
Bw1	18-39	170.59	15.68	151.2
Ac	39-50	170.59	15.80	112.0
M	50-75	127.94	14.04	142.2
Pedon 4 Haregoan Tal- Ausa, Dist- Latur (Typic Haplusterts).				
Ap	0-18	213.34	16.80	431.2
Bw1	18-42	106.62	16.16	324.8
Bss1	42-66	106.62	18.00	324.8
Bss2	66-90	105.28	16.40	311.6
Bss3	90-150	105.28	16.10	309.7
Pedon 5 Limbala Tal- Ausa, Dist- Latur (Typic Haplusterts).				
Ap	0-19	227.97	26.88	649.6
Bw1	19-38	148.41	23.52	488.3
Bw2	38-67	106.62	24.64	407.6
Bss1	67-96	106.62	25.76	344.9
Bss2	96-145	103.97	16.80	296.8
Pedon 6 Talani Tal- Ausa, Dist- Latur (Typic Haplusterts).				
Ap	0-16	291.91	28.00	1051.6
Bw1	16-31	149.26	25.76	548.8
Bw2	31-59	106.62	22.40	347.2
Bss1	59-87	105.28	20.16	358.4
Bss2	87-113	105.28	19.04	403.2
Bss3	113-150	103.97	20.16	473.7
Pedon 7 Dapegoan Tal- Ausa, Dist- Latur (Typic Ustorthets).				
Ap	0-28	291.91	22.40	560.0
Ac	28-40	106.62	20.16	320.4
M	40-50	107.63	19.04	190.4
Pedon 8 Fattepur Tal- Ausa, Dist- Latur (Typic Haplustepts).				
Ap	0-18	249.26	20.16	604.8
Ac	18-41	106.62	16.80	296.08
M	41-60	102.72	11.20	190.4
Pedon 9 Chincholi Tapse Tal- Ausa, Dist- Latur (Typic Ustorthets).				
Ap	0-18	170.59	16.80	246.4
Ac	18-31	127.94	12.32	137.7
M	31-45	106.62	12.80	168.0

Table-4.13 Available micronutrients of Tungi watershed

Horizons	Depth (cm)	Fe (mg kg^{-1})	Mn(mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})
Pedon 1 Borphal, Tal- Ausa, Dist- Latur (Typic Ustorthents).					
Ap	0-21	10.04	13.46	04.90	08.90
M	21-40	13.90	12.14	02.00	03.33
Pedon 2 Tungi Tal- Ausa, Dist- Latur (Typic Haplustepts).					
Ap	0-20	08.23	12.14	07.39	11.86
Bw1	20-34	12.07	14.29	07.34	12.31
Bw2	34-43	15.55	16.87	08.03	11.15
Ck	43-64	15.70	16.92	06.49	03.66
Sm	64-115	18.06	19.17	06.32	02.80
Pedon 3 Masalga Tal- Ausa, Dist- Latur (Typic Haplustepts).					
Ap	0-18	16.10	15.84	06.66	15.20
Bw1	18-39	16.75	17.77	05.89	15.31
Ac	39-50	18.21	20.59	03.49	09.31
M	50-75	19.24	18.19	02.03	06.95
Pedon 4 Haregoan Tal- Ausa, Dist- Latur (Typic Haplusterts).					
Ap	0-18	16.28	14.33	05.35	13.39
Bw1	18-42	19.44	27.09	05.73	14.33
Bss1	42-66	13.51	09.88	07.19	17.99
Bss2	66-90	15.53	14.55	07.25	18.13
Bss3	90-150	11.90	10.43	07.10	17.34
Pedon 5 Limbala Tal- Ausa, Dist- Latur (Typic Haplusterts).					
Ap	0-19	07.41	08.90	11.23	16.85
Bw1	19-38	07.21	08.08	09.63	16.56
Bw2	38-67	06.93	08.97	10.18	15.27
Bss1	67-96	06.90	08.63	10.27	25.69
Bss2	96-145	06.89	07.56	10.75	26.88
Pedon 6 Talani Tal- Ausa, Dist- Latur (Typic Haplusterts).					
Ap	0-16	04.83	06.07	09.56	28.69
Bw1	16-31	04.18	06.15	04.67	14.01
Bw2	31-59	06.15	10.08	03.36	10.09
Bss1	59-87	07.55	06.06	03.14	09.43
Bss2	87-113	07.49	05.23	02.88	08.65
Bss3	113-150	05.68	04.13	02.26	06.79
Pedon 7 Dapegoan Tal- Ausa, Dist- Latur (Typic Ustorthents).					
Ap	0-28	30.75	32.17	09.08	20.43
Ac	28-40	26.40	29.03	05.18	11.66
M	40-50	24.20	28.97	04.12	10.25
Pedon 8 Fattepur Tal- Ausa, Dist- Latur (Typic Haplustepts).					
Ap	0-18	12.57	15.90	04.12	09.28
Ac	18-41	11.51	15.40	4.06	6.13
M	41-60	13.15	15.45	03.24	02.29
Pedon 9 Chincholi Tapse Tal- Ausa, Dist- Latur (Typic Ustorthents).					
Ap	0-18	19.30	22.22	03.43	07.87
Ac	18-31	18.44	20.87	03.97	09.15
M	31-45	16.01	19.75	02.76	06.08

Table 4.14 Available nutrients in typifying pedons Tungi watershed (weighted means).

Pedon	N (kg ha^{-1})	P(kg ha^{-1})	K(kg ha^{-1})	DTPA Extractable micronutrient				Yield (q ha^{-1})	
				Fe (mg kg^{-1})	Mn(mg kg^{-1})	Zn(mg kg^{-1})	Cu(mg kg^{-1})	Soybean	Pigeonpea
P_1	139.43	16.80	311.36	11.87	12.83	3.52	6.25	07.9	06.50
P_2	133.98	11.69	174.03	14.99	16.76	6.79	6.34	21.5	15.75
P_3	185.22	16.09	168.23	17.89	18.49	4.70	12.22	18.8	11.25
P_4	118.67	16.54	329.14	14.47	14.13	6.70	16.61	23.5	17.20
P_5	127.10	22.36	399.90	07.01	08.29	10.45	21.65	21.5	18.75
P_6	129.51	21.78	485.49	06.18	06.20	3.75	11.27	20.8	18.25
P_7	210.58	21.19	428.57	28.29	30.77	7.15	16.28	15.7	10.00
P_8	148.17	16.38	355.38	8.51	15.56	3.81	5.85	18.8	12.50
P_9	138.36	14.26	190.60	18.02	21.06	3.37	7.68	07.9	06.50

Table 4.15Correlation coefficient between available nutrients and yield of Soybean

Crop	Parameter X Available nutrients in soil	Parameter Y	R
Soybean	N (kg ha^{-1})	Yield (q ha^{-1})	-0.57
	P(kg ha^{-1})	Yield (qha^{-1})	0.55
	K (kg ha^{-1})	Yield (qha^{-1})	0.24
	Fe (Mg kg^{-1})	Yield (qha^{-1})	-0.26
	Mn(Mg kg^{-1})	Yield (q ha^{-1})	-0.33
	Zn(Mg kg^{-1})	Yield (q ha^{-1})	0.54
	Cu(Mg kg^{-1})	Yield (q ha^{-1})	0.46

* Significant at 5 % **Significant at 1%

Table 4.16 Correlation coefficient between available nutrients and yield of Pigeonpea

Crop	Parameter X Available nutrients in soil	Parameter Y	R
Pigeonpea	N (kg ha^{-1})	Yield (q ha^{-1})	-0.57
	P(kg ha^{-1})	Yield (q ha^{-1})	0.64*
	K (kg ha^{-1})	Yield (q ha^{-1})	0.40
	Fe (Mg kg^{-1})	Yield (q ha^{-1})	-0.48
	Mn(Mg kg^{-1})	Yield (q ha^{-1})	-0.58
	Zn(Mg kg^{-1})	Yield (qha^{-1})	0.57
	Cu(Mg kg^{-1})	Yield (q ha^{-1})	0.50

* Significant at5 % **Significant at 1%

4.6 Land Evaluation

Land evaluation is the process of assessing the potential of land for alternative uses. There are several methods available for evaluating the land both for qualitative and quantitative evaluation. Among the various methods, the land capability classification (Klingebiel and Montgomery, 1961), land irrigability classification (AIS&LUS, 1971), land productivity (Riquier *et al.*, 1970) and land suitability classification (FAO, 1976) were used.

4.6.1 Land Capability Classification

The land capability classification is a broad grouping of soils based on their limitations and is designed to emphasize the hazards in different kinds of soils. Soils are grouped according to their potential and limitations for sustained production. Land suited for cultivation is grouped in class *I* to class *IV* according to the degree of limitations. Lands in class *V* to class *VII* are suited for silviculture, pasture and forestry. Class *VIII* land is neither suited to agriculture nor forestry but suitable for recreational use.

Land capability classes are divided into subclasses that represent groups of soils having the same kind of dominant limitation for agricultural use. Four kinds of limitation are recognized at subclass level, 'e' for slope, water or wind erosion, 'w' for drainage problems, wetness or overflow, 's' for soil limitations affecting the plant growth and 'c' for limitation due to climate.

Land capability subclasses identified in Tungi watershed are given in table 4.20 and land capability map shown in fig. 4.13. The soil of Tungi watershed are grouped in to three major capability classes (*III*, *IV* and *VI*) and four sub classes (*IIIs, III d, IV d, IV ds,* and *VI d*).

4.6.2 Land irrigability classification

Land irrigability classification facilitates grouping of soils into different classes of suitability along with their subclasses based on dominant limitation imposing factors. It is an interpretative grouping based on soil and land characteristics, which indicate relative suitability of land for irrigation as well as predicted behavior of soils under irrigation. The irrigability classification is a combined effect of soil and land characteristics. Factors considered while grouping soils under different irrigability classes are slope, erosion, texture, depth, drainage, salinity, alkalinity, permeability, etc. The results of different soil mapping units of watershed evaluated for their suitability for irrigation has been presented in table 4.24 and the map is shown in fig. 4.14 the soils are grouped under land irrigability subclasses 1, 2ds, 3ds and 4d comprising 29.32, 50.79, 0.35 and 16.49 per cent area, respectively.

Table 4.24 Irrigability classes of Tungi watershed

Sr. No.	Map unit	Description	Area	
			Hectors (ha)	**% of TGA**
1	1	Lands of this class are capable of producing sustained and relatively high yield. This soil has few or no limitation of depth, topography and drainage.	7264.69	29.32
2	2ds	Lands of that class has moderate limitation for sustained use under irrigation. These soil have moderate limitation of depth and slope,	12583.76	50.79
3	3ds	Lands of that class have severe limitation for sustained use under irrigation like, depth, slope, coarse fragments and slight limitations of texture.	87.50	0.35
4	4d	Lands of these class having very severe limitations of soil depth, and slope.	4086.53	16.49
5		Habitation	423.11	1.71
6		Waterbody	326.30	1.32
	Total		**24771.91**	**100**

4.6.3 Soil productivity evaluation

Soil productivity is based on productivity index (Table 4.25 and 4.26) of various soils, the soils were found to be extremely poor (P_1, P_7 and P_9), poor (P_1), average (P_2, P_3, P_5 and P_6) and good (P_4).

Table-4.17 Criteria for Land capability classification

Characteristics	*Class I*	*Class II*	*Class III*	*Class IV*	*Class V*	*Class VI*	*Class VI I*	*Class VIII*
TOPOGRAPHY (t)								
Slope (%)	0-1	1-3	3-8	8-15	Up to 3	15-35	35-50	>50
Erosion	nil	slight	Mod.	severe	nil	severe	v. severe	—
WETNESS(w)								
Flooding	nil (F0)	nil (F0/F1)	nil to slight (F0/F1)	slight to mod. (F1/F2)	mod. to severe (F0/F3)	nil to severe (F0/F4)	nil to very	—
Drainage	well	Mod. well	imperfect	poor	excessive	excessive	excessive	excessive
PHYSICAL CONDITION OF SOIL(s)								
Texture	loam	sil&cl	sil&cl	scl	s, c (m)	ls-cl	ls,s,c	ls,s,c
Coarse fragments (vol. %)	1-3	3-15	15-40	40-75	15-75	75+	---	—
Depth (cm)	<1	1-3	3-5	5-8	8-15	15-40	40-75	>75
FERTILITY(f)								
CEC (coml.(P^{+})kg^{-1}	40-16	16-12	16-12	---	---	---	---	---
Base saturation percentage	>80	>80	80-50	50-35	50-35	35-15	<15	—
Organic carbon (0-15cm)	>1	0.75-1.0	0.5-0.75	<0.5	<0.5	---	---	---
Salinity Ec (dSm^{-1})	<1.0	1-2	2-4	4-8	8-15	15-35	35-50	>50

Table-4.18 Soil site characteristics of Tungi watershed for land capability classification

Characteristics	Pedon 1	Pedon 2	Pedon 3	Pedon 4	Pedon 5	Pedon 6	Pedon 7	Pedon 8	Pedon 9
TOPOGRAPHY (t)									
Slope (%)	3-8	3-5	3-5	1-3	1-3	1-3	1-8	3-5	3-8
Erosion	v. slow	Mod.	Mod.	v. slow	v. slow	Mod.	Mod.	Mod.	Mod.
WETNESS(w)									
Flooding	nil	nil	nil	nil	nil	nil	nil	nil	nil
Drainage	well	m.well	well	Imper.	Imper.	Imper.	well	m.well	well
PHYSICAL CONDITION OF SOIL(s)									
Texture	cl	sic	cl	c	sic	sic	sicl	sic	sicl
Coarse fragments (vol. %)	12.98	9.29	40	04.43	03.04	09.45	21.79	19.10	31.95
Depth (cm)	21	64	50	145	150	150	40	41	31
FERTILITY(f)									
CEC (coml.(P^{+})kg^{-1}	62.27	42.72	42.89	61.55	54.70	58.08	32.61	50.11	38.37
Base saturation percentage	92.78	93.63	97.63	95.76	95.71	94.98	94.31	92.97	92.82
Organic carbon (0-15cm)	0.31	0.18	0.30	0.41	0.36	0.23	0.20	0.34	0.26
Salinity Ec (dSm^{-1})	015	0.16	0.14	0.19	0.36	0.48	0.27	0.16	0.26

Table-4.19 Land capability classes and sub-classes of soils of Tungi watershed

Characteristics	Pedon 1	Pedon 2	Pedon 3	Pedon 4	Pedon 5	Pedon 6	Pedon 7	Pedon 8	Pedon 9
TOPOGRAPHY (t)									
Slope (%)	III	III	III	II	II	II	III	III	III
Erosion	II	III	III	II	II	III	III	III	III
WETNESS(w)									
Flooding	I	I	I	I	I	I	I	I	I
Drainage	I	II	I	III	III	III	I	II	I
PHYSICAL CONDITION OF SOIL(s)									
Texture	II	I	III	III	II	III	IV	II	IV
Coarse fragments (vol. %)	II	II	IV	II	II	II	II	II	III
Depth (cm)	VI	III	II	I	I	I	IV	IV	IV
FERTILITY(f)									
CEC (coml.(P^{+})kg^{-1}	I	I	I	I	I	I	I	I	I
Base saturation percentage	I	I	I	I	I	I	I	I	I
Organic carbon (0-15cm)	IV	IV	IV	IV	IV	IV	IV	IV	IV
Salinity Ec (dSm^{-1})	I	I	I	I	I	I	I	I	I
LAND CAPABILITY CLASS	*VI (d)*	*IV (d)*	*IV (d)*	*III (d)*	*III (d)*	*III(d)*	*IV (sd)*	*IV (d)*	*IV (sd)*

Table 4.20 Extent and distributation area under different land capability subclasses in Tungi watershed

Sr. No.	Map unit	Description	Area (ha)	Area(% of TGA)
1.	IIId	Moderately good cultivable land on almost level plain or gentle slope. These have moderate limitation of soil drainage, soil texture, with slight limitation of slope, organic matter and coarse fragments.	7264.69	29.33
2.	IVd/IVds	Fairly good cultivable land on almost level plain or moderately steep slope. Generally unsuitable for growing a various crop because having high limitation of depth, erosion, texture and drainage problem.	12892.73	52.05
3.	VId	Non-arable land well suited for grazing or forestry use, moderate limitation of slope, severe erosion and limited depth.	3865.06	15.60
9.	Habitation	Habitation	326.30	01.32
10	Waterbody	Waterbody	423.11	01.71
	Total		**24771.91**	**100**

Table-4.21 Land Irrigability classification Criteria

Soil properties	Irrigable Soil Class				Non-Irrigable Soil Class
	A	B	C	D	
Soil depth (cm)	>90	45-90	22.5-45	7.5	>7.5
Slope (%)	<1	1-3	3-5	5-10	
Depth of water table`	>5	3-5	1.5-5		
Texture	Sandy loam to clay loam	loamy Sand; clay	Sand clay	Sand clay	Any Texture
Soil permeability (mm/hr)	5-50	50-130	130-250	>250	Not applicable
Coarse fragments (%)	<5	5-15	15-35	35-65	>65
Salinity Ec (dSm^{-1})	<1	1-1.5	1.5-2.5	2.5-3	>3
Salt affected area (visually in %)	<20		20-50		>50
ESP (%)	<15		>15		---

Table. 4.22 Soil Site Characteristics of Tungi watershed for Land Irrigability classification

Soil properties	Pedon 1	Pedon 2	Pedon 3	Pedon 4	Pedon 5	Pedon 6	Pedon 7	Pedon 8	Pedon 9
Soil depth (cm)	21	64	50	145	150	150	40	45	31
Slope (%)	3-8	3-5	3-5	1-3	1-3	1-3	3-5	1-5	1-8
Depth of water table (meter)	16.5	180	18	180	135	180	180	21	210
Texture	cl	sic	sic	sic	sic	sic	sicl	sic	sicl
Soil permeability (mm/hr)	13.92	19.27	10.08	3.55	1.97	6.98	12.94	10.4	10.4
Coarse fragments (%)	12.98	9.29	40.34	4.43	3.04	9.45	21.79	19.10	31.95
Salinity Ec (dSm^{-1})	0.15	0.16	0.14	0.19	0.36	0.48	0.27	0.16	0.26
Salt affected area (visually in %)	nil	nil	nil	nil	nil	nil	nil	nil	nil
LAND IRRIGABILITY CLASS	*IVd*	*IIds*	*IIds*	*I*	*I*	*I*	*IIIds*	*IIds*	*IIIds*

Table. 4.23 Land Irrigability classification of Tungi watershed

Soil properties	**Pedon 1**	**Pedon 2**	**Pedon 3**	**Pedon 4**	**Pedon 5**	**Pedon 6**	**Pedon 7**	**Pedon 8**	**Pedon 9**
Soil depth (cm)	D	B	B	A	A	A	C	B	C
Slope (%)	B	A	B	A	A	A	C	B	B
Depth of water table`	A	A	A	A	A	A	A	A	A
Texture	A	A	A	A	A	A	A	A	A
Soil permeability (mm/hr)	A	A	A	A	A	A	A	A	A
Coarse fragments (%)	B	B	B	A	A	A	C	B	C
Salinity Ec (dSm^{-1})	A	A	A	A	A	A	A	A	A
Salt affected area (visually in %)	A	A	A	A	A	A	A	A	A
LAND IRRIGABILITY CLASS	*IVd*	*IIds*	*IIds*	*I*	*I*	*I*	*IIIds*	*IIds*	*IIIds*

Table- 4.26 Productivity Index (Rating class with assigned values) and productivity classes of soils of Tungi watershed

pedon	Soil moisture	Drain age	Effective soil depth	Texture/ structure	Base saturatio n	Soluble salts	Organic matter	Nature of clay	Mineral reserves	Productivity Index	Productivity class
	H	D	p	T	N	S	O	A	M		
Pedon 1	H4c (100)	D4 (100)	P3 (50)	T4a (40)	N5 (100)	S1 (100)	01 (85)	A3 (100)	M2c (100)	1.70	Extremely poor (V)
Pedon 2	H3b (60)	D4 (100)	P5 (100)	T4b (50)	N5 (100)	S1 (100)	01 (85)	A3 (100)	M2c (100)	24.22	Average (III)
Pedon 3	H4a (80)	D4 (100)	P4 (80)	T4b (50)	N5 (100)	S1 (100)	01 (85)	A3 (100)	M2c (100)	27.20	Average (III)
Pedon 4	H3b (60)	D4 (100)	P6 (100)	T6b (90)	N5 (100)	S1 (100)	01 (85)	A3 (100)	M2c (100)	43.60	Good (II)
Pedon 5	H3b (60)	D4 (100)	P6 (100)	T6a (80)	N5 (100)	S2 (80)	01 (85)	A3 (100)	M2c (100)	31.00	Average (II)
Pedon 6	H3b (60)	D4 (100)	P6 (100)	T6a (80)	N5 (100)	S3 (80)	01 (85)	A3 (100)	M2c (100)	31.00	Average (II)
Pedon 7	H4c (100) ()	D4 (100)	P3 (50)	T4a (40)	N5 (100)	S1 (100)	01 (85)	A2 (95)	M2c (100)	1.61	Extremely poorb(V)
Pedon 8	H5 (100)	D4 (100)	P3 (50)	T4a (40)	N5 (100)	S3 (80)	01 (85)	A3 (100)	M2c (100)	8.5	Poor (IV)
Pedon 9	H5 (100)	D4 (100)	P3 (50)	T4a (40)	N5 (100)	S2 (80)	01 (85)	A2 (95)	M2c (100)	1.13	Extremely poor (V)

The soil productivity classes in different mapping units have been grouped and mapped in Table 4.11 & 4.00 and Fig. 4.8 as good, average, poor and extremely poor representing 29.33, 51.16, 0.89 and 15.60 per cent, respectively.

Table 4.25 Productivity classes of Tungi watershed

Sr. No.	Map unit	Area	
		Hectors	% of TGA
1	Good	7264.69	29.33
2	Average	12671.26	51.16
3	Poor	221.47	0.89
4	Extremely Poor	3865.06	15.60
5	Habitation	326.30	01.32
6	Waterbody	423.11	01.17
	Total	**24771.91**	**100**

4.6.4 Soil – site suitability evaluation

Decisions on land use have always been part of the evolution of human society. The function of the land use planning is to guide decisions on land use in such a way that the resources of the environment are put to the most beneficial use for man, this planning based on an understanding both of the natural environment and of the kind of land use envisaged. It also involves the execution and interpretation of basic surveys of climate, soils vegetation and other aspects of land in terms of the requirements of alternative form of land use.

Every plant species need specific soil- site conditions for its optimum growth and yield, imperative to use the finite soil resource according to its capability or suitability for particular land use. This can be achieved only by critically evaluating the soil- site conditions vis-a-vis specific requirement of different crops.

Soil-site suitability is the fitness of given type of land for a defined use. The process of the land suitability classification is the appraisal and grouping of specific areas of land in term of their suitability and to estimate the potential of particular soil for alternative use. An intensive study of soil-site conditions in the Pedhi watershed was therefore, carried out in order to determine the suitability of some dominant crops of the area. The FAO framework on Land Evaluation (FAO, 1976) suggests a crop specific suitability system. The basic feature is the comparison of the requirements of land use with the resources offered by the land. The framework sets out basic concepts and principles of land evaluation that are universally wide, applicable in any part of the world and at any level from blaaebule to single form. An attempt has been made here to interpret the basic data on climate, soil crop and qualities of land for determining soil-site suitability evaluation of the crop commonly cultivated in the area such as soybean, pigeonpea.

The literature on specific crop requirement forms an important part of the suitability evaluation. This kind of information on the crops under study have been adopted from the proceeding of the National Meet on soil site suitability criteria for different crops recognized at the National Bureau of Soil Survey and Land Use Planning, Nagpur (NBBS and LUP, 1994). The suggested soil site suitability criteria considered as a base was modified and refined keeping into account the local conditions.

The existing soil-site condition were compared with the criteria of each crop and based on the number of intensity of limitation. The overall suitability was determined (Sys, 1985, Sys *et al.*, 1991). The method defines land classes with regard to number and intensity of limitations. The criteria of limitation method as given by Sys *et al.* (1991) is slightly modified because of the increased number of parameter in the parent study for the suitability evaluation are given below:

Class S1 (Highly suitable)	: Land unit with nil. Or up to 5 slight limitation
Class S2 (Moderately suitable)	: Land units with more than 5 slight limitation and/ or no more than two severe limitations.
Class S3 (Marginally suitable)	: Land unit with more than 4 moderate limitation or and no more than two sever limitations.
N1 (Currently not suitable)	: Land unit with more than 2 severe limitation that can be corrected.
N2 (Unsuitable)	: Land units having very severe limitation that cannot be corrected.

Table-4.27 Climatic characteristics of crops like soybean and pigeon pea in Tungi watershed.

characteristics	Crop	
	Soybean	**Pigeonpea**
Total rainfall (mm)	794.80	794.80
Rainfall during growing season(mm)	729.58	550.44
Mean minimum temperature during growing season(C^0)	20.56	19.49
Mean maximum temperature during growing season(C^0)	31.34	30.31
Mean relative humidity in growing season (%)	78.70	73.61
Length of growing period	151	180

Table-4.28 Soil Site Characteristics of studied Soils of Tungi watershed

Soil - site Characteristics	Pedon1	Pedon 2	Pedon 3	Pedon4	Pedon 5	Pedon 6	Pedon 7	Pedon 8	Pedon 9
SITE CHARACTERISTICS									
Slope (%)	3-8	3-5	3-5	1-3	1-3	1-3	3-8	1-3	1-3
Erosion	Very slow	Moderate	Moderate	Very slow	Very slow	Moderate	Moderate	Moderate	Moderate
Hydraulic conductivity (mm hr^{-1})	13.92	19.27	10.80	03.55	01.97	06.98	12.94	8.30	13.00
Drainage	Well	M. well	Well	Imperfect	Imperfect	Imperfect	Well	M. well	Well
Coarse fragment (Vol.%) 50 cm	12.98	09.29	40.34	04.43	03.04	09.45	21.79	21.05	31.95
PAWC (mm)	62.67	154.22	184.70	278.56	281.55	277.46	67.56	127.80	56.17
SOIL CHARACTERISTICS									
Texture	c	c	si, c	c	si, c	si, c	si, c, l	si, c	si, c, l
Depth (cm)	40	115	75	150	145	150	50	60	45
SOIL FERTILITY									
$CaCO_3$ (%)	09.98	31.98	11.39	8.16	13.49	16.45	08.98	22.26	07.93
BS (%)	92.78	93.63	97.15	95.76	95.71	94.98	94.31	93.63	92.82
O.C. (%) (0-25cm)	0.31	0.18	0.30	0.40	0.36	0.23	0.20	0.46	0.26
EC (dSm^{-1})	0.15	0.16	0.14	0.19	0.36	0.48	0.27	0.16	0.26
pH (1:2)	8.07	8.27	7.97	7.61	8.12	8.11	7.9	8.37	8.00

Table-4.29 Soil-site suitability criteria for Soybean.

Soil - site Characteristics	DEGREE OF LIMITATION					
	0 (None)	1 (Slight)	2 (Moderate)	3 (Severe)	4 (Very severe)	
		S1	S2	S3	N1	N2
CLIMATIC CHARACTERISTICS						
Total rainfall (mm)	>850	750-850	650-750	550-650	<550	--
Rainfall growing season (mm)	>700	600-700	500-600	400-500	<400.	--
Length of growing period(days)	>120	110-120	100-110	90-100	<90	--
Mean temp. growing season (°C)	25-28	--	28-30	30-34	>34	--
Mean R.H. in growing season	>80	70-80	60-70	50-60	<50	--
SITE CHARACTERISTICS						
Slope (%)	<3	<3	3-5	5-8	>8	--
Erosion	--	--	--	--	--	--
Hydraulic conductivity (mm hr^{-1})	20-50	10-20	5-10	1-5, >50	<1	--
Drainage	Well	Mod.well	Imperfect	Poor & excessive	V.poor	--
PAWC (mm)	>200	150-200	100-200	50-100	<50	--
SOIL CHARACTERISTICS						
Texture	cl,sicl	l,sil,scl	sl.c	cm,ls	>25	--
Coarse fragments (Vol%) Within 50 cm	<5	5-15	15-25	25-35	<40	--
Depth (cm)	>75	60-75	50-60	40-50	--	--
$CaCO_3$ (%)	<5	5-10	10-20	>20	--	--
Exch. Ca/Mg ratio	>2.5	1.5-2.5	0.5-1.5	<0.5	--	--
BS (%)	>80	80-50	50-35	<35	--	--
O.C. (%) (0-25cm)	>0.75	0.5-0.75	0.5-0.2	<0.2	--	--
pH(1:2)	6.5-7.5	--	7.5-8.5	>8.5	--	--
ECe (dSm^{-1})	<1	1-2	2-3	3-4	>4	--

Table-4.30 Degree of Limitation in each of the soil and overall suitability class for Soybean

Soil - site Characteristics	Pedon 1	Pedon 2	Pedon 3	Pedon 4	Pedon 5	Pedon 6	Pedon 7	Pedon 8	Pedon 9
CLIMATIC CHARACTERISTICS									
Total rainfall (mm)	1	1	1	1	1	1	1	1	1
Rainfall growing season (mm)	0	0	0	0	0	0	0	0	0
Length of growing period(days)	0	0	0	0	0	0	0	0	0
Mean temperature. growing season (°C)	0	0	0	0	0	0	0	0	0
Mean R.H. in growing season	1	1	1	1	1	1	1	1	1
SITE CHARACTERISTICS									
Slope (%)	3	2	2	0	0	0	2	3	3
Hydraulic conductivity (mm hr^{-1})	1	1	1	2	3	2	1	2	1
Coarse fragment (Vol. %)	1	1	3	0	0	1	2	2	3
PAWC (mm)	3	1	0	0	0	0	2	3	2
SOIL CHARACTERISTICS									
Texture	0	0	0	0	0	0	1	0	1
Depth (cm)	3	0	0	0	0	0	2	2	3
$CaCO_3$ (%)	1	3	2	1	2	2	1	3	1
BS (%)	0	0	0	0	0	0	0	0	0
O.C. (%) (0-25cm)	2	2	2	2	2	2	2	2	2
ECe (dSm^{-1})	0	0	0	0	0	0	0	0	0
pH(1:2)	2	2	2	2	2	2	2	2	2
SUITABILITY CLASS	S3	S2	S2	S2	S2	S2	S2	S3	S3

Table-4.31 Degree and kind of major constraints, suitability and yield of Soybean

Pedon	Contents												Yield Q/ha	% Yield to optimum	Suitability based on actual yield
	LGP	Slope	Depth	Coarse Fragment	Texture	HC (Drainage)	PAWC	$CaCO_3$	ESP	EC dS m^{-1}	pH	Suitability Class			
Pedon 1	-	***	***	*	-	*	***	*	-	-	**	S3	07.9	31.6	S3
Pedon 2	-	**	-	*	-	*	*	***	-	-	**	S2	21.5	86.0	S1
Pedon 3	-	**	-	***	-	*	*	**	-	-	**	S2	18.8	75.2	S2
Pedon 4	-	-	-	-	-	**	-	*	-	-	**	S2	23.5	94.0	S1
Pedon 5	-	-	-	-	-	***	-	**	-	-	**	S2	21.5	86.0	S1
Pedon 6	-	-	-	*	-	**	-	**	-	-	**	S2	20.8	83.2	S1
Pedon 7	-	**	***	**	*	*	**	*	-	-	**	S2	15.7	62.8	S2
Pedon 8	-	***	**	**	-	**	***	***	-	-	**	S3	18.8	72.2	S2
Pedon 9	-	***	***	***	*	*	**	*	-	-	**	S3	07.9	31.2	S3

* Based on maximum observed yield as optimum : 25 q/ha (farmer management mean of 10 farmers)

Limitation-No; * Slight;/**Moderate; ***Severe; **** Very severe

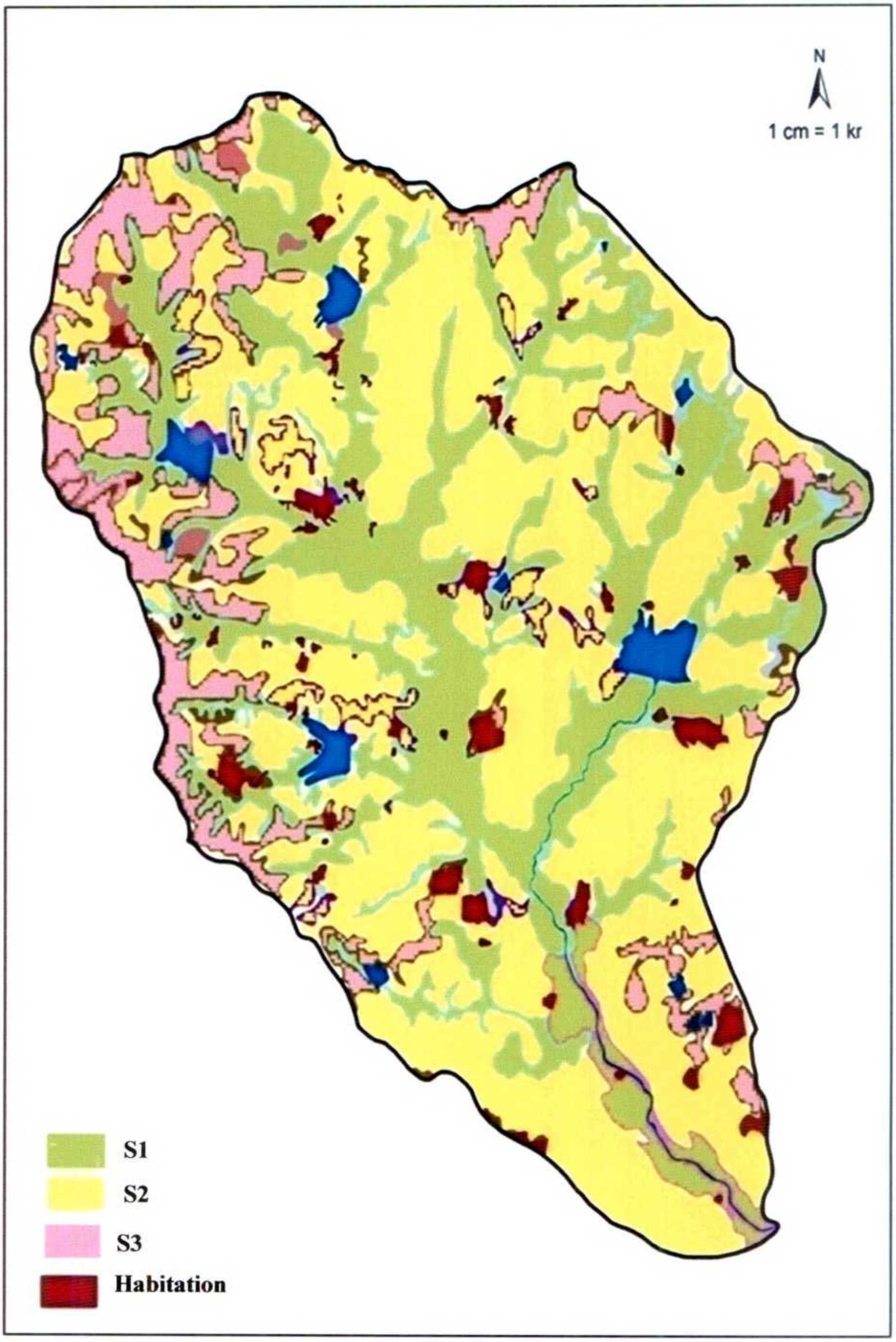

Fig- 4.16: Soil site suitability map of soybean

In addition , the suitability classes was also derived based on the actual yield as suggested by FAO (1983), this was based on the yield levels for the suitability classes as S1 > 80 % S2 40% to 80 % S320 to 40% and N< 20% . The yield reduction levels have been decided on the optimum yield of the crop. The optimum yield was calculated with the help at data collected from 10 farmer fields with similar management practices and the average of 3-6 commercial varieties grown in the soils of the Tungi watershed.

4.6.4.1 Soil- site suitability evaluation for soybean.

Soybean is the most important pulse and oilseeds crop the region it is a cash crop with low cost benefit ratio. The commercially growing variety in the study area, such as PK-472, JS-335 and KL-441. The soil-site requirement given for Soybean crop (NBSS and LUP, 1994) the soils of Typic Ustorthents (P_1, P7 and P_9), Typic Haplustepts (P_2, P_3 and P_8) and Typic Haplustepts (P_4, P_5 and P_6) all are marginally suitable. However, according to FAO 1983 the suitability based on optimum yield basis the soil of Typic Ustorthents Table 4.35. (P_1 and P_9) are marginally suitable; Typic Haplustepts (P_3 and P_8) are moderately suitable and Typic Haplustepts (P_4, P_5 and P_6) are highly suitable for soybean crop.

The perusal of data (Table 4.35) indicates that 8565.39 ha (34.57% of TGA) area is highly suitable (S1), 11998.62 ha (48.44 % of TGA) area is moderately suitable (S2) and 3458.30 ha (13.96 % of TGA) area is marginally suitable (S3), for soybean cultivation. The suitability map of Soybean is presented in fig.4.1

Table 4.35 Distribution of area under different Soybean suitability classes in Tungi watershed

Sr. No.	Soil suitability class	Area	
		Ha	% TGA
1	Highly suitable (S1)	8565.39	34.57
2	Moderate suitable (S2)	11998.62	48.44
3	marginally suitable(S3)	3458.30	13.96
4	Habitation	326.30	1.32
5	Waterbody	423.11	1.71
	Total	**24771.91**	**100**

4.5.4.2 Soil Site suitability for Pigeon pea

Pigeon pea is the most important pluses crop in this area followed by soybean. The commercial variety grown in this area *Viz.* BSMR-736, BDN-1.The soils of Tungi Watershed are Typic Ustorthents (P_1, and P_9) are not suitable(N1), Typic Haplustepts (P_2, P_3 and P_8) and Typic Haplustepts (P_4, P_5 and P_6) all are marginally suitable (S2).

Table 4.36 Distribution of area under different Pigeon pea suitability classes in Tungi watershed

Sr. No.	Soil suitability class	Area	
		Ha	% TGA
1	Highly suitable (S1)	7264.69	29.32
2	Moderately (S)	12679.50	51.15
3	Marginally suitable (S3)	4078.29	16.46
4	Habitation	326.3	01.32
5	Waterbody	423.11	01.71
	Total	**24771.91**	**100**

According to FAO 1983, the suitability of pigeonpea crop based on optimum yield level (21.00 qt/ha) the soils of Typic Haplusterts are highly suitable (S1) and Typic Haplustepts are moderately suitable (S2) were as the soils of Typic Ustorthents are marginally suitable (S3) for pigeon pea crop.

The perusal of data (Table 4.36) indicates that 7264.69 ha (29.32 % of TGA) area is highly suitable (S1), 12679.50 ha (51.15 % of TGA) area is moderately suitable (S2) and 4078.29 ha (16.46 % of TGA) area is marginally suitable (S3), for pigeonpea cultivation. The suitability map is presented in fig.4.17.

4.7 Land resources development and conservation

The integration of physiography, soil, and present land use and slope maps under GIS environment has brought out the three composite land units, which lead to identify the areas for resource development and conservation. The suggested land use plan includes agro-forestry, agro horticulture, silvipasture and intensive cultivation. The soils of pediment with very shallow depth are mainly suited short duration crops soybean, groundnut and Sorghum. To improve the productivity in these cultivated land units, agri-

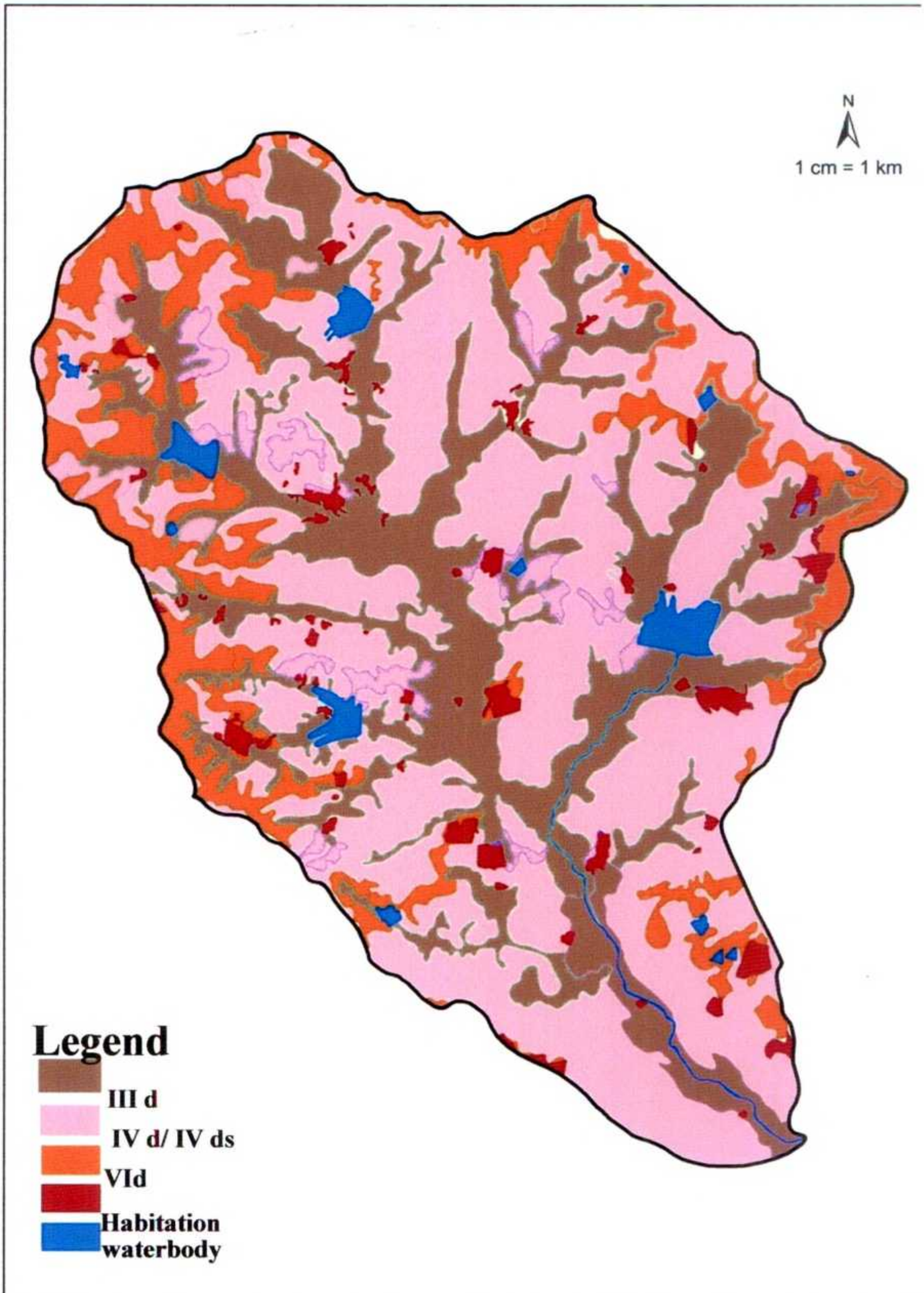

Fig- 4.13 Land capability classification of Tungi watershed

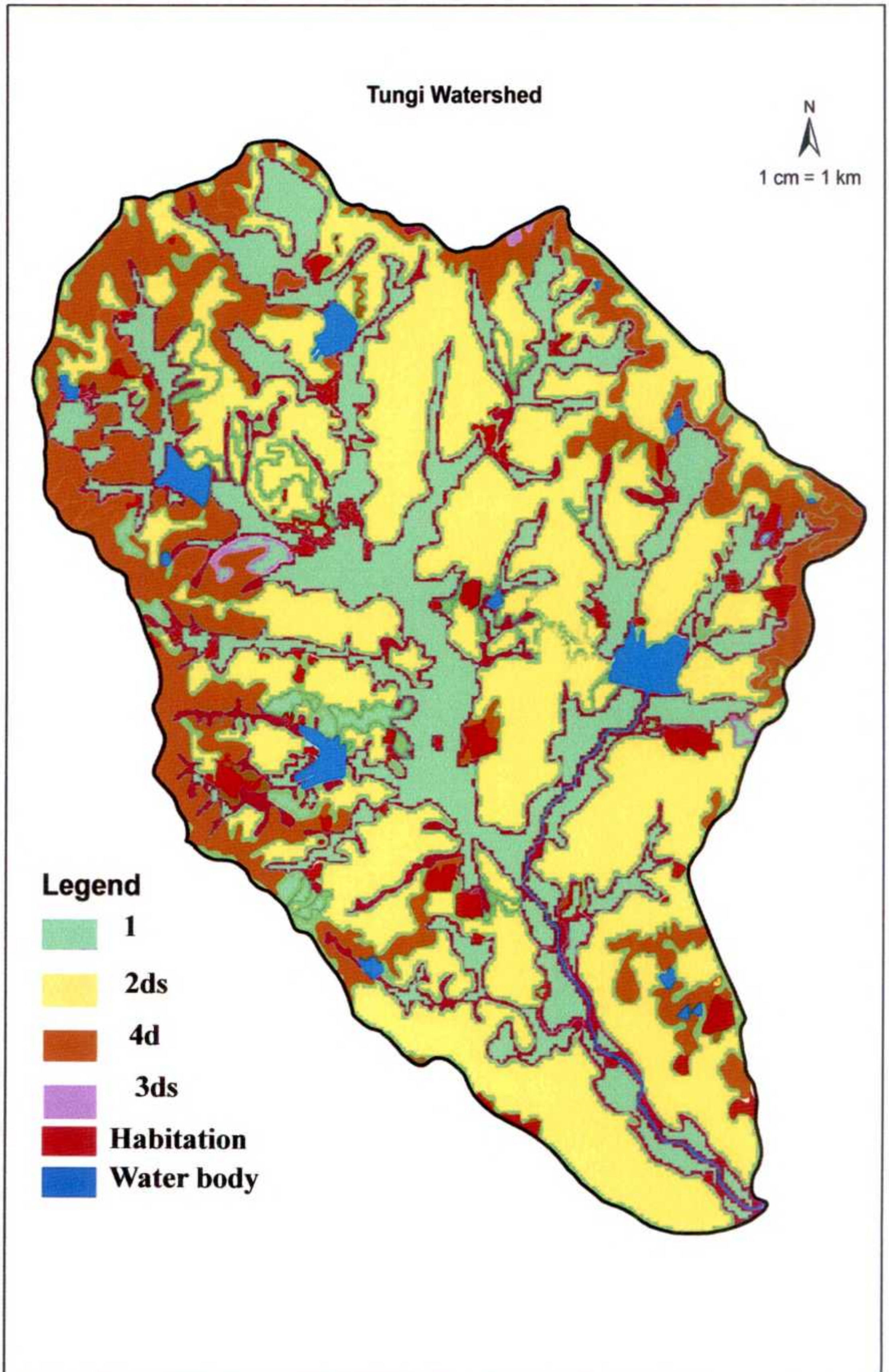

Fig-4.14 Land irrigability classification of Tungi watershed

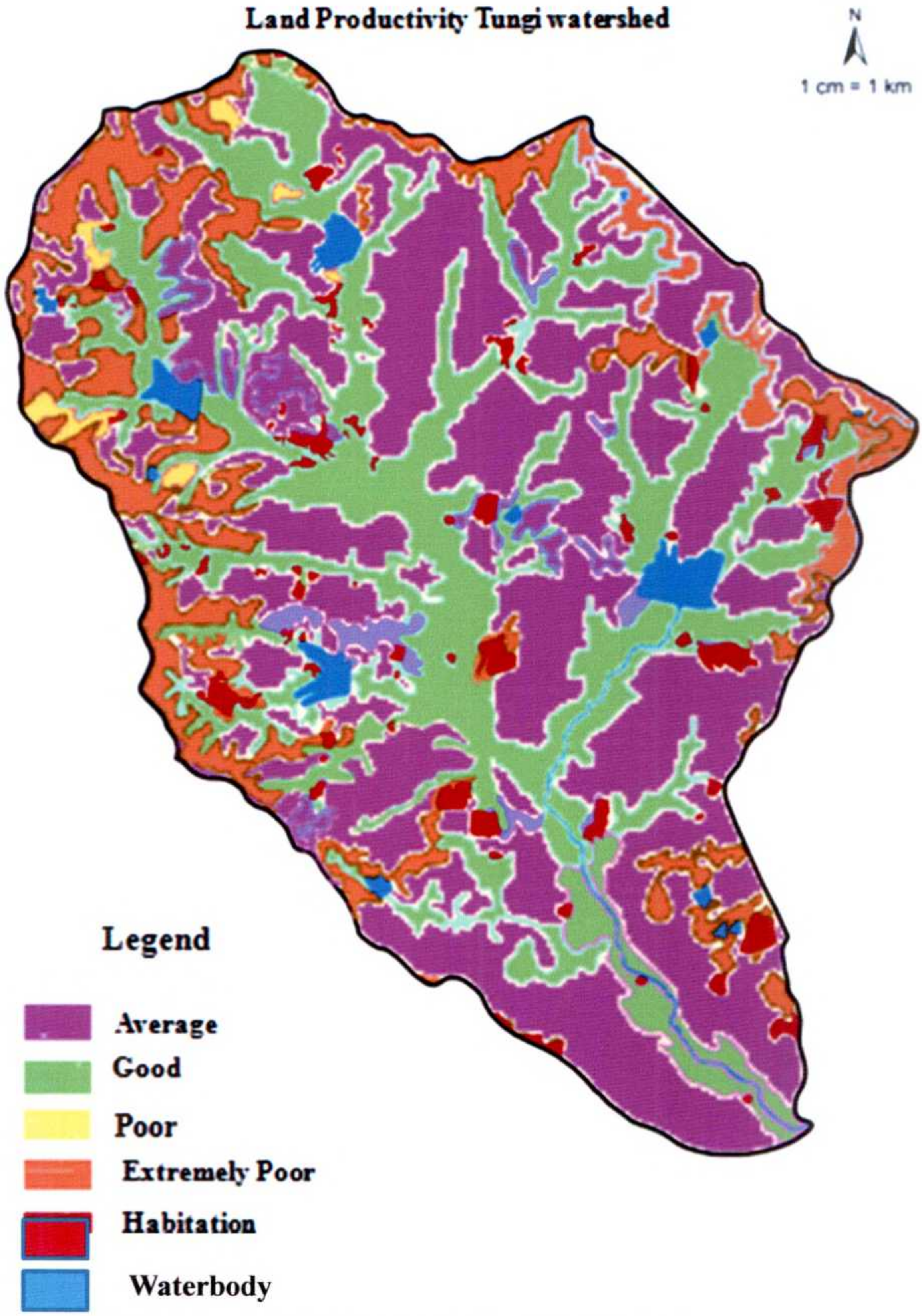

Fig-4.15 Land productivity map of Tungi watershed

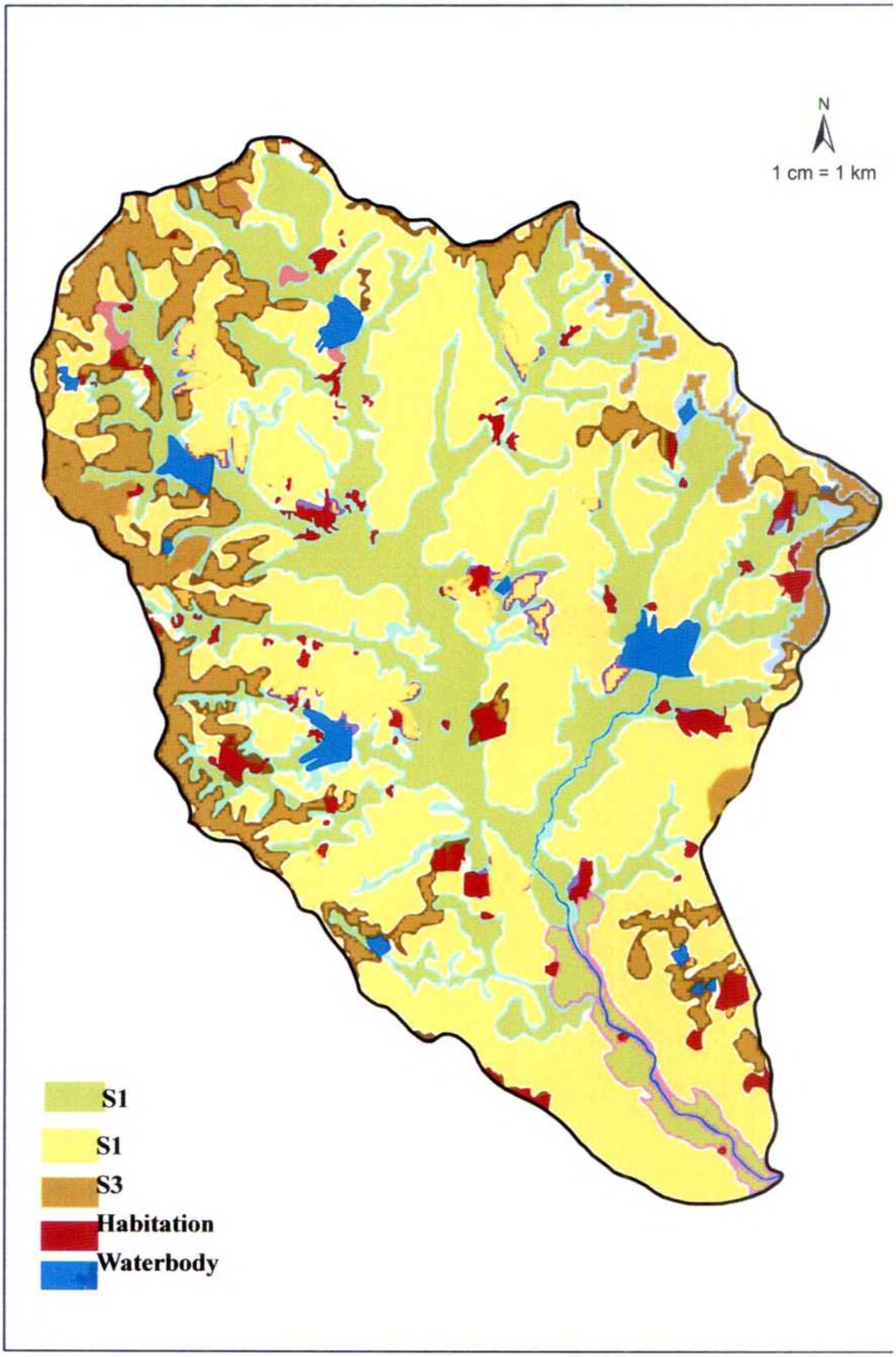

Fig-4.17: Soil site suitability map of pigeonpea

Table-4.32 Soil-site suitability criteria for pigeonpea

Soil - site Characteristics	DEGREE OF LIMITATION					
	0 (None)	1 (Slight)	2 (Moderate)	3 (Severe)	4 (Very severe)	
	S1		S2	S3	N1	N2
CLIMATIC CHARACTERISTICS						
Total rainfall (mm)	850-1000	750-850	650-750	550-650	<550	--
Rainfall growing season (mm)	700-850	600-700	500-600	<500	---	--
Rainfall during critical period (boll development)	>210	210-150	150-120	<120	---	--
Length of growing period(days)	160-180	135-160	120-135	<120	---	--
Mean temp. growing season (°C)	28-26	26-24	24-22	22-20	>20	--
Mean max. Temp. growing season(°C)	35-32	32-28	28-26	26-24	<24	--
Mean min. temp. growing season	---	---	---	<15	>40	--
Mean R.H. in growing season	80-90	60-80	---	<50	---	--
SITE CHARACTERISTICS						
Slope (%)	<1	1-3	3-5	5-8	>8	--
Erosion	el	el	e2	e3	--	--
Hydraulic conductivity (mm hr^{-1})	20-50	10-20	5-10	1-5, >50	<1	--
Drainage	Well	Mod.well	Imperfect	Poor & excessive	V.poor	--
PAWC (mm)	>200	200-150	150-100	<50	--	--
SOIL CHARACTERISTICS						
Texture	cl,sicl,sil,sc,sic,cl	c.sc	scl	sl,cl	s,ls	--
Coarse fragments (Vol %) Within 50 cm	<5	5-15	15-25	25-35	>35	--
Depth (cm)	>125	125-100	100-75	75-50	<50	--
$CaCO_3$ (%)	<5	5-10	10-20	>20	--	--
Exch. Ca/Mg ratio	>2.5	1.5-2.5	0.5-1.5	<0.5	--	--
BS (%)	>80	80-50	35-50	<35	--	--
O.C. (%) (0-25cm)	>0.75	0.75-0.50	0.5-0.20	<0.20	--	--
ECe (dSm^{-1})	<2	<2.3	3-4	>4	--	--
pH(1:2)	6.5-7.5	7.5-8.5, <6.5	8.5-8.5, <5.5	>9.0,--	--	--

Source: NBSS&LUP (1994).

Table-4.32 Soil-site suitability criteria for pigeonpea

Soil - site Characteristics	DEGREE OF LIMITATION					
	0 (None)	1 (Slight)	2 (Moderate)	3 (Severe)	4 (Very severe)	
	S1		S2	S3	N1	N2
CLIMATIC CHARACTERISTICS						
Total rainfall (mm)	850-1000	750-850	650-750	550-650	<550	--
Rainfall growing season (mm)	700-850	600-700	500-600	<500	---	--
Rainfall during critical period (boll development)	>210	210-150	150-120	<120	---	--
Length of growing period(days)	160-180	135-160	120-135	<120	---	--
Mean temp. growing season (°C)	28-26	26-24	24-22	22-20	>20	--
Mean max. Temp. growing season(°C)	35-32	32-28	28-26	26-24	<24	--
Mean min. temp. growing season	---	---	---	<15	>40	--
Mean R.H. in growing season	80-90	60-80	---	<50	---	--
SITE CHARACTERISTICS						
Slope (%)	<1	1-3	3-5	5-8	>8	--
Erosion	el	el	e2	e3	--	--
Hydraulic conductivity (mm hr^{-1})	20-50	10-20	5-10	1-5, >50	<1	--
Drainage	Well	Mod.well	Imperfect	Poor & excessive	V.poor	--
PAWC (mm)	>200	200-150	150-100	<50	--	--
SOIL CHARACTERISTICS						
Texture	cl,sicl,sil,sc,sic,cl	c.sc	scl	sl,cl	s,ls	--
Coarse fragments (Vol %) Within 50 cm	<5	5-15	15-25	25-35	>35	--
Depth (cm)	>125	125-100	100-75	75-50	<50	--
$CaCO_3$ (%)	<5	5-10	10-20	>20	--	--
Exch. Ca/Mg ratio	>2.5	1.5-2.5	0.5-1.5	<0.5	--	--
BS (%)	>80	80-50	35-50	<35	--	--
O.C. (%) (0-25cm)	>0.75	0.75-0.50	0.5-0.20	<0.20	--	--
ECe (dSm^{-1})	<2	<2.3	3-4	>4	--	--
pH(1:2)	6.5-7.5	7.5-8.5, <6.5	8.5-8.5, <5.5	>9.0,--	--	--

Source: NBSS&LUP (1994).

Table-4.33 Degree of Limitations in each of the soil and overall suitability class for pigeonpea

Soil - site Characteristics	Pedon 1	Pedon 2	Pedon 3	Pedon 4	Pedon 5	Pedon 6	Pedon 7	Pedon 8	Pedon 9
CLIMATIC CHARACTERISTICS									
Total rainfall (mm)	1	1	1	1	1	1	1	1	1
Rainfall growing season (mm)	2	2	2	2	2	2	2	2	2
Length of growing period(days)	0	0	0	0	0	0	0	0	0
Mean temp. growing season (^oC)	1	1	1	1	1	1	1	1	1
Mean R.H. in growing season	0	0	0	0	0	0	0	0	0
SITE CHARACTERISTICS									
Slope (%)	3	2	2	1	1	1	2	3	3
Erosion	0	2	2	0	2	0	0	0	0
Hydraulic conductivity (mm hr^{-1})	1	1	1	2	3	2	1	2	1
Drainage	0	1	0	2	2	2	0	2	1
Coarse fragment (Vol. %)	1	1	4	0	0	1	2	2	3
PAWC (mm)	3	1	1	0	0	0	2	2	2
SOIL CHARACTERISTICS									
Texture	0	0	0	0	0	0	0	0	0
Depth (cm)	4	1	2	0	0	0	3	3	4
SOIL FERTILITY									
$CaCO_3$ (%)	1	3	2	1	2	2	1	3	1
BS (%)	0	0	0	0	0	0	0	0	0
O.C. (%) (0-25cm)	2	2	2	2	2	2	2	2	2
ECe (dSm^{-1})	0	0	0	0	0	0	0	0	0
pH(1:2)	1	1	1	1	1	1	1	1	1
SUITABILITY CLASS	N1	S2	S2	S2	S2	S2	S2	S2	N1

Table-4.34 Degree and kind of major constraints, suitability and yield of Pigeonpea

Pedon	Contents												Yield	% Yield to optimum	Suitability based on actual yield
	LGP	Slope	Depth	Erosion	Texture	HC (Drainage)	PAWC	$CaCO_3$	ESP	EC dSm^{-1}	pH	Suitability Class	Q/ha		
Pedon 1	-	***	****	-	-	*	***	*	-	-	*	N1	06.50	30.95	S3
Pedon 2	-	**	*	**	-	*	*	***	-	-	*	S2	15.75	75.0	S2
Pedon 3	-	**	**	**	-	*	*	**	-	-	*	S2	11.25	53.57	S1
Pedon 4	-	*	-	-	-	***	-	*	-	-	*	S2	17.20	81.90	S1
Pedon 5	-	*	-	-	-	***	-	**	-	-	*	S2	18.75	89.28	S1
Pedon 6	-	**	-	**	-	**	-	**	-	-	*	S2	18.25	86.90	S1
Pedon 7	-	**	***	**	-	*	**	*	-	-	*	S2	10.00	47.61	S2
Pedon 8	-	***	***	**	-	**	**	***	-	-	*	S3	12.50	59.52	S2
Pedon 9	-	***	****	**	-	*	**	*	-	-	*	N1	06.50	30.95	S3

* Based on maximum observed yield as optimum : 21 q/ha (farmer management mean of 10 farmers)

Limitation-No; * Slight;/**Moderate; ***Severe; **** Very severe horticulture with aonla, guava, and custard apple and drumstick may be adopted with suitable soil and water conservation measures like contour bounding and construction of water harvesting structures. The soils at pediplains and pediments - pediplains complex soils are mostly suitable for long duration and double crops viz, soybean- gram, Tur, soybean-rabi sorghum, sugarcane, with supplementary irrigation with moderate leaching.

Summary and Conclusions

CHAPTER-V

SUMMARY AND CONCLUSIONS

The present study was carried out in Tungi watershed (total area 24771.91 ha) of Ausa tehsil, Latur district, Maharashtra to characterize the land resources *viz.* land use/land cover, physiography and soils using IRS LISS- III digital data of Jun 2013. The soils were evaluated for land capability, land irrigability, soil productivity and soil-site suitability for, soybean and pigeonpea. The results of the present investigation have been summarized below.

Visual interpretation of IRS LISS-III (1:10,000 scale) satellite data supported by field checks in the area, showed five categories of land use/land cover *viz.* single crop (kharif and Rabi crop), double crop, scrubland (Dense and open), water body and built-up area (Habitation). The total area under single crop (kharif and Rabi crop), double crop, scrubland (Dense and open), water body and built-up area (Habitation) are 68.69, 24.23, 1.71 and 2.72 per cent, respectively.

Visual interpretation of the IRS LISS-III in conjunction with SOI toposheet and subsequent ground truth revealed three major physiographic units *viz.* pediplain, pediments and pediments-pediplain complex.

Soil depth of the Tungi watershed varies from 21 to >150 cm that is correspond to shallow to very deep. Soil depth of Typic Ustorthents (P_1, P_7 and P_9) are shallow varies between 21 to 40 cm and moderately deep (50 to 60 cm) in Typic Haplustepts (P_2P_3 and P_8) and very deep in Typic Haplusterts (> 150 cm).

Most soils of the study area were black (10 YR 2.5/1) to dark brown (10 YR 3/3) in colour. The pedon P_1 P_7 and P_9 (Typic Ustorthents) soils colour varies from 10 YR 3/2 to 10YR 6/2 corresponds to the very dark grayish brown to light brownish gray. The pedon P_2, P_3 and P_8 (Typic Haplustepts) soils colour varies from 10 YR 3/1 to 10YR 6/2 corresponds to the very dark grey to light brownish gray in colour. The pedon P_4 P_5 and P_6 (Typic Haplusterts) soils colour varies from black (10 YR 2.5/1) to dark yellowish brown (10YR 4/4).

The soils have structure varies from, medium strong, angular blocky to medium weak, sub angular blocky in structure in pedon P_4, P_5 and P_6 (Typic Haplusterts) showed well developed intersecting slickenside and wedge shaped structural aggregates.

In Typic Ustorthents (P_1, P_7 and P_9) and in Typic Haplustepts (P_2, P_3 and P_8) soils structure varies from medium weak sub angular blocky to granular soils structure.

Texture of soils was clay loam to clay in texture and soils consistency varies non-sticky non-plastic to very sticky very plastic in nature. The high clay content was attributed to basaltic parent material.

The coarse fragment of soils varies from 7.03 to 71.33 per cent. It is obvious that the presence of coarse fragments is related with topographic situation

The bulk density of the soils of Tungi watershed varied from 1.30 to 1.92 Mg m^{-3}. The highest (1.92 Mg m^{-3}) bulk density was observed in Typic Haplusterts (pedon-P_6) as compared to Typic Ustorthents and Typic Haplustepts.

The saturated hydraulic conductivity of the study area varies from 0.42 to 30.00 cm hr^{-1}. This variation attributed to textural difference.

The highest clay content was found in the Typic Haplusterts pedon P_4 (71.00%) followed by Typic Haplustepts and Typic Ustorthents. This variation may be due to topographic deference. The soils at high topography Typic Ustorthents (P_1, P_7 and P_9) clay content varied from 22.89 to 50.19 per cent. The soils at sloping landscape Typic Haplustepts (P_2, P_3 and P_8) clay content ranged between 38.0 to 60.19 per cent were as at lower topographic position Typic Haplusterts (P_4, P_5 and P_6) clay content ranged between 53.52 to 71.00 per cent which correspond to clay texture

The available water capacity of the soils of Typic Ustorthents ranged from 07.5 to 12.7 per cent and PAWC value varies from 56.17 to 67.56 mm. The soils of Typic Haplustepts have AWC value ranged from 05.3 to 22.3 per cent and PAWC value varies from 127.08 to 184.7 mm. The available water capacity of soils of Typic Haplusterts ranged from 13.1 to 23.3 per cent and PAWC value varies from 277.86 to 281.55 mm. This indicated that the maximum available water content at soils of Typic Haplusterts followed by Typic Haplustepts and Typic Ustorthents. The correlation of soil depth with PAWC ($r=0.949271$) and clay content with PAWC ($r=0.884944$) were highly positive correlated.

The soils are slightly to strongly alkaline in reaction with pH ranged from 7.01 to 8.87. The electrical conductivity of the studied soil is < 1.0 dSm^{-1} (0.13 to 0.67 dSm^{-1}). This is well within safe limit of electrical conductivity range.

The organic carbon content of Typic Ustorthents soil varied from 0.11 to 0.42 per cent, Typic Haplustepts soil varied from 0.04 to 0.61 and Typic Haplusterts soil varied from 0.07 to 0.81 per cent respectively. It was observed that as depth increases, percent organic carbon decreased. The soils were low to high in organic carbon content.

The calcium carbonate content in soils of Typic Ustorthents was varied from 4.4 to 20.4 in Typic Haplustepts varies from (8.3 to 37.0) and Typic Haplusterts varies from (6.6 to 20.4). These soils contain low to high amount of $CaCO_3$; it may be attributed to the leaching of (HCO3)2 which get precipitate down to the slope as well as at lower horizon.

The cation exchange capacity of Typic Ustorthents (P_1, P_7 and P_9) ranged from 27.50 to 44.18 cmol (p^+) kg^{-1}, Typic Haplustepts (P2, P_3 and P_8) varied from 36.62 to 56.20 cmol (p^+) kg^{-1} and Typic Haplusterts (P_4, P_5 and P_6) ranged from 48.52 to 63.58 cmol (p^+) kg^{-1}. The highest CEC was observed in Typic Haplusterts as compared to Typic Haplustepts and Typic Ustorthents. The high CEC is attributed to the high amount of clay. The relationship of cation exchange capacity and clay content in soil found to be significant positively correlated (r=0.982697) and which was increased with increasing clay content in soil.

The calcium was the dominant cation followed by magnesium, sodium and potassium in all profiles. The base saturation per cent varied from 88.82 to 113.42 per cent.

Taxonomically these soils classified as Typic Ustorthents, Typic Haplustepts and Typic Haplusterts.

The ground water indicated that the ratio of monovalent to divalent cations (Kelley's ratio) is less than unity (0.23 to 1.43) indicating no sodiumfication of water in all well and tube well sample. The RSC less than 1.25 $mmol^{-1}$ indicatin this water is suitable for irrigation. The classification according to US salinity laboratory (Richards 1954). The water sample of Tungi watershed was medium Salinity low sodicity (C_2S_1) to high salinity low sodicity (C_3S_1).

The fertility status of soils was low to high. The available nitrogen content in the pedons varied from 102.72 to 291.91 kg ha^{-1} indicating that the soil was low to moderate in available nitrogen, moderate to high available phosphorous (11.20 to 28.00

kg ha^{-1}) and moderate to high is available potassium (168.23 to 485.49 kg ha^{-1}). The NPK content was found to be rich in surface layer than subsurface layer, possibly due to application of fertilizers.

The soils of Tungi watershed DTPA extractable Fe, Mn, Zn and Cu varied from (weighted mean) 6.18 to 28.39, 6.20 to 30.77, 3.37 to 10.45 5.85 to 21.65 mg kg^{-1} respectively. This indicated that the soils are high in Fe followed by Mn, Cu and Zn. The higher amount of Fe and Mn content in the soil may be due to the ferromagnesian parent material. The available micronutrient content in surface layer to be more than sub surface layers. This may be due to surface application of micronutrient.

As per the land capability classification the soil of Tungi watershed are grouped in to three major capability classes (*III, IV* and *VI*) and four sub classes *viz. IIId, IVd* and *IVds* and *VId* comprising 29.33, 52.05, and 15.60 per cent area, respectively.

As per irrigability classification the soils of Tungi watershed were grouped under land irrigability subclasses 1, 2ds, 3ds and 4d comprising 29.32, 50.79, 0.35 and 16.49 per cent area, respectively.

As per productivity classification the soil productivity classes in Tungi watershed have been grouped as good, average, poor and extremely poor representing 29.33, 51.16, 0.89 and 15.60 per cent, respectively.

Soil site suitability for soybean as per the criteria suggested by NBSS and LUP (1994) the soils of Typic Ustorthents, Typic Haplustepts and Typic Haplustepts all are marginally suitable. But according to FAO 1983 the suitability based on optimum yield basis the soil of Typic Ustorthents are marginally suitable; Typic Haplustepts are moderately suitable and Typic Haplustepts are highly suitable for soybean crop.

Soil site suitability for pigeon pea as per the criteria suggested by NBSS and LUP (1994) the soils of Tungi Watershed are Typic Ustorthents are not suitable (N1), Typic Haplustepts and Typic Haplustepts all are marginally suitable (S2). According to FAO 1983, the suitability of pigeonpea crop on the basis of optimum yield level the soils of Typic Haplusterts are highly suitable (S1) and Typic Haplustepts are moderately suitable (S2) were as the soils of Typic Ustorthents are marginally suitable (S3) for pigeon pea crop.

As per soil site suitability classification the total area of watershed 8565.39 ha (34.57% of TGA) area is highly suitable (S1), 11998.62 ha (48.44 % of TGA) area is moderately suitable (S2) and 3458.30 ha (13.96 % of TGA) area is marginally suitable (S3), for soybean cultivation, like that 7264.69 ha (29.32 % of TGA) area is highly suitable (S1), 12679.50 ha (51.15 % of TGA) area is moderately suitable (S2) and 4078.29 ha (16.46 % of TGA) area is marginally suitable (S3), for pigeonpea cultivation.

Interventions for agro forestry, agri-horticulture, silvipasture and conservation of forest for suitable soil and water conservation measures have been suggested for land resources development and conservation.

From the study, it can be concluded that,

Visual interpretation of false colour composite of IRS LISS-III data with enhanced spatial resolution supported by adequate field checks is useful for mapping physiography, soils and land use/land cover of Tungi Watershed.

The information generated from remote sensing data and integrated using Geographical Information System (GIS) helps in generation of various thematic maps for crop planning, conservation and management of land resources at village level.

From the above result suggested land use for Tungi watershade as per physiographic unit pediments soils are mostly suited for short duration and shallow rooted crops. Improvement of the productivity of these soils adopted suitable soil and water conservation measures like contour bounding and construction of water harvesting structures and tank hybridization in this area. The soils at pediplains and pediments - pediplains complex soils are mostly suitable for long duration and double crops viz, soybean- gram, Tur, soybean-rabi sorghum, sugarcane, with supplementary irrigation with moderate leaching.

From the present study the following conclusion are drawn:

- Visual interpretation of IRS LISS-III (1:10,000 scale) satellite data supported by field checks in the area, showed five categories of land use/land cover *viz.* single crop (kharif and Rabi crop), double crop, scrubland (Dense and open), water body and built-up area (Habitation).and three physiographic units *viz.* pediplain, pediments and pediments-pediplain complex.

- The soils of Tungi watershed shallow to very deep, black (10 YR 2.5/1) to light brownish gray (10YR 6/2) in colour. The soil structure granular to angular blocky in structure with well-developed intersecting slickenside.
- The soils texture is clay loam to clay in texture and soils consistency varies non-sticky non-plastic to very sticky very plastic in nature.
- The bulk density of the soils of Tungi watershed varied from 1.30 to 1.92 Mg m^{-3}.
- The saturated hydraulic conductivity of the study area varies from 0.42 to 30.00 cm $^{hr-1}$. This variation attributed to textural difference.
- The soils are slightly to strongly alkaline in reaction .The electrical conductivity of the studied soil is < 1.0 dSm^{-1}
- The organic carbon content of the soils was low to high in organic carbon content (0.1 to 0.8 %).
- The calcium carbonate content in soils of Typic Ustorthents was varied from 4.4 to 20.4 per cent.
- Low to high in cation exchange capacity varies from 27.50 to 63.58 $cmol(p^{+})kg^{-1}$. The highest CEC was observed in Typic Haplusterts .The calcium is the dominant cation followed by magnesium, sodium and potassium in all profiles. The base saturation percent varied from 88.82 to 113.42 per cent.
- Taxonomically these soils classified as Typic Ustorthents, Typic Haplustepts and Typic Haplusterts.
- The RSC of ground water is less than 1.25 $mmol^{-1}$ it indicates that this water is suitable for irrigation.
- The fertility status of soils was low to high. The soils are high in Fe followed by Mn, Cu and Zn. The higher amount of Fe and Mn content in the soil may be due to the ferromagnesian parent material.
- As per the land capability classification the soil of Tungi watershed were grouped in to three major capability classes (III, IV and VI) and four sub classes *viz. IIId, IVd* and *IVds* and *VId* comprising 29.33, 52.05, and 15.60 per cent area, respectively.

- As per irrigability classification, the soils of Tungi watershed are grouped under land irrigability subclasses 1, 2ds, 3ds and 4d comprising 29.32, 50.79, 0.35 and 16.49 per cent area, respectively.
- As per productivity classification the soil productivity classes in Tungi watershed have been grouped as good, average, poor and extremely poor representing 29.33, 51.16, 0.89 and 15.60 per cent, respectively.
- As per soil site suitability, Typic Ustorthents are marginally suitable; Typic Haplustepts are moderately suitable and Typic Haplustepts are highly suitable for soybean crop. Whereas Typic Haplusterts are highly suitable (S1) and Typic Haplustepts are moderately suitable (S2) and Typic Ustorthents are marginally suitable (S3) for pigeon pea crop.
- Typic Ustorthents soils mostly located at pediments and are suited for short duration and shallow rooted crops. Whereas Typic Haplustepts and Typic Haplusterts soils located at pediplains and pediments - pediplains complex soils and are suitable for both short and long duration and shallow and tap rooted crops

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Thesis Abstract

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Research Title: "Evaluation and Characterization of Tungi watershed by using Remote Sensing GIS techniques".

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ABSTRACT

In the present investigation entitled "Evaluation and Characterization of Tungi watershed by using Remote Sensing GIS techniques" The study was aimed at to characterization, classification and soil for land resource mapping. The Tungi weatershed is located in Ausa tehsil, Latur district, Maharashtra in between 18^0 14' 31" to $18^0$19' 36" N latitude and 76^0 24'28" to 76^0 37' 02" E longitude. The geographical area of Tungi watershed is 24771.91 ha. The climate of the area is hot, dry and sub-humid with annual rainfall of 794 mm. The mean maximum and minimum temperature are 32.7^0C and 18.1^0C respectively. Nine (09) representative pedon from different physiographic unit of watershed were characterized classified and carry out the Land capability, land irrigability, land productivity and soil site suitability. The twenty-one ground water samples of adjoining area of soil profile were collected and analyzed.

The soils of Tungi watershed shallow to very deep, black (10 YR 2.5/1) to light brownish gray (10YR 6/2) in colour, granular to angular blocky in structure with well-developed intersecting slickenside, clay loam to clay in texture , non sticky non plastic to very sticky very plastic in nature, the bulk density varied from 1.30 to 1.92 Mg m^{-3}. The saturated hydraulic conductivity of the study area varies from 0.42 to 30.00 cm $^{hr-1}$. The soils are slightly to strongly alkaline in reaction .The electrical conductivity is < 1.0 dSm^{-1} .The organic carbon content of the soils was low to high, low to high in cation exchange capacity varies from 27.50 to 63.58

$cmol(p^+)kg^{-1}$.Taxonomically these soils classified as Typic Ustorthents, Typic Haplustepts and Typic Haplusterts. The RSC of ground water is less than 1.25 $mmol^{-1}$ indicate in this water is suitable for irrigation. The fertility status of soils was low to high. The land capability classes are grouped in to three major capability classes (*III, IV* and *VI*) and four sub classes *viz. IIId, IVd* and *IVds* and *VId* comprising 29.33, 52.05, and 15.60 per cent area, respectively. The land irrigability classes are grouped under land irrigability subclasses 1, 2ds, 3ds and 4d comprising 29.32, 50.79, 0.35 and 16.49 per cent area, respectively. The soil productivity classes have been grouped as good, average, poor and extremely poor representing 29.33, 51.16, 0.89 and 15.60 per cent, respectively. As per soil site suitability Typic Ustorthents are marginally suitable (S3); Typic Haplustepts are moderately suitable (S2) and Typic Haplustepts are highly suitable (S1) for soybean crop. Whereas Typic Haplusterts are highly suitable (S1) and Typic Haplustepts are moderately suitable (S2) and Typic Ustorthents are marginally suitable (S3) for pigeon pea crop. From above however concluded that Typic Ustorthents soils mostly located at pediments and are suited for short duration and shallow rooted crops. Whereas Typic Haplustepts and Typic Haplusterts soils located at pediplains and pediments- pediplains complex soils and are suitable for both short and long duration and shallow and tap rooted crops.