CHARACTERIZATION OF SOIL QUALITY PARAMETERS UNDER PLAIN AND HILLY REGION OF EAST SIANG DISTRICT, ARUNACHAL PRADESH

THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE
REQUIREMENTS FOR THE AWARD OF DEGREE OF

MASTER OF SCIENCE (AGRICULTURE)
IN
SOIL SCIENCE – SOIL AND WATER CONSERVATION

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CERTIFICATE

To
The Joint Registrar (Academic),
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Sir,

I have great pleasure in forwarding the thesis entitled **"Characterization of soil quality parameters under plain and hilly region of East Siang District, Arunachal Pradesh"** submitted by **Miss Tuli Taga** (ID No. : 19430SAC016) in partial fulfilment of the requirements for the award of the degree of ***Master of Science (Agriculture)*** in ***Soil Science – Soil and Water Conservation***, Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University.

I certify that the entire scheme of investigation reported here in, was planned and carried out by the candidate under my guidance. To the best of my knowledge and belief, the data presented in the thesis are genuine and original. No part of the work has been submitted for any degree or distinction.

Thanking you,

Forwarded **Forwarded** **Yours sincerely**

Head **(Course Coordinator)** **(Dr. Ramawatar Meena)**
Chairman of the Advisory Committee

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By
Tuli Taga

ID. No. 19430SAC016 **2021** **Enrolment No. 417408**

Thesis submitted in partial fulfilment of the requirements for the degree of

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Date:
Place: Varanasi (Tuli Taga)

Contents

LIST OF SYMBOLS AND ABBREVIATIONS

%	Per cent
Agri.	Agriculture
B.D	Bulk density
BIS	Bureau of Indian standards
Ca	Calcium
cm	Centimeter
Cmol (P+) kg^{-1}	Centimol per kilogram
dSm^{-1}	Desisimen per meter
DTPA	Diethyline Triamine Penta acetic acid
EC	Electrical conductivity
EDTA	Ethylene di amine tetra acetic acid
Et al.	Et alia, and others
G kg^{-1}	Gram per kilogram
Ha.	Hectare
i.e.	Id est. that is
J	Journal
K	Potassium
Kg/ha	Kilogram per hectare
Meq/100g	Milli equivalents per 100 gram of soil
Mg	Magnesium
Mg/kg	Milligram per kilogram
Mha	Million hectare
Mm.	Millimeter
N	Nitrogen
NIV	Nutrient index value
O.C	Organic carbon

P	Phosphorus
P.D	Particle density
pH	Puissance de hydrogen
S	Sulphur
Sq. km	Square kilometer
viz.,	Vide licet, namely
WHC	Water holding capacity

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Chapter I

INTRODUCTION

Soil is a dynamic natural body comprising of unconsolidated mineral and organic matter with water and air on the uppermost layer of the earth surface. It plays an important role in maintaining the ecosystem functioning on which all life depends (**Agyemang *et al*., 2011**). It varies greatly in space and time, a single agricultural field may contain identifiably different types of soils with various nutrient contents (**Clark *et al*., 2005**) owing to many processes in their chemical and biological properties (**Milne *et al*., 2004**). In addition to these, variation in the weather specifically rainfall and temperature and the changing nutrient requirements of crops as they grow (**Barraclough, 1986**) end up in making the soil nutrients more dynamic. The Physico-chemical properties of soil govern the biological activities and interchanges the molecules/ions between the solids, liquid and gaseous phases which in turn influences the nutrient cycling, plant growth and decomposition of organic materials.

The potential of the production of crops is affected by several factors. Fertility of soil is considered as an important factor among those factors. When required to meet the basic needs of air, water and food, only the quality of life in its various aspects are viewed and the adverse effects are ignored. To increase food production and growth of plant, major areas of soil is needed to be concentrated as it has the capacity to provide nutrients to crop and improve its quality as it is the most effective way to ensure sufficient foods for sustainable life. The type, texture, structure, colour and nutritional value of soil depends on the parent material, vegetation, climate, topography and time.

East Siang is one among the 25 districts in Arunachal Pradesh where the present study is being carried out. The East Siang district is a wild mountainous region presenting a remarkable topographical variety. The District covers an area of 4005 sq.km. and lies approximately between 27º43' and 29º20' North latitudes and 94º42' and 95º35' East longitudes. According to the 2011 census, the population of

East Siang District was found to be about 99,214. The district has been divided into four sub-divisions and 15 blocks which contains 167 villages. The East Siang District shares its borders with Lower Dibang Valley District to the East, West Siang District to the West, Tinsukia District to the South. It also shares its border with the state Assam to the West. The name of the district was derived from the Mighty River Siang that originates from Tibet, where it is called Tsangpo, transcends down and flows through the entire length of the area until it descends down into the plains of Assam south of Pasighat town, where it meets Dihang and Lohit all the way to Assam where the river is known as Brahmaputra. The Mighty Siang river is the life line of East Siang District. The Pasighat town is the headquarter of East Siang District. It is situated at an altitude of 155 meters above mean sea level and is known as the oldest town in Arunachal Pradesh which was established in the year 1911 A.D. A political Officer was appointed in that year with an aim to help the natives of the area to come down to the plains of Assam for trade and commerce.

The East Siang district has cold mountainous climate in the north while tropical climate exists in the south where winter temperature drops upto 7ºC and summer temperature goes up to 36ºC. December and January are generally the coldest months whereas July and August are the hottest months. Important features of its climate are copious rainfalls during the monsoon season and wind circulation during the winter season. Rainfall occurs mostly throughout the year but maximum is from April to September. The highest annual rainfall in the district is 2910.18 mm.

Geomorphologically, the district has been divided into 3 major geomorphology units.

1. **Denudo -structural hills**: The Denudo structural hills accounts for 1885.625 sq.km. of the area, which consists of moderate to high grade metamorphic rocks like schists gneisses and quartzite. This unit is known to be of hilly nature with steep slopes and the area is mainly a run off zone.

2. **Structural hills**: Structural hills occupy about 793.75 sq.km. of the area and are less compact and are mainly composed of coarse to medium grained sandstone, siltstone, conglomerate, clay of Siwalik group and micacious and feldspathic sandstone of Gondwana group. Siwalik groups of rocks are less compact than Gondwana group. Gondwana group acts as a run off zone while Siwalik group acts as the recharge zone.
3. **Piedmont alluvial plains**: Piedmont alluvial plain occupies about 1031.25sq.km. It is highly permeable and acts as a good water recharge zone.

The East Siang can be divided into 3 district hydrogeological units namely consolidated, semi-consolidated and unconsolidated. The units such as Sela unit, Bomdilla groups, Mirki quartzites and Buxa formations occupy the consolidated and forms major part of the area. The area acts as a run off zone. The only source of water for the local villages are the springs and streams. Springs discharge varies from 15-28 m/day.

The ground water potential of the semi – consolidated formation consists of coarsed grained sandstone, siltstone, conglomerate etc. Slopes of this area vary from 15-20 percent and thus this area acts as a recharge zone. Ground water can be located under confined to semi-confined condition. Discharge of tubewell vary from 300-500 lpm (litres per minute) in this area.

The area of un-consolidated formations occupies SE part of the district. The N-S flowing Siang river divides entire piedmont plain. In the Eastern part of the river Siang, the upper terraces consist mainly of boulder. The river dries up during the lean period due to high permeability of the underlying formations. This area acts as a recharge zone.

The parameters of soil quality are frequently used to make comparative assessments in agricultural management practices to determine their sustainability (**Regnold *et al*; **and **Palmer *et al*; 1995; Islam *et al*** and **Well *et al*, 2000**). The problems of soil quality deterioration and fertility decline exist all over the world (**Harden *et al*; 2001; Lal *et al*; 2001**). Cropping intensification without adequate restoration of soil fertility may threaten the sustainability of agriculture (**Roy *et al*., 2003**). Under similar agroecological environments, soil properties and crop production are affected by dominant factors such as land use and cultural practices (**Nnaji *et al*; 2002**). People through their crop production practices influence course of the formation and the physico-chemical status of the soil at any given time (**Asadu *et al*; and Enete *et al*; 1997**). It was observed that due to different land use types, soils formed over the same parent material and under the same climate and relief had dissimilar soil physico-chemical properties (**Ogunkunle *et al***; and **Egghaghara *et al***; **1992; Akamigbo *et al*; 1999**). Unsuitable land use often leads to sub-optimal use of land and agricultural investments and as a result soil degradation takes place (**Onweremadu *et al*, 2007**). The position of the landscape creates differences in soil formation through runoff, drainage, temperature and soil erosion and consequently difference in soil properties along a hill slope (**Brubaker *et al*.,1993**). All these affect local carbon and nitrogen processes (**Hobbie, 1996**), the variability of soil properties in complex hills are also affected (**Miller *et al*., 1988; Bhatti *et al*., 1991**). High yields and good product can be achieved only when the right type of soil is used for a certain crop. However, for the areas in which suitable soil is not available, soil amendment may be done to facilitate the crop growth and optimum yield.

The ability to produce food is one of the fundamental factors in societal development is the ability to produce food, therefore for a better production it is mandatory to know the right kind of element or nutrients (**Saidou *et al*., 2004**). The study of the soil has been carried out by people interested in plant growth and food production (**Hinrich *et al*., 1985**). Proper evaluation of fertility of the soil before planting a crop helps in adopting appropriate measures and prevents any kind of possible shortcomings thereby ensuring a good crop production. However, deterioration of fertility of the soil is less visible and less spectacular and also much difficult to assess (**Belachew *et al*;** and **Abera,2010**).

The present study was carried out to know about the **"Characterization of soil quality parameters under Plain and Hilly Region of East Siang District, Arunachal Pradesh",** by using different principles, procedures and techniques with the following objectives:

1. To characterize the physico-chemical properties under plain and hilly areas soil of East Siang District, Arunachal Pradesh.
2. To ascertain the soil fertility status of East Siang District, Arunachal Pradesh.
3. To study the correlation matrix between the physico-chemical parameters of soil under East Siang District, Arunachal Pradesh.

Chapter II

REVIEW OF LITERATURE

Soil is the major component which important for plant growth, metabolism and crop production. With the aim of studying on **"Characterization of soil quality parameters under plain and hilly region of East Siang District, Arunachal Pradesh"** based on some sources available and information gathered literature is reviewed under following sections.

2.1 Physico-chemical properties of soils

- Bulk density
- Particle density
- Porosity
- Water holding capacity
- Soil pH
- Electrical conductivity
- Organic carbon

2.2 Primary and Secondary Macro-nutrients in soil

- Nitrogen
- Phosphorus
- Potassium
- Calcium
- Magnesium
- Sulphur

2.1 Physico-chemical properties of soil (BD, PD, WHC, Porosity)

Bulk density

A study on the canal command area of Maharashtra was held by **Bharambe *et al.*, (1999)** in which the bulk density in vertisol was found to be varying from 1.33 to 1.40Mg/m^3 thereby increasing along with its depth.

Rao *et al*., (2002) studies indicated that due to the coarse texture associated with the lesser space in the pores, the black soil's bulk density was found to be comparatively less (1.57 Mg/m^3) than red soils (1.63 Mg/m^3). **Rao (2003)** found that in the coastal sandy soil of Singarayakondal, Andhra Pradesh, the bulk density ranged from 1.49–1.63 Mg/m^3 and in the coastal of chiralamandal, it ranged from 1.3 –1.62 Mg/m^3.

In Buddham of Guntur district, the bulk density of sandy soils varied from 1.30 to 1.57 Mg/m^3 according to **Mydhii (2006)**. **Singh *et al*., (2008)** observed that the bulk density of sandy clay loam to clay textured soils ranged from 0.02 –1.48 Mg/m^3 in the district of Jaunpur of Uttar Pradesh. Also, in the town of Ramachandrapuram mandal of chittoor district, Andhra Pradesh, **Rao *et al*., (2008)** observed and concluded that the bulk density of sandy to clay loam textured soils ranged from 1.45 -1.66 Mg/m^3.

A study was held on the sandy loam soils of Gannavaram pilot area of Nalgonda district, Andhra Pradesh by **Rajeshwar *et al*., (2009)** in which the bulk density ranged from 1.37 to 1.50 Mg/m^3. The soils of Jalna district in Maharashtra was studied by **Prasad *et al*., (2009)** in which he examined the terrain and stated that due to large amount of gravels in the surface horizon, the presence of bulk densities are higher in the surface horizon as compared to the sub-surface horizon. Similarly, the study on the Bulk density of surface and sub-surface horizons due to presence of organic carbon and coarse fragments by **Prasad *et al*., (2010)** where the bulk density varied from 1.54 to 1.95 Mg/m^3 showed that the bulk density was higher on the surface horizon than the sub surface horizon.

The effect of soil moisture on bulk density and porosity of intact aggregates of Mollic soils were studied by **Korenkova *et al*., (2012)** and the soil samples were collected on various experimental sites i.e. Mollic grumsic vertisol (mogmVRpe), haplic Chernozen (haCH), calcic Mollic fluvisol (ccmoFL) on which well aggregated agricultural soils were found to be present. And about 5 cm layer of surface area were removed and samples were also taken at a depth of 5-15 cm. The Core method was followed for analysing the sample which resulted in the increase of aggregate bulk density from 1.75 to 1.93 Mg/m^3, from 1.46 to 1.83 Mg/m^3 in haCH, from 1.52 to 1.82 Mg/m^3 in along with it some other changes such as the magnitude changes were also observed between particular soils.

A study was held on the soil bulk density in Coimbatore by **Chaudhari *et al*., (2013)** related to soil texture, availability of total nutrients and total moisture content of a soil sample at a depth of (0-15 cm) the observed range of bulk densities for sand is 1.2 to 1.8 Mg/m^3 and for clay, it is around 1.0 to 1.6 Mg/m^3 thereby showing a negative relation with all of the soil properties.

The soil bulk density related to texture, porosity, and organic matter content in the kandi soils of Kashmir valley was examined by **Ahad *et al*., (2015)** in which soil samples were taken from 5 different locations at a depth of 20-35 cm in a zigzag pattern after which it was concluded that there is a negative correlation of porosity and organic matter with bulk density and also a positive correlation between sand content and bulk density was found.

Particle density

It refers to the density of solid particles collectively. The average particle density of soil is about 2.65 Mg/m^3, but generally, it varies from 2.5 to 2.7 Mg/m^3 and is mostly dependent on the organic matter where there is little amount or no organic matter and the particle density values are almost same.

A study was carried out by **Rao *et al*., (1993)** of the soils in the Chakicharla village of Andhra Pradesh in which he detected that the particle density for sandy soils ranged from 2.48 to 2.65 Mg/m^3. Also, the red coastal sand dune soils in Tamilnadu was examined by **Jawahar *et al*., (1999)** after which he concluded that its particle density varied from 2.12 to 2.97 Mg/m^3.

A study was held on the different surface layers of soil i.e., red soils, laterite soils, black soils, alluvial soils by **Sharma, (2004)**. The study concluded that the values of different particle densities was found to be 2.56, 2.40, 2.20, 2.55 respectively.

Water Holding Capacity

A study was carried out by **Rao *et al*., (1993)** studied the soils of in the Chakicharla village of prakasam district, Andhra Pradesh on the nature and characteristics of soils in which it was found that the water holding capacity of sandy soils ranged from 16.45 to 21.42% and it decreased slowly with its depth. **Bandyopadhyay *et al*., (1995)** examined the coastal soils of sunder bans in west Bengal and observed that the water holding capacity of soils ranged from 21.40 to 37.60%.

The soil orders i.e. Entisols and Inceptisols in Haryana and Delhi of shahibi basin was studied by **Swarnam *et al*., (2004)** after which he concluded that the moisture retention at 1500 KPa was found to be 3.20 to 8.89 % and at 33 KPa it was 8.20 to 19.00% in surface horizons.

The study by **Thangaswamy *et al*., (2005)** on the different pedons of water holding capacity in sivagiri micro watershed showed that it ranged from 13.05 to 58.99 %. These results were accepted by the significant and positive correlation of water holding capacity in soils as there was a difference in the organic carbon content, clay, silt and depth.

The different pedons related to its water holding capacity was studied by **Muthumanickam *et al*., (2010)** which resulted in the conclusion that its average water holding capacity ranges from 3.67 to 37.07 %. And noted that there were 26 positive and significant correlation between clay and water holding capacity (r = 0.650**).

A study was held on the cultivated soils in south Sikkim by **Deb *et al*., (2013)** to correlate the properties between physico chemical and water holding capacity in which it was seen that the water holding capacity of the subject stretched from 33 to

73.86 %, and most of the soil samples i.e. about 80% possessed medium to high water holding capacity. It was also noted that there is a positive correlation between WHC and organic carbon, clay and porosity and that there is a negative correlation with pH and Bulk density of sand and its silt content.

Roadside Tea cultivated soils in Dibrugarh district of Assam was studied by **Nath *et al*., (2015)** in which he noticed that the relation of physico-chemical properties with water holding capacity where soil samples were collected on either side of the national highway maintaining a distance of about 100m, 200m, 300m respectively and noticed that the physico chemical properties of soil decreased slightly with the increase in the roadside distances. And the Water holding capacity of soil on road sides cultivated tea mainly influenced by organic carbon and clay fraction thereby showing a negative correlation with its sand content and a positive correlation with clay content and organic carbon.

The examination of the soil properties to improve water holding capacity in Telangana region by **Sujatha *et al*., (2016)** concluded that the water retention and water holding capacity is less due to difference in the various soil structures and also the soil tends to be less permeable.

Physico-chemical properties of soil (pH, E.C, Organic carbon)

Basha S *et al*., (2007) examined the agricultural soils of chittoor district and found its physico chemical properties and nutrient content, it concluded that pH for red soil is 6.93, clay soil is 7.29, black soil is 7.41, and the values of electrical conductivity for red soil is 0.25, clay soil is 0.14 , black soil is 1.76 microhoms. The examination indicated that organic carbon for black soils is 1.22%, red soil is 0.61%, and clay soil is 0.66%.

A study was held by **Deshmukh *et al*., (2012)** on the soils from Sangamner area of Ahmednagar district in Maharashtra in which it was observed that the pH is alkaline in nature and it ranged from 8 to 9.7, EC noticed that 64% soils are problematic, 34.85% soils are normal. In the Low and medium carbon of soils it was found to be 29.03% and 48.38% of soils respectively whereas soil organic carbon ranged from 0.165 to 1.575%.

A study was held on the soils of kurhani block of Muzaffarpur district of Bihar by **Singh *et al*., (2012)** at a depth of 0-15 cm in which soil samples were collected at 332 sites in which it was noticed that the pH ranged from 7.80 to 8.42 which were mostly alkaline in nature, also, its EC ranged from 0.05 to 0.16 dSm^{-1} and the organic carbon varied from 0.41 to 0.54%.

Maragatham *et al*., (2014) carried out a study on the available nutrients in Salem district of Tamilnadu with the help of a GPS 348 in which soil samples were drawn from 58 villages at three different farmer's classes namely the small farmers (< 1ha), Medium farmers (1-3 ha), and large farmers(> 3ha) at a depth of 0-15 cm. The study concluded that the pH of the surface soils ranged from 5.09 to 9.51 and that, large proportion of soils were found to be alkaline. And the EC ranged from 0.03 to 1.51 dSm^{-1} where most of the samples were known to be under non-saline condition.

The organic carbon of the same ranged from 0.20 to 2.93% and with respect to addition of crop residues, the overall rating was found to be medium. **Kavitha *et al*., (2015)** carried out a study on the soils of agro ecosystems of Trissur district in Kerala. This study was conducted to examine the soil fertility status on eight Agro ecosystems namely Banana, Rubber, Paddy, Nutmeg, Pepper, Vegetables, Arecanut and Coconut. For this study, a Total of 5120 samples were collected at a depth of 0-15 cm along with the farmer's details such as name, irrigation, type of soil, types of Fertilizers used, crops sown before. The results concluded that the PH of the soils varied from 2.9 to 7.7 and were highly acidic to alkaline in reaction and that the pH is low in paddy growing areas (4.9) and high pepper (6.0). The EC of the various agro ecosystems were known to vary from 0.01 to 5.8 dSm^{-1}. And leaching of soluble salts were visible due to high rainfall and surplus irrigation water there also the EC was found to be higher in banana and nutmeg as for the rest i.e. 90 percent of samples the EC was comparatively low. The organic carbon content of different agro ecosystems varied from 0.04 to 7.6%. Also, the organic carbon found on banana, vegetables and nutmeg were known to be lesser than the organic carbon found on Arecanut and Coconut.

A study was carried out by **Tewari *et al*., (2016)** on the soil properties of different land uses in Uttarakhand, India like Agriculture, Plantation, Horticulture, Agro-Forestry, Natural forest etc. The data accumulated from the study indicated that the soil's pH ranged from 6.90 (Agriculture soil) to 7.54 (olericulture soil). Thus, the results from the study showed that the cultivated soils have more pH in comparison to the forest soils. The EC ranged from 0.2 to 0.7 dSm^{-1}. The organic carbon and organic matter seemed to rise in high percentage from olericulture land to about 1.64% and 2.85% respectively.

The soils of Milkipur Village,Arajiline block, Varanasi district of Uttar Pradesh was examined by **Singh *et al*., (2016)** which observed that pH ranged from 6.5 to 8.0.Also the soils were slightly alkaline in reaction, Whereas electrical conductivity varied from 0.07 to 0.60 dSm^{-1}. In the study, the outcome notified that organic carbon percent ranged from 0.32 to 0.77%.

A soil survey was conducted by **Amara *et al*., (2017)** in Bogur micro watershed in Karnataka by using nutrients index approach. By utilizing an auger at a depth of 0-20 cm, soil samples were taken after which it was noted that pH soils are acidic to alkaline, EC is (<1.0 dSm^{-1}) normal and about 70% of the area showed high carbon and overall soil organic carbon went low to high.

A study was held on the soils in the Paderu mandal of Visakhapatnam district of Andhra Pradesh by **Desavathu *et al*., (2017)** by collecting soil samples randomly at different land uses i.e Agriculture, Built up area, Forest, Scrub land, and Plantation at a depth of 0-30 cm, the study notified that Soil pH varied from 4.8 to 7.5. Also, it was found that about 83% of area is acidic in nature, whereas Electrical conductivity varied from 0.04 to 0.87 dSm^{-1} in non-saline condition.

The soils of Western Ghats and coastal Karnataka under various Agro-ecological systems namely Coconut, rubber, Arecanut, Multistoried cropping systems, Paddy, Forest areas of silver oak, Cashew etc., was studied by **Patil *et al*., (2017)**. The study observed that the soil pH ranged from 4.8 to 5.8 and bases were found to be leached due to excess rainfall in the area. The EC of the soils varied from 0.01 to 0.06 dSm^{-1} low EC was obtained due to heavy rainfall and irrigation water thereby giving rise to leaching of soluble salts. Their Organic carbon ranged from 5 – 24.8 % of soil, large amount of organic matter was obtained due to various root biomass left in the field after the harvest and also the rate of decomposition seemed to be more rapid due to extreme temperatures in the western Ghats and coastal areas of Karnataka.

The study held on the soils of Jaunpur district in eastern Uttar Pradesh by **Patel *et al*., (2017)** concluded that its pH varied from 7.1 to 8.5 and that almost 70% of soils are slightly alkaline, whereas Electrical conductivity ranged from 0.20 to 2.10 dSm^{-1}. Salt accumulation was not considered a threat as EC values were less than 4 ds/m, and organic carbon varied from 0.16 to 0.36%.

The soils of Hassan district of Karnataka was studied by **Basavaraja *et al*., (2017)** for which 1320 soil samples were collected at a depth of 0-15cm. The study notified that their pH varied from 3.72 to 9.71 and a large proportion of acidic soils were present due to excess rainfall, and the E.C ranged from 0.02 to 1.79 dSm^{-1} and that no saline soils were found to be present as high precipitation in the area contributed to the loss of salts through leaching.

Kashiwar *et al*., (2018) carried out a study on the soil fertility status in Rajiv Gandhi South Campus, Uttar Pradesh in which 260 soil samples were collected at a depth of 0-15cm, the samples indicated that soils are slightly acidic in nature and varied from 5.9 to 6.5, and its Electrical conductivity ranged from 0.25 to 0.76 dSm^{-1} along with its Organic carbon which were found to range from 0.26 to 0.75%.

Yuvaraj *et al*., (2018) examined the Pudukkottai district soils and found that its pH varied from 4.5 to 10.1 which proved the soils were acidic, neutral and alkaline in nature. Also, its EC showed that 92% of the samples are non-saline and suitable for plants whereas the rest are low to medium saline.

The soils of Tropical Humid region of Kerala were studied by **Chandrakala *et al*., (2018),** in which 155 composite soil samples were collected at depth of 0-20cm in various land use systems. Their pH varied from 4.0 – 6.4 and large proportion of these soils were found to be strongly acidic and the pH seemed to be higher only in paddy growing areas. The EC of the different land uses varied from 0.018 – 0.32 dSm^{-1}, the EC observed from under the soils of banana and pineapple were higher than the EC values received from the soils of palm land use which was comparatively lower. Also, the organic carbon of different land uses varied from 0.89 to 3.34 % and the organic carbon content found in oil palm land use was found to be the highest followed by the paddy soils.

The soils of Bareli watershed in Madhya Pradesh was studied by **Nagaraju *et al*., (2018)**. The study informed about the physico chemical properties that pH of the soils ranged from 6.3 – 7.2 i.e., neutral to alkaline and moderately alkaline. The EC of the soils ranged from 0.13 – 0.43 dSm^{-1} and therefore these soils were known to be non-saline in nature. Their organic carbon content ranged from 0.31 – 0.96%.

Sashikala *et al*., (2019) carried out a study on the soils of Tatrakallu village of Andhra Pradesh for site specific recommendations where it was found that there is a scarcity of rainfall in Tatrakallu village. Leaving the hills and water bodies in the area, 250 soil samples were collected, from the samples it was known that PH was neutral to alkaline (6.49 to 8.90) and also the pH was higher due to the calcareous nature and sodicity of soils. Also, Electrical conductivity varied from 0.01 to 0.84 dSm^{-1} with slightly higher levels of soluble salts due to the presence of semi-arid climatic condition. The Soil organic carbon escalated from 0.03 to 0.90% with low organic carbon content due to the occurrence of faster rate of organic carbon degradation and little or null amount of application of organic manures onto the fields.

A study on the Tamilnadu and Thanjavur soils was held by **Enosh *et al*., (2019)** where soil samples were collected from surface and subsurface at a depth of 0-15cm and 15-30cm respectively. The results concluded that pH of the farm soils ranged from 5.5 to 4.7 i.e., from strongly acidic to very strongly acidic, and that the organic carbon content decreased with increase in the depth from the surface to sub surface soils.

A study on the soils of eastern dry zone of Karnataka by **Kant *et al*., (2019)** where around 107 soil samples at a depth of 0-15 cm were collected from various different crops such as Arecanut, Coconut, Paddy, Ragi, Maize, Field bean etc. where soils are sandy to sandy loam in nature commenced and notified that about 53.27 soil samples were acidic to neutral in reaction and their pH ranged from 4.41 to 8.33. Due to leaching of bases in gentle slopes, the soil was found to be acidic in nature. Their EC was found to be low as the soils were prone to more drainage and thus the salts leached downwards making the EC to range from 0.10 – 1.21 dSm^{-1}. Also, of all the soil samples the organic carbon recorded as low in 48.59%, medium in 45.80% and high in 3.73% and these values fluctuated from 0.12 – 0.82% in the soil.

2.2 Primary and Secondary Macro-nutrients in soil (N, P, K & Ca, Mg, S)

Maragatham *et al*., (2014) carried out a study on the soils of Salem district of Tamilnadu in which about 348 soil samples were collected from 58 nearby villages. The results of the study concluded by stating that the available nitrogen varied from 123 – 431 kg/ha as 92.5 and 7.5% of the samples were found to contain low and medium availability of nitrogen. The availability of Phosphorus using Olsen method was found to range from 7 – 79 kg/ha, the same was found using Bray's method which was found to vary from 15-135 kg/ha as 13.6, 47.8, 38.6 of the overall samples ranged to low, medium and high category. The availability of potassium ranged from 75 – 599 kg/ha as 27.8, 37.5- 87.5 and 4.2 – 57.1 of the overall samples showed low, medium and high category. The sulphur content available in the samples ranged from 5.75 – 50.5 mg/kg.

Yurembam *et al*., (2015) carried out a study on the soils of someshwar watershed in Uttarakhand for which composite soil samples were collected from the agricultural watershed in two depths i.e. 0-15 cm and 15-30 cm. In the study it was observed that the surface soil's nitrogen content ranged from 235.15 – 470.73, Whereas their phosphorus content ranged from 16.3 – 33 and from 59.2 – 319.2 kg/ha was found to be the range available for its potassium content. For the sub surface soil, the study concluded that the nitrogen content available in them ranged from 147.35 – 488.78 kg/ha, their phosphorus content ranged from 13.4 – 29.70 kg/ha and potassium content ranged from 35 – 153.5 kg/ha. The surface soil seemed to contain more available phosphorus, Nitrogen, potassium as compared to the sub surface soil. The results concluded that the sulphur content ranged from 52 - 112 mg/kg and 32 - 109 mg/kg in the surface and sub-surface soils respectively. The sulphur content was found to be greater in the surface soils as compared to the sub surface soils.

The soils of Koch district in West Bengal was studied by **Das *et al*., (2015)**. In the study, it was found that at a depth of 0-20 cm, the nitrogen content available was minimum, and that only 27.35% and 20.05% of the area were mapped under the medium and high status of available nitrogen content respectively. Also, the phosphorus content available in the soils were found to be low in 17.89% of the area, it was average in 20.38% of the area and high in 52.02% of the area. Lastly, the potassium content availability was found to be low in 41.46% of the area, high in 9.71% of the area and medium in 30.11% of the area.

The soils of different land use systems in Uttarakhand was studied by **Tewari *et al*., (2016)**. For the study, the composite soil samples were accumulated from different land use systems like agriculture, olericulture, Horticulture and natural forest. The study observed that the available nitrogen content varied from 0.217% - 0.661% i.e. agriculture soil to oak soil. Also, the available phosphorus content varied from 0.0105 in oak soil and 0.0183 in olericulture soil and finally the potassium content varied from 0.0181% in agriculture soil to 0.0463 % in oak soil.

Dinesh *et al*., (2016) carried out a study on the soils of Belachapi in which 25 soil samples were collected randomly at a depth of 0-20 cm. The total nitrogen content available in the soils ranged from 0.04 – 0.09 %. The phosphorus content ranged from 0.78 – 145.51 ppm and the exchangeable potassium ranged from 21.6 – 369.6 ppm. Calcium content was found to be in the range of 180 – 2080 ppm. Extractable Magnesium content in the soils were in the range of 12 – 432 ppm. Lastly, the sulphur content available varied from 0.29 – 1.81 ppm.

Singh *et al*., (2016) carried out a study on the soils of Varanasi in which 38 surface soil samples were collected at a depth of 0-15 cm. The study noticed that the nitrogen content available in the samples ranged from 100 – 226 kg/ha and that all the samples showed low range of nitrogen whereas the phosphorus content available varied from 12.9 – 35.9 kg/ha it was found that among all the samples about 85.7 % of them showed medium range of phosphorus content and potassium content ranged from 125.8 – 237.6 kg/ha and about 94.2 % of soil samples were found to be medium.

Soni (2016) studied Physico-chemical parameters of soil samples from Abohar city. In this study the five soil samples were collected from a depth of 0-20 cm from different places of the city i.e., 1 to 2 samples from central Abohar, 3 to 4 samples from western Abohar and 5th sample from eastern Abohar. The results stated that the sulphur content in soil samples ranged from 0.145 g to 0.563 g.

Patel *et al*., (2017) carried out a study on the soils of Jaunpur district in Eastern Uttar Pradesh. In the study, one kg of composite soil sample was collected from each site at a depth of 0-15 cm. The results observed that the nitrogen content available in the samples varied from 186 – 269 kg/ha and thus it showed low to medium availability of nitrogen. The phosphorus content available ranged from 23.5 – 50.3 kg/ha, availability seemed to be higher in the district and there was no problem in availability of Phosphorus as soil was neutral in reaction. The potassium content available ranged from 325 – 489 kg/ha, it was seen that the potassium content obtained in the soils seemed to rise due to the presence of potash bearing minerals in Jaunpur district.

Singh *et al*., (2017) carried out research on physico-chemical characteristics of the soil of Lahar block in Bhind district of Madhya Pradesh. In this study ten surface soil samples were collected from farmer's field at a depth of 0-15 cm in Lahor block, Bhind district. The results stated that the calcium content in the soil samples ranged from 4.50 - 9.05, magnesium content in soil samples ranged from 2.73 - 6.99 whereas sulphur content of the soil samples ranged from 16.58 - 26.68. According to the results calcium and magnesium were found 100% sufficient in the soils and sulphur was found to be medium in 40% of samples and high in 60% of the samples.

Ingle *et al*., (2018) carried out a study on the soils of bareli watershed of seoni district in Madhya Pradesh in which soil samples were collected horizon wise where majority of the vegetation occupies Babul, teak, palas, ber, Charoli etc. and major fruit crops such as Mango and guava along with agricultural crops such as Paddy, Pigeon pea, Maize and Safflower. The study concluded that availability of soil nitrogen in the soils ranged from 139 – 435 kg/ha. The nitrogen content available at the rooting depth up to 45cm was found to be low. Similarly, the phosphorus content in the soils varied from 18.5 – 37.6 kg/ha but the availability of phosphorus decreased with increase in the depth. The potassium content available in the soils varied from 195.1 – 481.6 kg/ha. And it increased with the increase in clay content. The study also noted that as the weathering of potash was observed frequently, the surface soils seemed to bear more potassium.

The soils of udham Singh nagar district of Uttarakhand was studied by **Kumar *et al*., (2018)**. The soil samples for the study were collected from each village randomly. The study concluded that the available nitrogen, phosphorus, potassium and Sulphur content in the soils ranged from 125.44 – 338.68 kg/ha, 7.34 – 76.70 kg/ha, 66.08 – 271.04 kg/ha, and 2.41 – 42.5 kg/ha respectively.

Kashiwar *et al*., (2018) carried out a study on the soils of Rajiv Gandhi South Campus, Mirzapur District by using GIS 260 in which soil samples were accumulated at a depth of 0-15 cm. The nitrogen content available was found to vary from 160 –

241.5 kg/ha. The phosphorus content available varied from 8.24 – 11.79 kg/ha whereas the potassium content varied from 70.1 – 128.25 kg/ha.

Chandrakala *et al*., (2018) examined the soils in tropical humid region under different land use systems in Kerala. Soil samples were collected under different land use types at a depth of 0-20 cm. The results showed that the phosphorus content available varied from 0.6 kg/ha whereas the availability of exchangeable potassium varied from 11.35 – 494.28 kg/ha. The highest level of Calcium and the available calcium varied from 18.44 – 977.05 ppm which was obtained from under the paddy soils. The Magnesium content available varied from 3.86 – 223.67 ppm and under the coconut cultivation, its value recorded was higher whereas in oil palm growing areas the value recorded for magnesium content was the lowest. The Sulphur content available varied from 0.83 – 28.3 ppm, the highest value of Sulphur was recorded under the area where pineapple was cultivated and the lowest value was recorded in the coconut growing areas.

Gothwal and Kumar (2018) studied Physico-Chemical Analysis of Soil during Summer Season in Lentic Fresh Water Ecosystem Nakki Lake-Mount Abu (Rajasthan), India. In this study the soil samples were collected from three respective sites which included mountainous zone, populated zone and unpopulated zone from a depth of 15-20 cm. The results concluded that the magnesium content of the soil sample from a mountainous zone was 150 mgL^{-1}, magnesium content from populated zone was 158 mgL^{-1} whereas from an unpopulated zone the magnesium content was 153 $mg\ L^{-1}$. The Sulphur content of the soil sample from a mountainous zone was 245 mgL^{-1}, Sulphur content from populated zone was 223 mgL^{-1} whereas from an unpopulated zone the Sulphur content was 265 mgL^{-1}.

Sashikala *et al*., (2019) carried out a study on the soils of Tatrakallu village of Andhra Pradesh. Composite soil samples were collected by using handheld GPS 250. The results notified that on the surface soils, the available nitrogen content varied from 13.00 – 326.00 kg/ha. The available phosphorus and potassium content varied from 2.00 – 512.00 kg/ha and 0.37 – 628.05 kg/ha respectively. The available sulphur content varied from 0.12 – 50.11 mg/kg.

The soils of southern laterites of Kerala was studied by **Sheeba *et al*., (2019)** for which composite soil samples were collected from Farmer's field. The results of the study stated that the availability of nitrogen is medium to high in 85.32%, whereas availability of phosphorus is recorded high in 97% of the soils, the study also observed that 97.74% of the laterite soils showed medium content of potassium on the other hand 100% of soil samples showed deficiency in Calcium and Magnesium, whereas sulphur deficiency was observed in 89% of the soil samples.

Chapter III

MATERIALS AND METHODS

The soil samples collected from plain and hilly areas of East Siang District, Arunachal Pradesh to study about the physical and chemical parameters in the course lab of M.Sc. (Ag) Soil Sciences - Soil and water Conservation, RGSC (BHU). In this chapter the materials and methods used to investigate the nutrient content of soil of plain and hilly areas is dealt. The experimental area and other informations are mentioned below:

3.1 Reagents and instrument used in soil analysis

Table 3.1.1a. Reagents and solution used in soil analysis

ANALYSIS	REAGENTS USED	REFERENCE
Soil pH (pH meter)	• Buffer solutions - 4.0,7.0 and 9.2 • Soil and distilled water suspension in the ratio of 1:2.5	• Jackson, (1973)
Electrical conductivity (dSm^{-1}) (Electrical conductivity meter)	• Soil and distilled water suspension in the ratio of 1:2.5	• Jackson, (1973)
Available nitrogen (kg/ha) (Subbiah and Asija method)	• 2.5% of sodium hydroxide • Mixed indicator - (0.1 bromocrosol green 100ml ethanol) • Boric acid of about 2.5% • 0.32% of potassium chromate solutions	• Subbiah and Asija, (1956)
Available phosphorus (kg/ha) (Bray's method)	ACIDIC MEDIUM • Bray's reagent- (0.03N ammonium fluoride + 0.02N HCl)	• Bray and Kurtz, (1945)

	• Ascorbic acid • Molybdate tartrate solution- (ammonium molybdate +antimony potassium tartrate + H_2SO_4	
(Olsen's method)	BASIC MEDIUM • 0.5N sodium bicarbonate solution • Dacro-G-60 or charcoal • Ammonium molybdate solution • Ascorbic acid • Antimony potassium titrate solution • 2.5M Sulphuric acid • P-nitro phenol indicator	Olsen *et al*., (1954)
Available potassium (kg/ha) (Neutral Normal Ammonium acetate method)	• Standard potassium chloride solution • 1N Ammonium acetate solution	• Hanway and Heidal, (1952)
Soil calcium and magnesium (Meq/100gm) (Complexometric Titration method)	• Ammonium acetate solution • Aqua regia- (HCl +HNO_3) • Erichrome black-T indicator • EDTA (ethylene diamine tetra acetic acid • Muroxide indicator • 4N NaOH buffer solution • Ammonium chloride- ammonium hydroxide buffer solution	• Cheng and Bray, (1951)

Soil organic carbon (%) (Walkley and Black rapid titration method)	• 1N potassium dichromate • 0.5N ferrous ammonium sulphate • Diphenylamine indicator • Concentrated H_2SO_4 (sp.gr.1.84) • Orthophosphoric acid or sodium fluoride	• Walkey and Black, (1934)
Soil sulphur ($mgkg^{-1}$) (Calcium chloride method)	• 0.15% of Calcium chloride • Barium chloride crystal • 0.25% of gum acacia • Standard potassium sulphate solutions	• Chesnin andYien, (1950)

Table 3.1.1b.: Instrument and apparatus used in soil analysis.

MEASUREMENTS	INSTRUMENTS
Soil pH	pH meter
Salinity in soil	Electrical conductivity meter
Drying the soil for 24 hrs @105ºC	Hot air oven
Potassium & calcium content in soil	Flame photometer
Phosphorus content in soil	Spectrophotometer
Uniform mixing	Mechanical shaker
Chemicals & soil in gm or kg	Weighing balance
Estimation of nitrogen in soil	Semi-auto nitrogen analyser

3.2 Study site

3.2.1 Location

East Siang District is situated in the eastern foothills of the Himalayas, at 155 meters above mean sea level of Arunachal Pradesh. East Siang District, is a plain area surrounded with hills. It is known as the land of the rising sun. Mighty river Siang is the life line of East Siang. The region is situated between 27º43' to 29º20' N and

94º42' to 95º35' with a geographical area of about 4005 sq.km. The district is divided into four sub division and 15 blocks with 167 villages. The headquarter of East Siang District is Pasighat town. The East Siang shares its border with Lower Dibang Valley District to the East, West Siang District to the west, and Tinsukia District to the south. The extent space of East Siang District is given in figure No.- 3.2.1a.

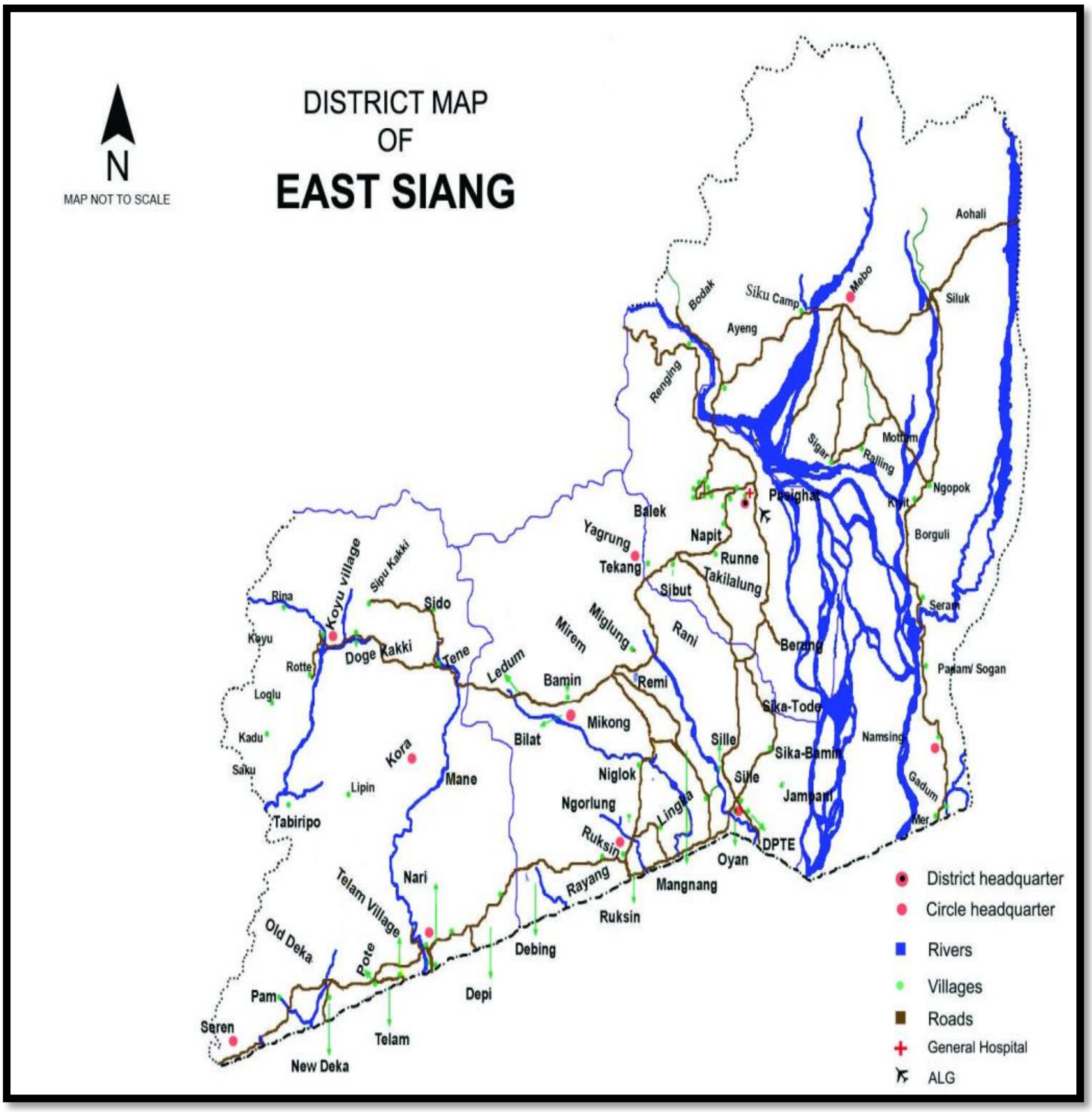

Fig. 3.2.1a: Location map of East Siang District, Arunachal Pradesh

3.3 Weather and Climate

East Siang District's area is surrounded by hills, and major areas is covered under Forest with waterfalls. As the region is present on 155m above sea level, the District has cold mountainous climate in the north with tropical climate existing in the south where winter temperature drops upto 7°C and summer temperature goes upto 36ºC. December and January are generally the coldest months and July to August are referred to as the hottest months. Continuous rainfall during monsoon and harsh wind circulation during the winter are important features of its climate. The average annual rainfall varies from 150 to 460 mm. Rainfall occurs mostly throughout the year but maximum from April to September. The average rainfall in the district is 2910.18 mm.

Table 3.2.1b: Annual rainfall status of East Siang district

Month	**Mean rainfall (mm)**
January	365.5
February	612.4
March	748.0
April	315.5
May	177.6
June	142.1
July	22.4
August	52.2
September	147.9
October	42.7
November	233.8
December	130.5
Total annual rainfall	**3733.6**

3.2.2 Soils of East Siang District

Soils of East Siang District are well diversified and comprises of all types of soils i.e. Black soils, Red soils, alluvial soils. The soil colour of this region was found to be red yellow to mild yellow. The soil texture of the East Siang District area is loamy sand to sandy loam. As the area is hilly and large proportion of land covered with forest area so pH of the soils is acidic to neutral in some places and these soils are acidic in nature. In soils of East Siang District region, the organic carbon content is low to medium. Electrical conductivity is less and macronutrients like Nitrogen availability is low to medium, Phosphorus content is medium, exchangeable potassium also found low to medium. The soils associated with secondary nutrients like Ca and Mg do not have any problem but availability of Sulphur content is minimum.

3.3 Method of soil sampling and processing

3.3.1 Soil sample collection

By using GPS camera major 30 soil samples from plain areas and 30 soil samples from hilly areas were collected from different villages of East Siang District, Arunachal Pradesh. Firstly, the litter existing on the surface was removed, then dug in using a signifier of ‘V’ shape, a depth of 15-20 cm was dug with the help of a Spade. Each field yielded around 4-5 representative samples, which were collected in the form of zig-zag manner. Soil samples collected were found to be of 2 cm in thickness, 3-5 cm in width and 15 cm in depth. Approximately, about 3 kg of soil samples was collected and spread on the large cloth and mixed in order to make soil homogenous. Once the mixing is done left over root twigs, leaves were removed and the sample was reduced to 1 kg by quadratic method. Then the soil was packed in jute bag or polythene bag and sample number, farmers name, sample location and date of sampling were noted on the bags.

3.3.2 Soil sample processing

Collected soil samples were kept to air dry at room temperature for 2 days. After drying, with the help of wooden rollers, soil samples were crushed, grounded and powdered. The powdered soil sample was made to pass through 2 mm sieve. The processed soil sample, about 500 gm was preserved in a cloth bag and labelled accordingly for further laboratory analysis.

3.4 Soil sample analysis

The different physical and chemical parameters of soil were analyzed in the soil samples that were collected, which included its Bulk density, Particle density, Water holding capacity and chemical parameters like pH, EC, Organic carbon, primary and secondary macro nutrients like Nitrogen, Phosphorus, Potassium, Calcium, Magnesium and Sulphur.

3.4.1 Procedure for estimation of Bulk Density

The bulk density of the soil can be estimated using two different methods, one is pycnometer and the other one is Core method. Core method is used for undisturbed soil, and vice versa for Pycnometer method **(Black *et al*., 1965)**. The Pycnometer method was used in the analysis. In the pycnometer method, dry Pycnometer was taken and weighed in the weighing electrical balance (W_1) thereby noting its value. The weighed pycnometer was then filled with the soil by taking soil in spatula. By tapping, the pycnometer was then filled with soil up to the neck so that all its spaces were covered with soil. Now the pycnometer with soil was taken and weighed in the weighing electric balance (W_2) again noting the value found. The Burette was filled with water and the soil removed from Pycnometer. To get the actual volume of pycnometer, it should be filled with water using a burette and the reading was noted (V). The values which were noted down while estimation was used in the following formula to get the bulk density of soil samples in mg/m^3.

$$\text{Bulk density} = \frac{W2-W1}{V}$$

3.4.2 Procedure for estimation of Particle density

The estimation of Particle density was done by using Pycnometer or R.D. Bottle. The dried pycnometer was weighed in weighing electric balance (W1) and its value was noted. Now, the pycnometer filled with water before taking weight was cleaned i.e., water was ejected outside of the pycnometer and weighed in weighing electric balance (W2) and the process was repeated by noting down its value. After which 10 gm of soil was added using a beaker and water was sprayed into it, then boiled for a few minutes to expel all air from the soil. After boiling, the beaker was allowed to cool down, then soil was added into the pycnometer and water was filled in the pycnometer (W3). The entire moisture from outside was wiped out with tissue paper before taking its weight and the value found was noted. To get true density of the soil divided the weight of soil taken to the weight of the water displaced by the soil, using the formula

Particle density of soil (mg/m^3) = $\frac{10}{(W2+10)-W3}$

3.4.3 Procedure for estimation of porosity in soil

The percentage of porosity was calculated with the help of Bulk density and particle density as following formula-

% Porosity = $1-\frac{BD}{PD}\times 100$

3.4.4 Procedure for estimation of Water holding capacity of soil

The water holding capacity of soil was estimated by using keen box **(Piper, 1996)**. The filter paper was placed in the keen box, then filter paper with keen box is weighed and its value was noted. The keen box was then filled with soil by tapping approximately 20 times, then to make the surface horizontal, a knife was used for cutting the soil. The soil with keen box was kept in petri dish with water for 5-6 hours after which the wet soil was weighed and the value found was noted accordingly. The wet soil was kept in the filter sheet for a few minutes to drain excess water from the keen box. Now, the wet soil kept for oven drying at 105ºC for 24 hours. After 24 hours dry soil weight was noted.

$$\text{Saturation \%} = \frac{Wet\ weight - Dry\ weight}{Dry\ weight} \times 100$$

3.4.5 Procedure for estimation of soil reaction (pH)

pH was estimated by using pH meter **(Jackson, 1973)**. For estimation of pH in soil, a solution in 1:2.5 ratio was prepared i.e. a weight of 10 gm of soil was taken using a beaker and 25ml of distilled water was added to it. To get saturation, this soil was kept in suspension for half an hour undisturbed. After half an hour, the readings were noted by stirring the soil kept in suspension.

Table 3.4.5a: Classification of soil sample under pH ranges

Classes	Limit
Moderately acidic	5.6 – 6.5
Neutral	6.6 - 7.3
Strongly acidic	<5.5
Alkaline	>7.3

3.4.6 Procedure for estimation of Electrical conductivity (EC)

The amount of soluble salts present in the soil was expressed through Electrical conductivity. The estimation of Electrical conductivity of soil was done by EC meter **(Jackson, 1973)**. The soil solution was prepared in a ratio of 1:2.5 after which it was allowed to settle until the supernatant becomes clear. The readings in EC meter i.e. dSm^{-1} were then noted down.

Table 3.4.6a: Classification of soil samples under salinity ranges

Classes	EC (dSm^{-1})
All crops	<0.7
Most crops	0.7-2.0
Salt tolerant	2.0-10.0
Most halophytes	10-32
No crops	>32

3.4.7 Procedure for estimation of organic carbon

By using Titration method **(Walkley and black, 1934)** determined organic carbon in soil samples by taking 1gm of soil in 500ml of conical flask. After which 10 ml of Potassium dichromate was added to the conical flask and shaken, then 20ml of sulphuric acid was added and was shaken for 2 – 3 times, the conical flasks were then allowed to stand for half an hour to get oxidation. After that, 200ml of distilled water was added to the conical flask then 10 ml of ortho - phosphoric acid followed by 1ml of diphenyl amine indicator. The entire content was then titrated with 0.5 N Ferrous Ammonium Sulphate solution until the content turns from blue violet to green in colour. A blank titration along with soil samples follows.

% of Organic Carbon in soil = $N \frac{B-C}{Weight\ of\ soil\ (g)} \times 0.003 \times 100$

Where,

N - Normality of Ferrous Ammonium Sulphate

B - Volume of 0.5N Ferrous Ammonium Sulphate used for blank sample

C - Volume of 0.5N Ferrous Ammonium Sulphate used for soil sample

3.4.8 Procedure for estimation of Available Nitrogen

The estimation of available nitrogen was determined through alkaline permanganate method **(Subbaiah and Asija, 1956)** by taking 20g of soil in 800ml of Kjeldhal flask, to this 20ml of distilled water was added and then swirled respectively. During distillation, to prevent frothing, 1ml of liquid paraffin and a few glass beads were added. Then, 0.32% $KMnO_4$ solution about 100 ml was added to the Kjeldhal flask. Now, to the conical flask, 20ml of boric acid with mixed indicator was added and the delivery tube was dipped into the conical flask. The 100ml of 2.5% NaOH solution added was distilled and kept it in a distillation apparatus. After distillation, the contents and the liberated ammonia are then collected in a conical flask containing boric acid with mixed indicator. As ammonia was absorbed, the aliquot turns into a green from pinkish colour. The distillation continues for 30 minutes for each soil sample, then this distillate titrated with 0.02N H_2SO_2 now changes from green to original colour i.e. Pink. Blank titration also done along with soil samples.

Available N (kg/ha) = (S-V) × 0.02 × 14 × 10^6 × 2.24 / 1000 × 5

Where,

S - Volume of 0.02N Sulphuric acid was used for sample

V - Volume of 0.02N Sulphuric acid used for blank

3.4.9 Procedure for estimation of Phosphorus

The estimation of phosphorus was done through two method's, one was bray's method and other one was Olsen's method.

Bray's method was used for acidic soils. As most of the soil were under acidic in nature for which Bray's method was considered. 5 gm of sample was taken in a 150 ml conical flask. Bray's P-1 extractant of 50 ml was added and was allowed to shake for 5 minutes in a rotatory shaker. Similarly, a blank along with soil samples was done. The filtered soil solution was extracted using a Whatman No.1 filter paper. Pipetted out 5 ml of aliquot from extract was put into a volumetric flask of 25 ml, then added 5 ml of ammonium molybdate solution, shaken for a while and was diluted to about 22 ml. Also, added 1 ml of diluted $SnCl_2$ (0.5 ml diluted to 66 ml), was mixed and shake for a little and the volume was makeup in a volumetric flask of 50 ml. After, 15 minutes the intensity of blue colour at 660 nm in Spectrophotometer was observed. Similarly, a blank without a soil was done. Firstly, standard absorbance was noted down followed by soil sample.

Whereas, the Olsen's method was used for neutral and alkaline soils. As the soil samples were under neutral and alkaline in nature for which Olsen's method was considered. 2.5 gm of soil sample was taken in a conical flask. A phosphorus free charcoal was added to it, after which 50ml of $NaHCO_3$ solution was added and allowed to shake in a Rotatory shaker at 120 strokes per minute. Similarly, a blank along with soil samples was done. The filtered soil solution was extracted using a Whatman No.1 filter paper. Pipetted 10ml of aliquot from extract was put into a volumetric flask, then 10ml of distilled water was added, after that one drop of P-nitro phenol indicator, further the content was acidified by adding 2.5M H_2SO_4 drop wise till its colour disappears. Also, 8ml of Murphy - Riley solution was added thereby lifting up the volume to 50ml of volumetric flask. After 15 minutes, the intensity of blue colour at 730nm in Spectrophotometer was observed. Similarly done a blank without soil. Firstly, standard absorbance was noted down followed by soil samples.

$$\text{Available Phosphorus (kg/ha)} = \frac{\text{R} \times \text{Volume of extract} \times 2.24 \times 106}{\text{Volume of aliquot} \times \text{wt.of soil (gm)} \times 106}$$

Where, R = µg P from extract i.e. obtained from Standard curve

3.4.10 Procedure for estimation of Potassium

The exchangeable Potassium was determined with the help of neutral normal Ammonium Acetate in Flame Photometer given by the **(Schollenberger and Simon, 1945)**. Placing 5g of soil in a 250ml conical flask in which 25ml of neutral normal Ammonium Acetate was added and put on a rotatory shaker for 5 minutes, then immediately filtered in a conical flask through Whatman No. 1 filter paper. The first few ml of filtrate was discarded and fed to the flame photometer. The standard readings were noted down first followed by its sample readings.

$$\text{Available Potassium (kg/ha)} = \frac{\text{C} \times \text{Volume of extractant}}{\text{Weight of soil taken}} \times 2.24$$

Where, C = ppm of K

3.4.11 Determination of exchangeable calcium

The determination of exchangeable calcium in soil was done by use of neutral normal ammonium acetate solution which was given by **(Jackson, 1973)**. In 100 ml conical flask, 5 g of soil sample was taken and to that 25 ml of extractant was added. Then the contents were shaken in a rotatory shaker for 5 min and immediately the contents were filtered with Whatman no: 1 filter paper and calcium was determined after pre-treatment. After pre-treatment, 5 ml of sample was pipetted out in a conical flask and diluted to 25 ml with distilled water. Then 5 drops of 4N sodium hydroxide buffer solution and 50 mg of Muroxide indicator was added to the sample. The sample was then titrated with 0.01N EDTA until its colour changes from orange red to purple and the titrated value was noted down.

$$\text{Amount of Ca (Meq L}^{-1}\text{)} = \frac{\text{R x Normality of EDTA x 1000}}{\text{Aliquot (ml)taken}}$$

Amount of Ca (Meq/100g) = $\frac{100}{\text{soil weight (g)}}$ x $\frac{\text{extract volume (ml)}}{100}$ x Ca (Meq L^{-1})

Where, R= Volume (ml) of standard EDTA used in titration

3.4.12 Determination of exchangeable calcium +magnesium

The determination of exchangeable calcium + magnesium in soil was done by use of neutral normal ammonium acetate solution which was given by **(Jackson, 1973)**. In 100 ml conical flask, 5 g of soil sample was taken and to that 25 ml of extractant was added. Then the contents were shaken on a rotatory shaker for 5 min and immediately the contents were filtered with Whatman no: 1 filter paper and calcium + magnesium were determined after pre-treatment. After pre-treatment, 5 ml of sample was pipetted out in a conical flask and diluted to 25 ml with distilled water. Then 10 drops of ammonium chloride-ammonium hydroxide buffer solution and 4 drops of Erichrome black- T indicator was added to the sample. The sample was further titrated with 0.01N EDTA until its colour changed from wine red to blue and the titrated value was noted down. To get the magnesium content in soil sample calcium + magnesium content in soil sample was subtracted with calcium content in soil sample.

Amount of Ca + Mg (Meq L^{-1}) = $\frac{\text{R x Normality of EDTA x 1000}}{\text{Aliquot (ml)taken}}$

Amount of Ca + Mg (Meq/100g) = $\frac{100}{\text{soil weight (g)}}$ x $\frac{\text{extract volume (ml)}}{100}$ x Ca in Meq L^{-1}

Amount of Mg (Meq L^{-1}) = Ca + Mg (Meq L^{-1}) – Ca (Meq L^{-1})

Where,

R= Volume (ml) of standard EDTA used in titration.

Pre-treatment to estimate exchangeable calcium and Calcium + Magnesium in soil

1.Transfer ammonium acetate extractant to 250 ml beaker and evaporate the content on water bath.

2.Wash down the walls of the beaker with small quantity of water and again evaporate.

3.Add 1 ml of nitric acid and 3 ml of hydrochloric acid.

4.Dissolve the residue after evaporation in 20 ml 0.1N acetic acid.

5.Filter through Whatman no: 1 filter paper into 50 ml volumetric flask and dilute the volume.

3.4.13 Procedure for estimation of Sulphur

The estimation of Sulphur by turbidimetric method was given by **Chesin and Yein (1951)**. In which 10g of soil sample was placed in a 250 ml conical flask. Adding 50ml of 0.15% $CaCl_2$ to the sample and allowing it to shake on a rotatory shaker for 30 minutes. After which, it was immediately filtered into the conical flask through Whatman No. 1 filter paper. Then taking 25 ml of volumetric flask and adding 10ml of filtrate, further 2g of $BaCl_2$ crystals were added followed by 2 ml of gum acacia to stabilize the solution by using distilled water to make up the volume. Shaked and kept for 10 minutes. Then, Absorbance reading in the spectrophotometer was taken at 340 nm. First standard readings were noted down followed by samples readings.

$$\text{Available Sulphur in soil (mg/kg)} = R \times \frac{50}{10} \times \frac{1}{10}$$

Where, R stands for S content in µg as read on X-axis.

3.5 Evaluation of Soil nutrient index

The Soil nutrient index expresses the percentage of the soil nutrient in adequate amount for optimum yields. According to the nutrient index values, the soil samples were classified into three classes. The nutrient index formula is given by the **Muhr *et al*., (1963)**.

$$\text{Soil nutrient index} = \frac{\text{\% in high category} \times 3 + \text{\% in medium category} \times 2 + \text{\% in low category} \times 1}{100}$$

Table No. 3.5.1a: Soil rating test values for different nutrients

Nutrients	Low	Medium	High
Organic carbon (%)	< 0.5	0.5 – 0.75	> 0.75
Available N (kg/ha)	< 280	280 – 560	>560
Available P (kg/ha)	< 12.5	12.5 – 25	> 25
Available K (kg/ha)	< 135	135 – 335	>335
Available S (mg/kg)	< 10	10 – 20	>20
	DEFICIENT	**SUFFICIENT**	
Magnesium (Meq/100g)	<1.5	>1.5	-
Calcium (Meq/100g)	<1.0	>1.0	-

Table No. 3.5.1b: Soil Nutrient index values

Nutrient index	Range	Remarks
I	< 1.67	Low
II	1.67 – 2.33	Medium
III	>2.33	High

3.6 Statistical analysis

By using Microsoft excel the standard measures like Mean, Range, Standard deviation and coefficient of variation were calculated with the data obtained from analysis of soil samples. The formula for computing statistical data were given below-

i. Mean = $\frac{\text{Sum of all sample}}{\text{Total number of sample}}$

ii. Range = Largest value – smallest value

iii. Standard Deviation = $\sqrt{\frac{\sum X^2 - \frac{(\sum X)^2}{n}}{n-1}}$

Where, $\sum x^2$ = Sum of all sample

n = Total number of samples

iv. Coefficient of variation $= \frac{\text{Standard deviation}}{\text{Mean}} \times 100$

The relevant soil properties and available cationic micronutrient of soils relationship was calculated by using the standard statistical methods. The correlation of coefficient formula

$$\text{Correlation of coefficient} = \frac{n\,(\Sigma xy) - (\Sigma x)\,(\Sigma y)}{[n \sum x^2 - (\sum x)^2]\,[n \sum y^2 - (\sum y)^2]}$$

(Shedecon & Cochoram, 1967)

Where,

Σxy = Sum product of x, y variables

Σx^2 = Sum of x variable

Σy^2 = Sum of y variable

Chapter IV

RESULTS AND DISCUSSION

To find out the status of physical and chemical properties of plain and hilly region soil in East Siang District, Arunachal Pradesh is our primary objective. In order to attain this, 30 soil samples from the plain areas and 30 soil samples from the hilly area were collected randomly from East Siang District. In the present investigation, attempts were made to evaluate the status of soil properties under plain and hilly area's soil by using assorted quality parameters and results has been interpreted with activity of determination and existing causes were made known by connection with subject. Mentioning the possible reasons of fluctuation in data was further discussed and its nutrient map has been aforethought to justify the results. The present investigation results are presented in the following headings:-

4.1 Analysis of plain area soil

4.1.1 Physico-chemical properties of plain area soil.

4.1.2 Status of available primary and secondary macronutrients in plain area soil.

4.1.3 Soil nutrient index value of plain areas.

4.1.4 Correlation matrix between physico-chemical properties of plain areas.

4.2 Analysis of hilly area soil

4.2.1 Physico-chemical properties of hilly area soil.

4.2.2 Status of available primary and secondary macronutrients in hilly area soil.

4.2.3 Soil nutrient index value of hilly areas.

4.2.4 Correlation matrix between physico-chemical properties of hilly areas.

4.1 Analysis of plain areas soil

4.1.1 Physico-chemical properties of plain area soil

The Physical properties of plain area's soil results such as its Bulk density, Particle density, Porosity, Water Holding Capacity and chemical properties of plain soil like pH, Electrical conductivity and Organic carbon information reference can be seen in the Table No. 4.1.1 and in Appendix 2 & 3.

The information shows that the plain area soil's Bulk density ranges from 1.14-1.32 Mg/m^3 with a mean value of bulk density 1.24 Mg/m^3. The bulk density S.D and C.V values were found 0.04 and 1.13%. The particle density of plain area's soil was found in range of 2.0 – 2.6 Mg/m^3 with 2.35 Mg/m^3 mean value. The values were calculated 0.35 and 15.06 % for S.D and C.V particle density for plain area's soil. Highest Bulk density was observed as 1.32 Mg/m^3 in sample no. 14 from Lingka village and sample no. 28 from Lingka village, and lowest bulk density 1.14 Mg/m^3 in sample no. 18 from Mikong village was observed. The highest particle density (2.6 Mg/m^3) was observed in sample no.21 from Yagrung village while lowest particle density (2.0 Mg/m^3) was determined in sample no. 3,6,8,11,13,17,23 and 30 equally.

Table 4.1.1: Statistical analysis data on physico-chemical parameters of plain areas soil in East Siang District, Arunachal Pradesh.

Soil characteristics	Range	Mean	S.D ±	C.V (%)
B.D (Mg/m^3)	1.14-1.32	1.24	0.04	3.81
P.D (Mg/m^3)	2.0-2.6	2.35	0.35	15.06
W.H.C (%)	40.4-50.82	45.37	2.99	6.59
Porosity (%)	35-54.4	46.45	8.34	17.96
pH (1:2.5)	4.8-7.2	5.7	1.41	24.79
E.C (dSm^{-1})	0.038-0.274	0.094	0.062	66.47
O.C (%)	0.21-1.69	0.59	0.34	57.43

In plain area's soils porosity percentage ranged from 35-54.4% with 46.45% mean value. The values 8.34 and 17.96% have been observed for S.D and C.V respectively. In plain area soils, water holding capacity ranged from 40.4-50.82 % with a mean value of 45.37%. The water holding capacity values 2.99 and 6.59% was observed for S.D and C.V respectively. The highest porosity (54.4 %) was reported in sample no.18 from Mikong village and lowest percentage (35%) was observed in sample no.11 of Mirem village, while highest water holding capacity (50.82%) and lowest (40.4%) was observed in sample no.12 and sample no.3 respectively.

In plain areas soils, pH ranged from 4.8-7.2 with a mean value of 5.7. The values 1.41 and 24.79% was observed for S.D and C.V respectively. The highest pH (7.2) was observed in sample no.22 whereas the lowest pH (4.8) was observed in sample no. 16 and 19. Among all samples 83.4% were found Acidic (pH 5.0-6.5) and remaining 16.6% of soil samples was found Neutral (pH 6.6-7.3). In the soils of chikkmangalur district in Karnataka by **Sachin H E *et.al.*, (2019)** similar data was observed.

Table 4.1.1a: Classification of plain areas soil samples under different pH range in East Siang District, Arunachal Pradesh

Classes	Limit	No. of samples	% Samples
Acidic	5.0 - 6.5	25	83.4
Neutral	6.6 – 7.3	5	16.6
Slightly alkaline	7.4 – 7.8	0	0
Moderately alkaline	7.9 – 8.4	0	0

(Source: USDA - Natural Resources Conservation Service, 1998)

The Electrical conductivity of the plain area's soil samples ranges from 0.038-0.274 dSm^{-1} with a 0.094 dSm^{-1} mean value. The values 0.062 and 66.47% was observed for S.D and C.V values respectively. In sample no.17 highest electrical conductivity (0.274 dSm^{-1}) was observed, while the lowest electrical conductivity (0.038 dSm^{-1}) was reported in sample no.13. All the plain area soil samples (100%) were found to be under non-saline condition. In the soils of Sriganganagar district in Rajasthan by **Kumar *et al.*, (2017)**, similar data was observed.

Table-4.1.1b: Classification of plain areas soil samples under different EC range in East Siang District, Arunachal Pradesh.

Salinity level	Degree of crops sensitivity	EC (dSm^{-1})	No. of sample	% of sample
Non-saline	Very sensitive crops	0-2	30	100
Low salinity	Sensitive crops	2-4	0	0
Mild salinity	Mildly sensitive crops	4-8	0	0
High salinity	Mildly resistant crops	8-16	0	0
Severe salinity	Resistant crops	>16	0	0

(Sources:-FAO-USDA classification)

The status of organic carbon in plain area soils was found to range from 0.21-1.69 % with 0.59% of mean value. The values 0.34 and 57.43% was observed for S.D and C.V respectively. Sample no.3 was found to have the highest organic carbon (1.69%) and lowest organic carbon (0.21%) was found in the sample no. 18 and 30. From the study area, about 43.3% of soil samples showed low level of organic carbon, 33.3% of total plain area's soil samples observed medium status of organic carbon. Similar data was observed in soils of Mugali by **Amara *et al*., (2017)**.

Table-4.1.1c: Classification of plain area soil samples under different Organic carbon range in East Siang District, Arunachal Pradesh.

Classes	Limits (%)	No. of samples	% of samples
Low	<0.5	13	43.3
Medium	0.5 – 0.75	10	33.3
High	>0.75	7	23.3

(Source: Muhr *et.al.*, 1963)

4.1.2 Status of available primary and secondary Macro-nutrients in plain areas soil

The status of available primary and secondary macronutrients in plain area's soil samples were Nitrogen, Phosphorus, Potassium, Calcium, Magnesium and Sulphur as presented in Table-4.1.2 and Appendix no.4.

Table 4.1.2: Status of available primary and secondary macro-nutrients in plain areas soils of East Siang District, Arunachal Pradesh.

Soil characteristics	Range	Mean	S.D.±	C.V (%)
Available N (kg/ha)	105-360	194.06	59.45	30.63
Available P (kg/ha)	12.2-21.5	16.23	2.68	16.55
Available K (kg/ha)	67.2-235.2	128.8	48.21	37.43
Available Ca (Meq/100g)	1.5-11.4	4.73	2.61	55.17
Available Mg (Meq/100g)	0.12-4.10	1.50	1.12	74.72
Available S (mg/kg)	0.11-0.23	0.145	0.02	16.86

In Plain area's soil samples, the available nitrogen was found to be ranged from 105-360 kg/ha with 194.06 kg/ha mean value. The S.D and C.V of nitrogen in plain areas soils were found to be 59.45 and 30.63% respectively. The highest nitrogen content (360 kg/ha) was reported in sample no. 3 whereas the lowest nitrogen content (105 kg/ha) was reported in the sample no.12 and 18. Out of total plain area's soil samples, 93.3% of soil samples were found to have low nitrogen content whereas the 6.6% of soil samples were found under the medium. In Table-4.1.2a plain area's soil nitrogen status classification are mentioned. The available nitrogen content in the plain area's soil are found low. **Dameshwar *et al*., (2018)** in Matya village of Kasdol block, Chhattisgarh, similar data was observed.

In plain area's soil, available phosphorus content was found to be vary from 12.2-21.5 kg/ha with a 16.23 kg/ha mean value. In sample no.2, the highest phosphorus content (21.5 kg/ha) was observed, and lowest phosphorus (12.2 kg/ha) was found in the sample no.26. The S.D and C.V of phosphorus in plain area's soil was found to be 2.68 and 16.55% respectively. Out of total plain area's soil samples 96.6% of soil samples was found to have medium phosphorus content and 3.3% of soil samples were found to have low P content. In Tonk district of Rajasthan by **Meena *et al*., (2006)**, similar data was observed.

Table 4.1.2.a: Classification and status of available N in plain areas soils in East Siang District, Arunachal Pradesh.

Available N (kg/ha)	No. of samples	% of samples
Low (<280)	28	93.3
Medium (280-560)	2	6.6
High (>560)	0	0

(Source: - Ramamoorthy and Bajaj, 1969)

Table 4.1.2b: Classification and status of available P in plain areas soils in East Siang District, Arunachal Pradesh.

Available P (kg/ha)	No. of samples	% of samples
Low (<12.5)	1	3.3
Medium (12.5-25)	29	96.6
High (>25)	0	0

(Source: Ramamoorthy and Bajaj, 1969)

In Plain area's soil, available potassium content ranged from 67.2-235.2 kg/ha with 128.8 kg/ha of mean value. The highest (235.2 kg/ha) potassium content was observed in sample no.28 and lowest (67.2 kg/ha) potassium content was observed in the sample no.11,29 and 30 equally. The S.D and C.V values of potassium were found to be 48.21 and 37.43% respectively. From the total plain area's soil samples, 60% of soil samples were found to have low potassium content whereas 40% of the remaining soil samples were found to have medium potassium content. In the plain area's soil, the low potassium content was assumed to be due to presence of less organic matter and unfavourable soil environment. Similar data was observed in soils of Sangamner area, Ahmednagar district, Maharashtra by **Deshmukh (2012)**.

Table 4.1.2c: Classification and status of available K in plain areas soils in East Siang District, Arunachal Pradesh.

Available K (kg/ha)	No. of samples	% of samples
Low (<135)	18	60
Medium (135-335)	12	40
High (>335)	0	0

(Source: Ramamoorthy and Bajaj, 1969)

Values of calcium in soil samples were found to have ranged from 1.5 to 11.4 Meq/100g with 4.73 as a mean value. The standard deviation and coefficient of variation of calcium were 2.61 and 55.17% respectively. The lowest calcium content was observed in sample no: 14 of Lingka village whereas highest calcium content was reported in sample no:5 of Remi village. The plain area's soil shows zero percent of low calcium content and 100% of soil samples were found to be in high range of calcium content.

Table 4.1.2d: Classification and status of available Calcium (Meq/100g) in plain areas soil in East Siang District, Arunachal Pradesh.

Classes	Limit	No. of samples	% of samples
Low	<1.0	0	0
High	>1.0	30	100

(Source: Ramamoorthy and Bajaj, 1969)

Values of magnesium in soil samples was found to have ranged from 0.12 to 4.10 Meq/100g with 1.50 as a mean value. The standard deviation and coefficient of variation of magnesium were found to be 1.12 and 74.72% respectively. The lowest magnesium content was observed in sample no:15 and 20, whereas highest magnesium content was reported in sample no: 21. Out of total soil samples, 63.3% of the samples was found to have low magnesium content whereas 36.6% of the samples was in high magnesium content.

Table 4.1.2e: Classification and status of available Magnesium (Meq/100g) in plain areas soil in East Siang District, Arunachal Pradesh.

Classes	Limit	No. of sample	% of sample
Low	<1.5	19	63.3
High	>1.5	11	36.6

(Source: Ramamoorthy and Bajaj, 1969)

In plain areas soil, the available sulphur ranged from 0.11-0.23 mg/kg with 0.145 mg/kg of mean value. The highest (0.23 mg/kg) sulphur content was observed in the sample no.29 whereas lowest (0.11 mg/kg) was observed in the sample no.16 and 28. The S.D and C.V values of sulphur were found to be 0.02 and 16.86% respectively. From the total plain area's soil sample, it shows that there is lesser content of sulphur and the result reported that all 30 samples are deficient in sulphur. In Table-4.1.2f sulphur content results were presented. Similar data was observed in Myorpur block, Sonbhadra district, UP by **Singh *et al*., (2019)**.

Table 4.1.2f: Classification and status of available Sulphur in plain areas soils of East Siang District, Arunachal Pradesh.

Available S (mg/kg)	No. of samples	% of samples
Low (<10)	30	100
Medium (10-20)	0	0
High (>20)	0	0

(Source: Kanwar, 1976)

4.1.3 Soil Nutrient index value of plain areas East Siang District, Arunachal Pradesh.

The nutrient index value of plain area's soils in East Siang District, Arunachal Pradesh was found and available primary and secondary macronutrients like Nitrogen, Phosphorus, Potassium, Calcium, Magnesium and Sulphur were calculated and represented in the following Table-4.1.3a.

Table-4.1.3a: Nutrient index values of plain areas soils of East Siang District, Arunachal Pradesh.

Sl.No.	Available nutrient	NIV	Category
1	Organic carbon	1.8	Medium
2	Nitrogen	1.06	Low
3	Phosphorus	1.96	Medium
4	Potassium	1.4	Low
5	Sulphur	1	Low

4.1.4 Correlation Matrix between Physical and chemical properties of plain areas soils of East Siang District, Arunachal Pradesh.

The correlation between physical and chemical properties of plain area's soils from East Siang District, Arunachal Pradesh, its data were presented in Table-4.1.4a.

In plain area's soils, the bulk density data was presented positively non-significantly correlated with particle density (r = 0.121) and phosphorus (r = 0.212) and negatively non-significantly correlated with porosity (r = -0.287) and organic carbon (r = -0.282).

The particle density of plain area's soils data showed negatively non-significantly correlated with porosity (r = -0.941) and organic carbon (r = -0.170) and positively non-significantly correlated with pH (r = 0.170).

The porosity of plain areas soils data showed positively significantly correlated with potassium (r = 0.421*) and positively non-significantly correlated with water holding capacity (r = 0.212) and organic carbon (r = 0.065).

The water holding capacity of plain areas soils data showed positively non-significantly correlated with organic carbon (r = 0.188), nitrogen (r = 0.207) and phosphorus (r = 0.179) and negatively non-significantly correlated with pH (r = -0.047), potassium (r = -0.049) and sulphur (r = -0.039).

The pH of plain areas soils data showed positively significantly correlated with calcium (r = 0.429*), and positively non-significantly correlated with magnesium (r = 0.295) and negatively non-significantly with electrical conductivity, organic carbon, nitrogen, and potassium.

The electrical conductivity of plain areas soils data showed positively non-significantly correlated with organic carbon (r = 0.234), nitrogen (r = 0.171), phosphorus (r = 0.140), potassium (r = 0.155) and positively significantly correlated with magnesium (r = 0.438*) and negatively non-significantly with sulphur (r = -0.022) and calcium (r = - 0.243).

The organic carbon content of soil was positively and highly significant with nitrogen (r = 0.975**) and positively significant with potassium (r = 0.415*) and positively non-significantly correlated with sulphur (r = 0.146).

The primary macronutrients- nitrogen content of soil was positively non-significantly correlated with phosphorus (r = 0.116) and magnesium (r = 0.047) and positively significantly correlated with potassium (r = 0.405*) and negatively non-significantly correlated with calcium (r = -0.220). Phosphorus content of soil was positively non-significantly correlated with sulphur (r = 0.129) and negatively non-significantly correlated with calcium (r = -0.032) and magnesium (r = -0.061). potassium content of soil was negatively non-significantly correlated with calcium (r = - 0.062) and positively non-significantly correlated with magnesium and sulphur.

The secondary macronutrients – calcium content of soil was positively non-significantly correlated with magnesium (r = 0.180) and sulphur (r = 0.083) and magnesium content of soil was positively non-significantly correlated with sulphur (r = 0.046).

Table 4.1.4a: Correlation Matrix between Physical and chemical properties of plain areas soil from different village of East Siang district, Arunachal Pradesh.

Parameters	*BD*	*PD*	*Porosity*	*WHC*	*pH*	*EC*	*OC*	*N*	*P*	*K*	*Ca*	*Mg*	*S*
BD	1.000												
PD	0.121	1.000											
Porosity	-0.287	-0.941	1.000										
WHC	0.260	-0.199	0.212	1.000									
pH	0.057	0.170	0.113	-0.047	1.000								
EC	-0.183	-0.184	-0.198	-0.212	-0.211	1.000							
OC	-0.282	-0.170	0.065	0.188	0.256	0.234	1.000						
N	-0.218	-0.167	-0.075	0.207	-0.249	0.171	0.975**	1.000					
P	0.212	-0.245	-0.269	0.179	0.056	0.140	0.149	0.116	1.000				
K	-0.357	0.288	0.421*	-0.049	-0.124	0.155	0.415*	0.405*	-0.278	1.000			
Ca	0.182	0.229	0.166	0.044	0.429*	-0.243	0.244	-0.220	-0.032	-0.062	1.000		
Mg	-0.162	0.083	-0.056	-0.175	0.295	0.438*	-0.032	0.047	-0.061	0.226	0.180	1.000	
S	-0.047	0.097	0.130	-0.039	-0.288	-0.022	0.146	-0.185	0.129	0.234	0.083	0.046	1.000

Note:- '*' represents significant at 0.05 level and '**' represents significant at 0.01 level

4.2 Analysis of hilly areas soil parameters

4.2.1 Physico-chemical properties of hilly areas soil

The Physical parameters of the hilly area's soil were Bulk density, Particle density, Porosity, Water Holding Capacity and the chemical parameters of hilly area's soils such as pH, Electrical conductivity and Organic carbon results were presented in the Appendix 6 & 7 and Table No. 4.2.1.

In the hilly area's soils, their bulk density was found to have ranged from 1.16-1.44 Mg/m^3 with 1.24 Mg/m^3 of mean value. The values 0.74 and 59.92% was found for S.D and C.V bulk density respectively. In hilly area's soils, particle density was found to have ranged from 2.0-2.6 Mg/m^3 with 2.37 Mg/m^3 of mean value. The values 0.35 and 14.87% was found for S.D and C.V of particle density respectively.

Table-4.2.1: Statistical analysis data on Physico-chemical parameters of hilly areas soil in East Siang District, Arunachal Pradesh.

Soil characteristics	Range	Mean	S.D ±	C.V (%)
B.D (Mg/m^3)	1.16-1.44	1.24	0.745	59.92
P.D (Mg/m^3)	2.0-2.6	2.37	0.35	14.87
W.H.C (%)	40.17-54.66	46.35	2.93	6.33
Porosity (%)	34-53.6	47.24	5.51	11.67
pH (1:2.5)	4.7-6.7	5.72	0.45	7.41
E.C (dSm^{-1})	0.041-0.247	0.10	0.041	41.81
O.C (%)	0.15-1.47	0.75	0.34	45.92

In hilly area's soil samples, porosity was found to have ranged from 34-53.6% with 47.24% of mean value. The values 5.51 and 11.67% was found for S.D and C.V of porosity respectively. In hilly area's soil samples, the water holding capacity was found to have ranged from 40.17-54.66% with 46.35% of mean value. The S.D value of 2.93 and C.V value of 6.33% was observed.

Table 4.2.1a: Classification of hilly areas soil samples under different pH range in East Siang District, Arunachal Pradesh.

Classes	Limit	No. of samples	% Samples
Acidic	5.0 - 6.0	28	93.3
Slightly acidic	6.1 – 6.5	2	6.6
Neutral	6.6 – 7.3	0	0
Slightly alkaline	7.4 – 7.8	0	0
Moderately alkaline	7.9 – 8.4	0	0

(Source: USDA - Natural Resources Conservation Service, 1998)

In hilly area's soil samples pH was found to range from 4.7-6.7 with a 5.72 mean value. The S.D value of 0.45 and C.V value of 7.41% was observed. About 93.3% of hilly area's soil samples were found to be Acidic (pH 5.0-6.0) in nature and 6.6% of soil samples were found to be slightly acidic (pH 6.1-6.5). Similar data was observed in Trissur district, Kerela by **Kavitha and Sujatha (2015)**.

The Electrical conductivity of the hilly area's soil samples was found to have ranged from 0.041-0.247 dSm^{-1} with a value of 0.10 dSm^{-1} of mean value. The S.D value of 0.041 and C.V value of 41.81% was observed. All the hilly area's soil samples (100%) were found to be under non-saline condition. In the soils of Muzaffarnagar district, Uttar Pradesh by **Kumar *et al*., (2013)**, similar data was observed.

In hilly area's soils, the organic carbon content was found to have ranged from 0.15-1.47% with 0.75% of mean value. The values 0.34 and 45.92% was found for S.D and C.V respectively. Only about 30% of soil samples were found to be of medium range, 26.6% of soil samples was found to be low and about 43.3% of soil samples were found to be high. This clearly shows that the hilly area's soils were low to high in Organic carbon content. In the soils of Majhwa block of Mirzapur district, Uttar Pradesh by **Singh *et al*., (2017)**, similar results were observed.

Table-4.2.1b: Classification of hilly areas soil samples under different EC range in East Siang District, Arunachal Pradesh.

Salinity level	Degree of crops sensitivity	EC (dSm^{-1})	No. of sample	% of sample
Non-saline	Very sensitive crops	0-2	30	100
Low salinity	Sensitive crops	2-4	0	0
Mild salinity	Mildly sensitive crops	4-8	0	0
High salinity	Mildly resistant crops	8-16	0	0
Severe salinity	Resistant crops	>16	0	0

(Source:-FAO-USDA classification)

Table-4.2.1c: Classification of hilly areas soil samples under different Organic carbon ranges in East Siang District, Arunachal Pradesh.

Classes	Limits (%)	No. of samples	% of samples
Low	<0.5	8	26.6
Medium	0.5 – 0.75	9	30
High	>0.75	13	43.3

(Source: Muhr *et.al*, 1963)

4.2.2 Status of available primary and secondary Macro-nutrients in hilly areas soil

In hilly area's soil sample, the status of available macronutrients such as Nitrogen, Phosphorus, Potassium and Calcium, Magnesium, Sulphur are presented in the Appendix 8 and Table-4.2.2.

Table 4.2.2: Status of available primary and secondary macro-nutrients in hilly areas soils of East Siang District, Arunachal Pradesh.

Soil characteristics	Range	Mean	S.D.±	C.V (%)
Available N (kg/ha)	100-400	230.4	67.94	29.48
Available P (kg/ha)	12.32-18.36	15.28	1.69	11.05
Available K (kg/ha)	67.2-257.6	153.8	50.36	32.73
Available Ca (Meq/100g)	1.1-11.7	5.97	2.55	42.77
Available Mg (Meq/100g)	0.10-2.02	0.66	0.55	83.23
Available S (mg/kg)	0.11-0.18	0.14	0.19	9.843

In hilly area's soils, available nitrogen ranged from 100-400 kg/ha with 230.4 kg/ha of mean value. The values 67.94 and 29.48% were found for S.D and C.V respectively. Hilly area's soil samples were observed to have low to medium Nitrogen content. The hilly area's soil nitrogen status is presented in Table-4.2.2a. In the soils of Bogur micro watershed in Karnataka by **Amara *et al*., (2017)**, similar results were observed.

Table 4.2.2.a: Classification and status of available N in hilly areas soils in East Siang District, Arunachal Pradesh.

Available N (kg/ha)	No. of samples	% of samples
Low (<280)	22	73.3
Medium (280-560)	8	26.6
High (>560)	0	0

(Source: - Ramamoorthy and Bajaj, 1969)

In hilly area's soils, the available phosphorus content ranged from 12.32-18.36 kg/ha with 15.28 kg/ha of mean value. The values 1.69 and 11.05% were found for S.D and C.V respectively in phosphorus. Out of the total hilly area's soil samples, 96.6% of soil samples was found to have medium P content, maximum number of soil samples showed medium P content and due to a low pH in soil, P is fixed as a Fe & Al phosphate. Similar results was observed by **Kashiwar *et.al.*, (2018)** in the soils of Rajiv Gandhi south campus (BHU), Mirzapur district, Uttar Pradesh by using GIS.

Table 4.2.2b: Classification and status of available P in hilly areas soils in East Siang District, Arunachal Pradesh.

Available P (kg/ha)	No. of samples	% of samples
Low (<12.5)	1	3.33
Medium (12.5-25)	29	96.6
High (>25)	0	0

(Source: - Ramamoorthy and Bajaj, 1969)

In hilly area's soil from 67.2-257.6 kg/ha the available potassium content ranged with 153.8 kg/ha of mean value. The S.D and C.V values of potassium were 50.36 and 32.73% respectively. From the total hilly area's soil samples, 36.6 % of soil samples was found to be under low whereas 63.3 % of soil samples was found to be under medium in potassium content. These results were tabulated in the Table-4.2.2c. In the hilly area soils, potassium was found to be low to medium assuming it to be as such due to the presence of medium organic matter and unfavourable soil environment. Similar results were observed in the soils of Rajiv Gandhi south campus, Mirzapur, Uttar Pradesh by **Kashiwar *et al.*, (2018)** using GIS.

Table 4.2.2c: Classification and status of available K in hilly areas soils of East Siang District, Arunachal Pradesh.

Available K (kg/ha)	No. of samples	% of samples
Low (<135)	11	36.6
Medium (135-335)	19	63.3
High (>335)	0	0

(Source: - Ramamoorthy and Bajaj, 1969)

Values of calcium in soil samples was found to have ranged from 1.1 to 11.7 Meq/100g with 5.97 as a mean value. The standard deviation and coefficient of variation of calcium were 2.55 and 42.77% respectively. The lowest calcium content was observed in sample no: 37 whereas highest calcium content was reported in sample no: 47. High levels of calcium was found in 100% of soil samples.

Table 4.2.2d: Classification and status of available Calcium (Meq/100g) in hilly areas soils of East Siang District, Arunachal Pradesh.

Classes	Limit	No. of samples	% of samples
Low	<1.0	0	0
High	>1.0	30	100

(Source: Ramamoorthy and Bajaj, 1969)

Values of magnesium in soil samples was found to have ranged from 0.10 to 2.02 Meq/100g with 0.66 as a mean value. The standard deviation and coefficient of variation of magnesium were 0.55 and 83.23% respectively. The lowest magnesium content was observed in sample no: 44 whereas highest magnesium content was reported in sample no: 33. Out of total soil samples, 90% of the samples was found to be in low range whereas 10% of the samples was found to be in high range.

Table 4.2.2e: Classification and status of available Magnesium (Meq/100g) in hilly areas soil of East Siang District, Arunachal Pradesh.

Classes	Limit	No. of samples	% of samples
Low	<1.5	27	90
High	>1.5	3	10

(Source: Ramamoorthy and Bajaj, 1969)

In hilly area's soil, available sulphur was found to have ranged from 0.11 to 0.18 mg/kg with 0.14 mg/kg of mean value. The S.D and C.V values of sulphur were 0.19 and 9.843 % respectively. From the total hilly area's soil samples, 100% of soil samples was found to be under low. In Table-4.2.2d, Sulphur status in hilly area's soils were presented. The available Sulphur content is low in the hilly area's soil due to the presence of low organic matter and organic carbon. Similar results were reported by **Singh *et al*., (2017)**, in soils of Majhwa block of Mirzapur district of Uttar Pradesh in India.

Table 4.2.2f: Classification and status of available S in hilly area soils of East Siang District, Arunachal Pradesh.

Available S (mg/kg)	No. of samples	% of samples
Low (<10)	30	100
Medium (10-20)	0	0
High (>20)	0	0

(Source: Kanwar, 1976)

4.2.3 Soil Nutrient index value of hilly areas soils of East Siang District, Arunachal Pradesh.

The nutrient index value of hilly area soils from different available primary and secondary macronutrients like Nitrogen, Phosphorus, Potassium, Calcium, Magnesium, Sulphur, were calculated and represented in the following Table-4.2.3a.

Table-4.2.3a: Nutrient index values of hilly areas soils from East Siang District, Arunachal Pradesh.

Sl.No.	Available nutrient	NIV	Category
1	Organic carbon	2.16	Medium
2	Nitrogen	1.26	Low
3	Phosphorus	1.96	Medium
4	Potassium	1.63	Low
5	Sulphur	1	Low

4.2.4: Correlation matrix between physical and chemical properties of hilly areas soils of East Siang District, Arunachal Pradesh.

The correlation of hilly area's soils between physical and chemical properties in East Siang District, Arunachal Pradesh data were presented in the Table-4.2.4a.

The hilly areas soils bulk density was observed as positively non-significantly correlated with the pH (r = 0.263), and positively significantly with particle density (r = 0.449*), and negatively non-significant with porosity (r = -0.054) and organic carbon (r = -0.718).

The particle density of hilly areas soils showed negatively non-significantly correlated with porosity (r = -0.901) and organic carbon (r = -0.274).

The porosity of hilly areas soils data showed positively non-significant correlation with WHC (r = 0.214), organic carbon (r = 0.012) and phosphorus (r = 0.126) and negatively non-significant with sulphur (r = -0.022).

The water holding capacity of hilly areas soils was recorded positively non-significantly correlated with organic carbon (r = 0.238), phosphorus (r = 0.189), negatively non-significantly correlated with pH (r = -0.018).

The pH of hilly areas soils was recorded as positively significantly correlated with calcium (r = 0.388*) and negatively non-significant with organic carbon, nitrogen, phosphorus, magnesium and sulphur.

The EC of hilly areas soils was recorded as positively non-significantly correlated with organic carbon (r = 0.219), nitrogen (r = 0.140), potassium (r = 0.107), and negatively and highly significant with calcium (r = -0.478**).

The Organic carbon of soils data showed positively and highly significantly correlated with nitrogen (r = 0.931**), and positively significant with phosphorus (r = 0.408*) and show positively non-significant with sulphur (r = 0.291) and negatively correlated with calcium and magnesium.

The nitrogen of hilly area's soils was recorded as positively significantly correlated with phosphorus (r = 0.395*) and positively non-significant with potassium and magnesium and negatively non-significant with calcium.

The phosphorus of hilly area's soils was recorded as positively non-significantly correlated with sulphur (r = 0.264) and negatively non-significant with potassium, calcium and magnesium.

The potassium of hilly area's soils was recorded as positively non-significantly correlated with magnesium (r = 0.011) and sulphur and negatively non-significant with calcium (r = -0.106). The calcium showed positively non-significantly correlated with magnesium (r = 0.339) and sulphur (r = 0.262). The magnesium of hilly areas was positively non-significantly correlated with sulphur (r = 0.077).

Table-4.2.4a Correlation Matrix between Physical and chemical properties of hilly areas soils from different village of East Siang District, Arunachal Pradesh.

Parameters	*BD*	*PD*	*Porosity*	*WHC*	*pH*	*EC*	*OC*	*N*	*P*	*K*	*Ca*	*Mg*	*S*
BD	1.000												
PD	0.449*	1.000											
Porosity	-0.054	-0.901	1.000										
WHC	-0.107	0.226	0.214	1.000									
pH	0.263	0.053	-0.046	-0.018	1.000								
EC	0.013	0.067	0.057	-0.042	0.359	1.000							
OC	-0.718	-0.274	0.012	0.238	-0.222	0.219	1.000						
N	-0.740	-0.336	-0.066	-0.106	-0.311	0.140	0.931**	1.000					
P	-0.255	0.016	0.126	0.189	-0.317	-0.019	0.408*	0.395*	1.000				
K	-0.003	-0.171	-0.199	-0.071	-0.341	0.107	0.006	0.025	-0.101	1.000			
Ca	0.200	-0.035	-0.132	0.093	0.388*	-0.478**	-0.033	-0.135	-0.096	-0.106	1.000		
Mg	0.070	-0.013	-0.072	-0.169	-0.187	-0.014	-0.099	0.039	-0.140	0.011	0.339	1.000	
S	-0.340	-0.182	-0.022	0.071	-0.112	-0.162	0.291	0.359	0.264	0.167	0.262	0.077	1.000

Note: - '*' represents significant at 0.05 level and '**' represents significant at 0.01 level

Chapter V

SUMMARY AND CONCLUSION

A research was conducted in the rural areas of East Siang District, Arunachal Pradesh on the assessment of soil status and entitled as **"Characterization of soil quality parameters under plain and hilly region of East Siang District, Arunachal Pradesh".** The soil samples collected from the plain and hilly areas was processed and brought to the laboratory to investigate various physical and chemical properties of the soil by using standard procedures. The correlation between the various parameters in plain areas soil and hilly areas soils was observed. The important findings of the current investigation were summarized under:-

5.1 Analysis of plain areas soil in East Siang District

- The bulk density and particle density of the plain area's soil was found to be of 1.24 and 2.66 Mg/m^3 mean value and ranging from 1.14-1.32 Mg/m^3 and 2.0-2.6 Mg/m^3 respectively. The highest bulk density of 1.32 Mg/m^3 was reported in sample no.14 and 28 equally and lowest value of 1.14 Mg/m^3 was reported in sample no. 18. The highest particle density value of 2.6 Mg/m^3 was reported in sample no.21 and lowest value of 2.0 Mg/m^3 was reported.
- The porosity and water holding capacity of the soil ranged from 35-54.4 % and 40.4-50.82 % with a mean value of 46.45% and 45.37%. The highest porosity (54.4%) was reported in sample 18 and lowest percentage (35 %) observed in sample 11, while highest WHC (50.82%) was observed in sample 12 and lowest (40.4%) was observed in sample 3 respectively.
- The plain area's soil samples pH was found to range from 4.8-7.2 i.e., acidic to neutral in reaction with 5.70 of mean value and about 83.3% of soil samples were found to be in acidic condition with only 16.6% of soil samples being neutral. The highest pH (7.2) was reported in sample 22 whereas lowest pH or acidic pH (4.8) was reported in sample 16 and 19 equally.

- The plain area's soils electrical conductivity ranged from 0.038-0.274 dSm^{-1} with 0.094 dSm^{-1} of mean value. All 100% of plain area's soil samples were found to be non-saline in condition. The highest value of electrical conductivity (0.274 dSm^{-1}) was reported in sample 17 while the lowest value of electrical conductivity (0.038 dSm^{-1}) was reported in sample 13.
- The soils of plain area's in East Siang District organic carbon content was found to vary from low to medium. In the plain area's soil, organic carbon ranged from 0.21 – 1.69 % with a 0.59% of mean value. About 43.3% soil samples were found to be low in organic carbon and 33.3% of soil samples were observed to be under medium in organic carbon content. The highest organic carbon (1.69%) was found in sample no. 3 and the lowest organic carbon (0.21%) was found in the sample no. 18 and 30 equally.
- The soils of East Siang District under different plain area's available nitrogen content was found to be low. In the plain area's soil, available nitrogen content varied from 105-360 kg/ha with 194.06 kg/ha of mean value. In plain area's soil samples, available nitrogen was found to be low in 93.3% of soil samples whereas, available nitrogen was found to be medium in 6.6% of soil samples. The highest nitrogen content (360 kg/ha) was reported in sample no. 3 whereas the lowest nitrogen content (105 kg/ha) was reported in sample no. 12,18 and 30 equally.
- The soils of the plain area's under different selected soil was found to be medium availability of phosphorus content. In plain area's soil under plain areas available phosphorus ranged from 12.2-21.5 kg/ha with 16.23 kg/ha of mean value. In plain area's soil samples, available phosphorus was found to be medium in 96.6% of soil samples and remaining 3.3% of soil samples were found to have low phosphorus content. The highest phosphorus content (21.5 kg/ha) was observed in sample no. 2 and lowest phosphorus (12.2 kg/ha) was found in sample no.26.
- The soils of the East Siang under different selected plain areas available potassium content was found to vary from medium to low. In plain area's soil,

available potassium ranged from 67.2-235.2 kg/ha with 128.8 kg/ha of mean value. In plain area’s soil, available potassium was found to be low in 60% of soil samples whereas available potassium was found to be medium in 40% of soil samples. The highest 235.2 kg/ha) potassium content was observed in the sample no. 28 and lowest (67.2 kg/ha) potassium content was observed in the sample no. 11, 29 and 30 equally.

- The available calcium content in soil samples was found to be in high range. The range of available calcium in the soil samples was varied from 1.5-11.4 Meq/100g with 4.73 Meq/100g as a mean value. The present findings concluded that low range of calcium content was found in 0% of the soil samples and high range of calcium content was found in 100% of the soil samples.
- The available magnesium content in the soil samples was found to be in low range. The range of available magnesium in the soil samples varied from 0.12-4.10 Meq/100g with 1.50 Meq/100g as a mean value. The present findings concluded that low range of magnesium content was found in 63.3% of the soil samples and high range of magnesium content was found in 36.6% of the soil samples.
- The soils of the East Siang under different selected plain area’s sample found available sulphur to be very low. In plain areas soil, available sulphur ranged from 0.11-0.23 mg/kg with 0.145 mg/kg of mean value. In Plain areas soil, available sulphur was found to be low in 100% of the soil samples. The highest (0.23 mg/kg) sulphur content was observed in the sample no.29 whereas lowest (0.11 mg/kg) was observed in sample no.16 and 18 equally.
- The correlation study of plain areas of East Siang District, Arunachal Pradesh has disclosed that bulk density of plain areas soil was positively non-significantly correlation with particle density (r = 0.121) and phosphorus (r = 0.212. The particle density of plain areas soil was negatively and non-significantly correlated with porosity (r = -0.941) and organic carbon (r = -0.170)

- The porosity of plain areas soil was positively significantly correlated with potassium (r = 0.421*). The water holding capacity of plain areas soil positively non-significantly correlated with organic carbon (r = 0.188), available nitrogen (r = 0.207). The pH of plain areas soils was positively and significantly correlated with calcium (r = 0.429*), and positively non-significantly with magnesium (r = 0.295). The electrical conductivity of plain areas soil was positively non-significantly correlated with organic carbon (r = 0.234)
- **5.2 Analysis of hilly areas soil in East Siang District**
- In hilly areas soil particle density was found to range from 2.0-2.6 Mg/m^3 and from 1.16-1.44 Mg/m^3 the bulk density of the hilly areas soil ranges with 2.37and 1.24 Mg/m^3 of mean value respectively
- The porosity and water holding capacity of hilly areas soil was found to range from 34-53.6 % and 40.17-54.66 % with a mean value of 47.24 % and 46.35%.
- The hilly areas soil sample was found to be under acidic to slightly acidic in reaction pH and varied from 4.7-6.7 with 5.72 of mean value and about 93.3% of soil samples were found to be acidic in nature and only about 6.6% of soil samples were found to be slightly acidic.
- In hilly areas soil, electrical conductivity was found to vary from 0.041-0.247 dSm^{-1} with 0.10 dSm^{-1} of mean value. All 100% of hilly areas soil samples were found to be under non-saline in condition.
- The soil of hilly areas organic carbon was found to vary from medium to high. In soil, the organic carbon ranged from 0.15-1.47% with 0.75% of mean value. The hilly areas soil samples were found to have medium organic carbon of 30%, found low in about 26.6% and found high in 43.3% of soil samples.
- The soil of the hilly areas available nitrogen content was found to be low to medium. In hilly areas soil, available nitrogen ranged from 100-400 kg/ha with 230.4 kg/ha of mean value.

- The soils of the hilly areas available phosphorus content was found to be medium. In hilly areas soil, available phosphorus ranged from 12.32-18.36 kg/ha with 15.28 kg/ha of mean value. No hilly areas soil samples in available phosphorus found high content.
- The soils of the hilly areas available potassium content was found to be low to medium. In hilly areas soil, available potassium seemed to range from 67.2-257.6 kg/ha with 153.8 kg/ha of mean value. Among all hilly areas soil samples, low available potassium was found in 36.6% of soil samples and medium available potassium was found in 63.3%.
- The available calcium content in soil samples was found to be in high range. The range of available calcium in the soil samples was varied from 1.1-11.7 Meq/100g with 5.97 Meq/100g as a mean value. The present findings concluded that low range of calcium content was found in 0% of the soil samples and high range of calcium content was found in 100% of the soil samples.
- The available magnesium content in soil samples was found to be in low range. The range of available magnesium in the soil samples varied from 0.10-2.02 Meq/100g with 0.66 Meq/100g as a mean value. The present findings concluded that low range of magnesium content was found in 90% of the soil samples and high range of magnesium content was found only in 10% of the soil samples.
- The soils of the hilly areas available sulphur was found to be very low. In hilly areas soil, available sulphur ranged from 0.11-0.18 mg/kg with 0.14 mg/kg of mean value. Among all hilly areas soil samples, low availablility of sulphur was found in 100% of soil samples.
- The correlation study of hilly areas has disclosed that bulk density of soil showed positively and non-significantly correlated with pH (r = 0.263), and negatively non-significantly correlated with organic carbon (r = -0.718) and porosity (r = -0.054).

- The water holding capacity of hilly areas soil was recorded as positively and non-significantly correlated with phosphorus (r = 0.189), and negatively non-significantly correlated with pH (r = -0.018). The pH of plain areas soil was recorded as a positively and significantly correlated with electrical conductivity (r = 0.359**). The EC of hilly areas soil was positively and highly significantly correlated with calcium content (r = 0.388*).
- The organic carbon of hilly areas soil was positively and highly significantly correlated with nitrogen (r = 0.931**) and positively significantly correlated with phosphorus (r = 0.408*).
- The nitrogen of hilly areas soil was recorded as a positively and significantly correlated with phosphorus (r = 0.395*). The phosphorus of hilly areas soil was recorded as a positively and non-significantly correlated with sulphur (r = 0.264). The potassium of hilly areas soil was recorded as a positively non-significantly correlated with magnesium (r = 0.011).

Conclusion

According to the soil nutrient index of study area, the soils of plain area of East Siang District, Arunachal Pradesh was found that soil qualities were low in the available nitrogen, potassium and sulphur content, medium in the organic carbon and phosphorus contents of soil. The plain area's soil was found to vary from acidic to neutral in reaction and free from salinity.

The present investigation clearly shows that the nutrient index soils of hilly areas was found that they were low in nitrogen, potassium and sulphur and medium in organic carbon content and phosphorus. The pH of hilly area's soil varied from acidic to slightly acidic in reaction and free from salinity.

According to the soil nutrient index of study area, in plain and hilly areas of East Siang District, Arunachal Pradesh hereby it concluded that availability of nutrients was unevenly distributed. Availability of nutrients was low due to low in pH of specific soil or their properties or crop and also due to heavy and continuous rainfall the essential nutrients leached out from the soil. It was observed that besides heavy application of FYM, low availability of nutrient was occurred in many of the samples and there was very minute differences found in the nutrient contents of plain and hilly areas. As the pressure due to increasing population, the soil fertility status should be maintained to ensure an increase of Agriculture sector for continuous supply of food to the growing population.

BIBLIOGRAPHY

Agyemang O, Golow AA, Serfor-Armah Y, Ackah M, Ahiamadjie H, Gyampo O, Akortia E, Tandoh JB, Yankey RK (2011). *Soil fertility analysis in two cocoa farming towns in the central region of Ghana*. Asian J. Agricultural Sciences. *3*(2):94-99.

Ajay Sharma and Arun Kumar (2016), Assessment of Heavy metal Contamination in soil sediments of Jaipur and Kota industrial areas, Rajasthan India. *International journal of Engineering, Management and sciences, 3*: 10.

Akamigbo FRO (1999). Influence of land use n soil properties of the humid tropical agroecology of Southeastern Nigeria. Niger. *Agricultural Journal 30*:59-76.

Alok Patel, Sudhanshu Verma, Shani Kumar Singh and Rajiv Kumar Singh (2017), Soil Fertility status of Jaunpur district in Eastern, Uttar Pradesh. *Journal of Pharmacognosy and Phytochemistry,* 949-952.

Asadu CLA, Enete AA (1997). Food crop yields and soil properties under population pressure in Sub-Saharan Africa: the case of cassava in Southeast Nigeria. *Outlook Agriculture*. *26*:29-34.

Barraclough PB (1986). The growth and activity of winter wheat roots in the field: nutrient inflows of high-yielding crops. J. *Agricultural Science 106*:53-59

Belachew T, Abera Y (2010) Assessment of soil fertility status with depth in wheat growing highlands of Southeast Ethiopia. World J. *Agricultural Science 6*(5):525-531.

Bhatti AU, Mulla DJ, Frasier BE (1991) Estimation of soil properties and wheat yields on complex eroded hills using geostatistics and thematic mapper images. *Remote Sensing Environment*. *37*:181-191.

B.K. Yadav, A.S. Sidhu and Sudhir Thaman (2016). Soil fertility status of Punjab Agricultural university seed farm, Chakruldu singh Wala, Sangat, Bathinda, Punjab. *Annals of plant and soil research; 18*(3): 226-231.

B.M Madhu and Arun A. David (2017). Soil fertility status of Jamuna paar region of Allahabad district, Uttar Pradesh, India. *International Journal of Current Microbiology and Applied Sciences*, *6*(12): 3069-3076.

Black. C. A. (1965). Methods of Soil Analysis. Part I and II. *American Society of Agronomy.*

Bandyopadhyay, B. K., & Maji, B. (1995). Nature of acid soils of Sundarbans delta and suitability of classifying them as acid sulphate or potential acid sulphate soils. *Journal of the Indian Society of Soil Science*, *43*(2), 251-255.

Brubaker SC, Jones AJ, Lewis DT, Frank K (1993). Soil properties associated with landscape positions. *Soil Science Society of America Journal 57*:235- 239.

Clark LJ, Gowing DJG, Lark RM, Leeds Harrison PB, Miller AJ, Wells DM, Whalley WR, Whitmore AP (2005). Sensing the physical and nutritional status of the root environment in the field, A review of progress and oppurtunities. J *Agricultural Science 143*:347-358.

C. Kavitha and M. P. Sujatha (2015), Evaluation of soil fertility status in various agro ecosystems of Trissur district, Kerala, India. *International Journal of Agriculture and Crop Sciences, 8*:328-338.

Chaudhari. P.R., Ahire. D.V., Ahire. V.D., Chakravarty. M. and Maity. S. (2013). Study of Soil bulk density as related to soil texture, organic matter contents and available total nutrients of Coimbatore soil. *International Journal of Scientific and Research publications, 3*(2): 1-8.

Chesnin, L. and Yien, C. H. (1950). Turbidimetric determination of available sulphur. *Proceeding of Soil science. American*, *14*: 149-151.

Dameshwar, Mamta and MO Navaz (2018), Evaluation of Soil Fertility Status of Matiya village of Kadsol block under Balodabazar district of Chhattisgarh. *International Journal of Chemical Studies, 6*(2): 38-41.

Deb P., Debnath. P., and Patnaik S.K. (2013). Physico-chemical properties and water holding capacity of cultivated Soils along altitudinal gradient in South Sikkim, India. *Indian Journal of Agricultural Research, 48*(2): 120-126.

Denis Magnus Ken Amara, Paramesh Gouda L. Patil, Augustine M. Kumara and Daniel H. Saidu (2017). Assessment of soil fertility status using nutrient index approach. *Academia Journal of Agricultural Research, 5*(2):028-038.

FAO (1993): Agriculture: Towards 2010. Rome, Italy.

G. Sashikala, M. V. S Naidu, K.V Ramana, K.V. Nagamadhuri and P. Sushakar (2019) Soil fertility status in Tatrakallu Village of Andhra Pradesh for Site Specific Recommendations. *International journal of Current Microbiology and Applied Sciences, 8*(6): 1016-1023.

Guhathakurta P, Rajeevan M, Sikka D R and Tyagi A, 2015 ‘Observed changes in southwest monsoon rainfall over india during 1901-2011”., *International Journal on Climatology, 35*: 1881-1898.

G.S Yurembam, Harish Chandra and Vinod Kumar (2015), Status of Available Macro and Micro nutrients in the soils of Someshwar watershed in Almora district of Uttarakhand. An *International Quarterly Journal of Environmental Sciences*, *9*(3&4): 725-730.

Geeta Tewari, Deepti Khati, Lata rana, Poonam Yadav, Chitra Pande and Sunita Bhatt (2016), Assessment of Physico chemical Properties of soils from different land use systems in Uttarakhand, India. *Journal of Chemistry, Engineering Chemical Resources*, *3*: 1114-1118.

Harden CP (2001). Soil erosion and sustainable mountain development: experiments, observations and recommendations from the Ecuadorian Andes. *Mountain Resource Development*, *21*:77-78.

H.B. Meena, R.P Sharma and U.S. Rawat (2006), Status of macro and micronutrients in some soils of Tonk district of Rajasthan, *Journal of the Indian society of Soil science*, *54*: 508-512.

Hinrich LB, Brain LM, George AO (1985). Soil Chemistry, 2nd ed. Wiley *Interscience Publication*, pp. 3-20.

Hobbie SE (1996) Temperature and plant species control over litter decomposition in Alaskan tundra. *Ecolology Monographs*. *66*:503-522.

Islam KR, Well RR (2000) Soil quality indicator properties in mid- Atlantic soils as influenced by conservation management. J. *Soil water conservation*. *55*:69-78.

Jackson, M.L. (1973). Soil Chemical Analysis. New Delhi: *Oxford & IBH Publications*.

Jawahar, D., Arunachalam, G., & Janakiraman, M. (1999). Theries-Red coastal sand dunes of Tamil Nadu and their characteristics. *Journal of the Indian Society of Soil Science (India)*.

Joffee. (1949).Pedology. pp. 455 – 524.

Jyothi M, G. Sudhakar, P. Brahmajirao (2018), Heavy metals in soil samples of Guntur Autonagar, Andhra Pradesh. *International journal of Computer sciences and Engineering*, *6*: 9

K. K. Deshmukh (2012), Evaluation of Soil Fertility Status from Sangamner area, Ahmednagar district, Maharashtra, India. *Research Journal on Chemistry*, 5:3.

K.N. Sujatha, G.Kavya, P.Manasa, K.Divya (2016). Assessment of soil properties to improve water holding capacity in soils. *International Research Journal of Engineering and Technology*, *3*(3): 2395-0056.

Kanwar, J. S. (1976). Soil Fertility: Theory and practice. S.S. Grewal, Under Secretary, for the ICAR, New Delhi.

Milne AE, Lark RM, Addiscott TM, Goulding KWT, Webster CP, O. Flaherty S (2004). Wavelet analysis of the scale and location dependent correlation of modelled and measure nitrous oxide emissions from soils, Eur. J. *Soil science 56*: 3-17.

Miller PM, Singer MJ, Nielsen DR (1988). Spatial variability of wheat yield and soil properties on complex hills. *Soil Science Society of America Journal. 52*:1133-1141.

M. Chandrakala, M. Ramesh, K, Sujatha and S. K. Singh (2018), Soil fertility Evaluation under different land use system in Tropical humid region of Kerala, India. *International journal of Plant and Soil science, 24*(4): 1-13.

Mydhii, K. (2006). Land characterization and classification of soils around aqua ponds in Guntur district, Andhra Pradesh. M.Sc. (Ag.) Thesis. Acharya N G Ranga Agricultural University, Hyderabad, India.

Nanda, S. K, Mishra, B. K. and Bhatta A. K. (1997). Soil classification and soil and land suitability for irrigation in Kuanria irrigation project. *Journal of the Indian Society of Soil Science, 45*(2): 333-338.

Nnaji GU, Asadu CLA, Mbagwu JSC (2002). Evaluation of physic-chemical properties of soils under selected agricultural land utilization types. *Agro-Science 3*:27-33.

Ogunkunle AO, Egghaghara OO (1992). Influence of land use on soil properties in forest region of Southern Nigeria. *Soil Use Management 8*:121-125.

Olsen, S, R., Cole, C.V., Watanabe, F.S. and Dean, L.A. (1954). Estimation of Available Phosphorus in soils by extraction with Sodium Bicarbonate. U. S. *Department of Agriculture* Circular No. 939. Banderis, A. D., D. H. Barter and K. Anderson. Agricultural and Advisor.

Onweremadu EU (2007). Availability of selected soil nutrients in relation to land use and landscape position. Int. J. *Soil Science 2*(2):128-134.

P.K. Basavaraja, P.Dey, H. Mohamed Saqeebulla and N. D. Yogendra (2017), Geo-reference Based soil fertility status in Hasan district of Karnataka, India for development of nutrient plan. *Indian Journal of Soil conservation, 45*: 141-147.

Page, A. L., Miller, R. H. and Keeney, D. R. (1982). Method of soil analysis part 2(Ed.). *Agron. Series ASA – SSSA Publishers*, Madison, USA.

Parvaiz Ahmad Lone, Ajay Kumar Bhardwaj, Kunwar Wajahat Shah and Fayaz Ahmad Bbahar (2016) Assessment of soil Micronutrient status of some threatened medicinal plants of Kashmir Himalaya, India. *Research Journal of Botany*, *11*: 18-24.

Piper, C. S. (1966). Soil and Plant analysis. *Hans Publisher,* Bombay.

Pramod Kumar, Ashok Kumar, B.P. Dhyani, Pardeep Kumar, U.P.shahi, S.P. Singh, Ravindra Kumar, Yogesh Kumar, Amit Kumar and Sumit Raizada (2013. Soil Fertility status in some soils of Muzaffarnagar district of Uttar Pradesh, India, along with Ganga canal command area. *African journal of Agricultural research*, Vol. *8*(14), pp.1209-1217.

Proloy Deb (2013) Physico-Chemical properties and water holding capacity of Cultivated soils along altitudinal gradient in South Sikkim, India. *Indian Journal of Agriculture Resources*, *48*(2): 120-126.

R. M. Yuvaraj and Dr. M. Rajeswari (2018) GIS Based Soil Fertility Status of Padukkottai District. *International Journal of interdisciplinary Research and innovations*, *6*: 25-35.

Ramamurthy. B, Bajaj. J.C. (1969). Nitrogen, Phosphorus and Potash status of Indian soils. *Fertilizer News, 14*: 25-28.

Rao M. (1993) Characterization and classification of soils of Ulavapadu mandal of Prakasam district in Andhra Pradesh, M.Sc. (Ag) thesis, Andhra Pradesh Agricultural University, Rajendranagar, Hyderabad.

Rao R., S. (2003). Morphology, characterization and taxonomy of soils in Chirala mandal of Andhra Pradesh. M.Sc. (Ag.) Thesis. Acharya N G Ranga Agricultural University, Hyderabad, India.

Rao V., M., Seshagiri Rao, M. and Bhanu Prasad, V. (2005). Nutrient status of red, black and their associated soils of Tiruvuru mandal of Krishna district of Andhra Pradesh. *The Andhra Agricultural Journal, 52*(4): 597-599.

Regnold JP, Plamer AS (1995). Significance of gravimetric versus volumetric measurements of soil quality under biodynamics, conventional and continuous grass management. J. *Soil water conservation 149* (1):51-58.

Roy RN, Mishra RV, Lesschen JP, Smaling EM (2003). Assessment of soil nutrient balance: approaches and methodologies. FAO, *Fertilizer and Plant Nutrition Bulletin*-14. FAO. Rome.

S.N. Singh, A.M. Latare, and S.K. Singh (2017), Soil Fertility Status of Majhwa Block of Mirzapur District of Eastern UP, India, *International Journal of Current Microbiology and Applied Sciences, 6*(9): 2019-2026.

Sagar N Ingle, MSS Nagaraju, Nisha Sahu,Nirmal Kumar, Pramod Tiwary,Rajeev Srivastava, TKSen and RA Nasre (2018). Soil fertility status of Macronutrients and Micronutrients in Bareli watershed of seoni district, Madhya Pradesh, India. *International journal of Chemical studies*, *6*(4): 1950-1953.

Saidou A, Kuyper TW, Kossou D, Tossou R, Richards P (2004). Sustainable soil fertility management in Benin: Learning from farmers. NJAS – Wageningen. J. *Life Sciences. 52*:349-369.

Sanjay Kumar, Navneet, M.M. Tiwari and Vinod Kumar (2015), Assessment of Mineral Elements Composition of Medicinal Plants Used In Yagya (Agnihotra), *Advances in Biological Research, 9* (3): 189-195.

Schollenberger, C. J. and Simon, R. H. (1945). Determination of Exchange Capacity and Exchangeable bases in Soil Ammonium Acetate method. *Soil Science*, *59*:13-24

Sheeba SS, P Shalini pillai and V Mini (2019), Assessment and rating of available nutrient status of rice soil in the southern laterites of kerala. *Journal of Pharmacognosy and Phytochemistry,* 269-272.

Sharma, D. R., & Minhas, P. S. (2004). Soil properties and yields of upland crops as influenced by the long-term use of waters having variable residual alkalinity, salinity and sodicity. *Journal of the Indian Society of Soil Science*, *52*(1), 100-104.

Snigdha singh (2017), Assessment of Heavy Metals Accumulation in the soil and Cultivated crops along a highway in Lucknow city, Uttar Pradesh. *Journal of Agriculture, Food and natural resources, 1*(1): 55-60.

Snigdha Singh (2017). Assessment of heavy metals accumulation in the soil and the cultivated crops along a highway in Lucknow City, Uttar Pradesh. *Journal of Agriculture, Food and Natural resources, 1*(1):55-60.

Subbaiah, B. V. and Asija, G. L. (1956). A rapid procedure for the determination of available nitrogen in soils. *Current Science, 25*: 259-260.

Sudheer Kumar Annepu, Mahantesh shirur and Sharma, V. P. (2017). Assessment of soil Fertility Status of Mid Himalayan region, Himachal Pradesh. *Indian journal of Ecology, 44*(2):226-231.

Sumedh Raj Kumar Kashiwar, Triyugi Nath, Manik Chandra kundu and Usha Ramachandra Dongarvar (2018), Evaluation of soil fertility status of Rajiv Gandhi South campus (Banaras Hindu University), Mirzapur, Uttar Pradesh by using GIS, *International journal of Current Microbiology and Applied sciences, 7*: 3825-3836.

Suraj Sharma, Parthankar Choudhary and Naryan Chetry (2016), Status of soil nutrients and Fertility of Four land use system in Raid-Marwet region, Ri-Bhoi District of Meghalaya, India. *Journal of Global Biosciences*, *5*: 4178-4187.

Swarnam, T. P., Velmurugan, A. and Rao, Y. S. (2004). Characterization and classification of some soils from Shahibi basin in parts of Haryana and Delhi. *Agropedology*, *14*: 114-122.

Shukla, M. K., Lal, R., Underwood, J., & Ebinger, M. (2004). Physical and hydrological characteristics of reclaimed minesoils in southeastern Ohio. *Soil Science Society of America Journal*, *68*(4), 1352-1359.

Tanveera Ahad, T.A. Kanth and Shazia Nabi (2015), Soil bulk density as related to texture, organic matter content and porosity in Kandi soils of district in Kashmir Valley. *International Journal of Scientific Research*, 2277-8179.

Thangaswamy, A, Naidu M. V. S., Ramavatharam N. and Raghava Reddy E. (2005). Characterisation, classification and evaluation of soil resource in Sivagiri watershed of chittoor district of Andhra Pradesh for sustainable land use planning. *Journal of the Indian Society of Soil Science*, *53* (1): 10-20.

USDA (1954). U.S. Salinity Laboratory Staff, Diagnosis and improvement of Saline and Alkali soils. *Handbook 60.* Washington, D.C.

Vinnet Kumar, Ajaya Srivastava Veer Singh, Sarvesh Kumar (2018), Availability of Macro and Micronutrients and their correlation with some physico-chemical properties in soils of Udhan Sindh District of Uttarakhand. *International Journal of Chemical Studies*, *6*(3): 1445-1449.

Walkley, A. and Black, T. A. (1934). An examination of the Degt. Jrett method for determination of soil organic matter and a proposed modification of Chromic acid titration. *Soil Science*, *37*: 29-38.

Walkley, A. J. and Black, I. A. (1934). Soil Science.*37*: 29-38

Y. V. Singh, S.K Singh, Sanjay Kumar sahi, S.K. Verma (2016), Evaluation of Soil Fertility Status from Milkipur Village, Arajiline Block, Varanasi District, Uttar Pradesh in relation to soil Characteristics. *Journal of Pure and Applied Microbiology*, *10*(2): 1455-1461.

APPENDICES

Appendix-1: Description of soil sampling sites of plain areas

Sample No.	Farmers Name	Village Name	Crops cultivated	Latitude	Longitude	Altitude
S_1	Along Eko	Remi	Banana	27°57'46"N	95°14'25"E	190.5m
S_2	Gandhi Amoh	Remi	Paddy	27°57'49"N	95°14'33"E	186.32m
S_3	Endung Jamoh	Bilat	Rubber	27°55'27"N	95°12'17"E	217.44m
S_4	Di Tago	Mirem	Bamboo	27°56'51"N	95°11'39"E	241.63m
S_5	Rokjing Dupak	Remi	Paddy	27°57'9"N	95°14'32"E	178.51m
S_6	Daniel Gao	Miglung	Oil palm	27°57'50"N	95°14'18"E	180.22m
S_7	Tasan Dupak	Remi	Oil palm	27°56'32"N	95°15'9"E	155.19m
S_8	Kalo Ering	Mirem	Oil palm	27°5640N	95°14'14"E	178.67m
S_9	Tayem Padung	Bilat	Banana	27°56'43"N	95°10'34"E	282.14m
S_{10}	Nabu Nonang	Mirem	Tea	27°57'6"N	95°12'25"E	229.53m
S_{11}	Tajom Tabing	Mirem	Paddy	27°56'48"N	95°11'34"E	232.57m
S_{12}	Diking Panor	Sille	Paddy	27°56'57"N	95°16'11"E	149.33m
S_{13}	Toklen Dupak	Niglok	Rubber	27°54'2"N	95°13'57"E	171.97m
S_{14}	Abe Tago	Lingka	Rubber	27°53'22"N	95°15'8"E	154.68m
S_{15}	Tani Tago	Lingka	Tea	27°53'31"N	95°15'2"E	162.56m
S_{16}	Takiam Moyong	Niglok	Rubber	27°53'44"N	95°13'56"E	176.61m
S_{17}	Tanyup Tago	Mikong	Oil palm	27°54'45"N	95°14'33"E	161.22m
S_{18}	Tagom Pabo	Mikong	Pineapple	27°55'40"N	95°14'10"E	180.74m
S_{19}	Raja Taki	Mirem	Paddy	27°56'52"N	95°12'51"E	206.64m
S_{20}	Ranjan Moyong	Mirem	Oil palm	27°57'12"N	95°12'33"E	213.23m
S_{21}	Bosir Siram	Yagrung	Paddy	27°58'40"N	95°14'42"E	194.84m
S_{22}	Tajing Tabing	Yagrung	Paddy	27°59'57"N	95°13'43"E	229.45m
S_{23}	Kamin Tali	Yagrung	Paddy	27°58'13"N	95°15'4"E	171.91m
S_{24}	Tabi Kangko	Rani	Rubber	27°56'37"N	95°17'51"E	137.44m
S_{25}	Pandok Siram	Sikatode	Paddy	27°56'31"N	95°19'48"E	141.51m
S_{26}	Gopal Tamut	Sikabamin	Rubber	27°52'27"N	95°19'42"E	139.64m
S_{27}	Ramu Eko	Lingka	Mustard	27°51'19"N	95°15'39"E	123.47m
S_{28}	Takar Doke	Lingka	Banana	27°52'32"N	95°15'10"E	146.63m
S_{29}	Arun Jamoh	Miglung moli	Paddy	27°58'4"N	95°13'31"E	198.74m
S_{30}	Oyin Dupak	Miglung	Paddy	27°57'38"N	95°13'45"E	191.93m

Appendix-2 Status of Bulk Density, Particle Density, Porosity and WHC in soil of plain areas

Sample No.	Bulk Density (Mg/m^3)	Particle Density (Mg/m^3)	Porosity (%)	WHC (%)
S_1	1.28	2.5	48.8	40.51
S_2	1.24	2.5	50.4	40.60
S_3	1.16	2	42	40.40
S_4	1.18	2.5	52.8	43.92
S_5	1.3	2.5	48	46.10
S_6	1.28	2	36	44.82
S_7	1.22	2.5	51.2	45.84
S_8	1.16	2	42	45.21
S_9	1.18	2.3	48.7	42.38
S_{10}	1.26	2.5	49.6	44.01
S_{11}	1.3	2	35	49.78
S_{12}	1.22	2.4	49.2	50.82
S_{13}	1.28	2	36	43.35
S_{14}	1.32	2.5	47.2	49.59
S_{15}	1.28	2.5	48.8	44.06
S_{16}	1.28	2.5	48.8	44.98
S_{17}	1.28	2	36.	45.94
S_{18}	1.14	2.5	54.4	48.01
S_{19}	1.22	2.5	51.2	49.02
S_{20}	1.24	2.5	50.4	43.45
S_{21}	1.24	2.6	52.4	46.44
S_{22}	1.26	2.5	49.6	43.10
S_{23}	1.24	2	38	49.20
S_{24}	1.26	2.5	49.6	44.29
S_{25}	1.22	2.4	49.2	42.52
S_{26}	1.26	2.5	49.6	47.34
S_{27}	1.2	2.4	50.0	47.70
S_{28}	1.32	2.4	45	42.85
S_{29}	1.28	2.4	46.7	49.86
S_{30}	1.26	2	37	44.73
Mean	**1.24**	**2.35**	**46.45**	**45.37**
Range	**1.14-1.32**	**2.0-2.6**	**35-54.4**	**40.4-50.82**
SD±	**0.047**	**0.35**	**8.34**	**2.99**
CV (%)	**1.135**	**15.06**	**17.96**	**6.59**

Appendix-3 Status of available pH, EC and Organic carbon in soil of plain areas

Sample No.	**pH**	**EC (dSm^{-1})**	**Organic carbon (%)**
S_1	5.1	0.271	0.67
S_2	5.4	0.113	0.49
S_3	5.1	0245	1.69
S_4	6.8	0.092	0.91
S_5	6.9	0.050	0.63
S_6	5.4	0.054	0.27
S_7	5.2	0.079	0.63
S_8	5.6	0.084	0.94
S_9	5.3	0.128	1.47
S_{10}	5.4	0.047	0.63
S_{11}	5.6	0.089	0.46
S_{12}	6.9	0.073	0.25
S_{13}	5.1	0.038	0.67
S_{14}	5.0	0.048	0.85
S_{15}	5.5	0.066	0.78
S_{16}	4.8	0.049	0.6
S_{17}	5.1	0.274	0.24
S_{18}	4.9	0.072	0.21
S_{19}	4.8	0.091	0.42
S_{20}	5.6	0.064	0.64
S_{21}	6.5	0.096	0.27
S_{22}	7.2	0.079	0.40
S_{23}	6.3	0.128	0.55
S_{24}	5.8	0.090	0.58
S_{25}	5.6	0.132	0.36
S_{26}	5.5	0.058	0.58
S_{27}	5.7	0.043	0.45
S_{28}	5.8	0.042	0.84
S_{29}	6.1	0.065	0.23
S_{30}	7.1	0.077	0.21
Mean	**5.70**	**0.094**	**0.59**
Range	**4.8-7.2**	**0.038-0.274**	**0.21-1.69**
SD±	**1.41**	**0.062**	**0.344**
CV (%)	**24.79**	**66.47**	**57.43**

Appendix-4 Status of Available Primary & Secondary macronutrients in soil of plain areas

Sample No.	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)	Calcium (Meq/100g)	Magnesium (Meq/100g)	Sulphur (mg/kg)
S_1	200	16.6	134.4	3.7	1.21	0.17
S_2	175	21.5	78.4	5.7	0.72	0.15
S_3	360	16.5	190.4	2.4	3.10	0.14
S_4	265	17.5	190.4	2.2	1.31	0.17
S_5	200	21.1	100.8	11.4	0.81	0.12
S_6	150	17.1	100.8	4	0.58	0.13
S_7	200	13.8	156.8	7.6	0.18	0.15
S_8	265	16.3	112	3.1	1.31	0.16
S_9	320	18.3	190.4	3	2.2	0.13
S_{10}	200	13.6	89.6	2.3	0.72	0.15
S_{11}	175	14	67.2	3	2.50	0.14
S_{12}	105	16.3	168	4.8	1.10	0.16
S_{13}	200	17.3	78.4	3	0.91	0.13
S_{14}	250	20.2	100.8	1.5	1.30	0.17
S_{15}	230	18.3	168	3.1	0.12	0.16
S_{16}	200	20.8	89.6	3	0.71	0.11
S_{17}	125	19.2	145.6	3.4	2.61	0.12
S_{18}	105	13.2	145.6	1.7	1.31	0.13
S_{19}	175	13.3	123.2	6.2	1.81	0.14
S_{20}	200	13.5	100.8	7	0.12	0.12
S_{21}	150	14.2	100.8	7.9	4.10	0.14
S_{22}	175	15.7	78.4	4.8	3.20	0.15
S_{23}	195	16.2	100.8	6.7	2.30	0.14
S_{24}	195	13.2	123.2	2.2	3.11	0.13
S_{25}	167	13.7	145.6	2.3	2.81	0.15
S_{26}	195	12.2	190.4	4.2	0.51	0.12
S_{27}	175	14.8	224	9.9	0.25	0.15
S_{28}	250	12.5	235.2	8.9	0.18	0.11
S_{29}	115	16.3	67.2	5.6	0.92	0.23
S_{30}	105	18.3	67.2	7.5	3.10	0.18
Mean	**194**	**16.23**	**128.8**	**4.73**	**1.50**	**0.145**
Range	**105-360**	**12.2-21.5**	**67.2-235.2**	**1.5-11.4**	**0.12-4.10**	**0.11-0.23**
SD±	**59.45**	**2.68**	**48.21**	**2.61**	**1.12**	**0.024**
CV (%)	**30.63**	**16.55**	**37.43**	**55.17**	**74.72**	**16.86**

Appendix 5: Descriptions of soil sampling sites of Hilly areas

Sample No.	Farmers name	Village name	Crops cultivated	Latitude	Longitude	Altitude
S_{31}	Tarung Kadu	Mirem	Orange	27º57'40"N	95º14'4"E	275.2m
S_{32}	Tapir Tago	Mirem	Ginger	27º57'7"N	95º11'44"E	241.14m
S_{33}	Atiyang Tagi	Moli Remi	Rubber	27º58'26"N	95º13'9"E	258.7m
S_{34}	Tapu Darang	Miglung	Oil palm	27º58'35"N	95º12'57"E	262.93m
S_{35}	Tabor Tapak	Miglung	Orange	27º58'35"N	95º12'48"E	289.16m
S_{36}	Lomyar Mibang	Miglung	Orange	27º58'20"N	95º12'56"E	312.05m
S_{37}	Ogom Tamuk	Miglung	Orange	27º58'15"N	95º13'5"E	322.13m
S_{38}	Gambo Tayeng	Bodak	Orange	28º9'38"N	95º15'31"E	251.61m
S_{39}	Lombu Tayeng	Bodak	Orange	28º9'32"N	95º15'45"E	270.67m
S_{40}	Kamin Perme	Bodak	Orange	28º7'12"N	95º18'59"E	197.42m
S_{41}	Lingka Jamoh	Takilalung	Orange	28º1'36"N	95º17'21"E	238.56m
S_{42}	Ape Taki	Takilalung	Pineapple	28º1'20"N	95º15'41"E	240.38m
S_{43}	Tajing Dupak	Takilalung	Pineapple	28º1'9"N	95º15'15"E	256.67m
S_{44}	Tanong Taki	Sibut	Orange	28º0'59"N	95º14'34"E	313.71m
S_{45}	Olak Panggeng	Mirem	Orange	27º58'6"N	95º10'32"E	291.01m
S_{46}	Tabir Tatan	Mirem	Orange	27º57'26"N	95º11'17"E	316.01m
S_{47}	Non Talom	Mirem	Orange	27º57'21"N	95º11'33"E	285.17m
S_{48}	Tapir Darang	Mirem	Orange	27º57'51"N	95º10'23"E	301.65m
S_{49}	Dilip Ering	Bilat	Orange	27º56'46"N	95º10'23"E	301.65m
S_{50}	Baten Siram	Bilat	Ginger	27º56'51"N	95º10'25"E	304.39m
S_{51}	Tatong Padung	Ledum	Tea	27º56'56"N	95º7'36"E	396.21m
S_{52}	Tayin Padung	Ledum	Tea	27º57'45"N	95º7'4"E	426.58m
S_{53}	Takir Padung	Ledum	Orange	27º58'2"N	95º7'10"E	427.88m
S_{54}	Mathew Padung	Ledum	Orange	27º56'48"N	95º8'34"E	375.4m
S_{55}	Talu Siram	Ledum	Mausambi	27º56'46"N	95º8'56"E	325.62m
S_{56}	T Dupak	Ledum	Orange	27º56'47"N	95º8'33"E	356.06m
S_{57}	Natem Nonang	Ledum	Orange	27º56'48"N	95º8'34"E	360.5m
S_{58}	Rajeev Pango	Bilat	Orange	27º56'27"N	95º10'12"E	286.89m
S_{59}	Kaling Dupak	Bilat	Orange	27º56'41"N	95º10'20"E	339.97m
S_{60}	Daniel Gao	Miglung	Orange	27º58'14"N	95º13'29"E	263.31m

Appendix-6 Status of Bulk Density, Particle Density, Porosity and WHC in soil of hilly areas

Sample No.	Bulk Density (Mg/m^3)	Particle Density (Mg/m^3)	Porosity (%)	WHC (%)
S_{31}	1.28	2.5	48.8	46.56
S_{32}	1.18	2.5	52.8	46.58
S_{33}	1.16	2.5	53.6	47.29
S_{34}	1.16	2.5	53.6	44.62
S_{35}	1.32	2	34	45.16
S_{36}	1.22	2.5	51.2	49.29
S_{37}	1.2	2	40	43.72
S_{38}	1.3	2.1	38.1	45.47
S_{39}	1.2	2.5	52	42.78
S_{40}	1.18	2.5	52.8	41.74
S_{41}	1.28	2.5	48.8	48.46
S_{42}	1.24	2.5	50.4	22.69
S_{43}	1.34	2.6	48.5	54.66
S_{44}	1.32	2.3	42.7	44.15
S_{45}	1.44	2.4	40.0	49.49
S_{46}	1.26	2.5	49.6	46.94
S_{47}	1.2	2	40	44.66
S_{48}	1.44	2.5	42.4	45.01
S_{49}	1.2	2	40	49.21
S_{50}	1.22	2.5	51.2	43.05
S_{51}	1.32	2.5	47.2	48.72
S_{52}	1.18	2.4	50.9	43.06
S_{53}	1.22	2.5	51.2	54.23
S_{54}	1.26	2.5	49.6	42.73
S_{55}	1.24	2.5	50.4	49.35
S_{56}	1.18	2.5	52.8	47.23
S_{57}	1.24	2.5	50.4	46.37
S_{58}	1.22	2.5	51.2	46.59
S_{59}	1.16	2	42	40.17
S_{60}	1.18	2	41	50.71
Mean	**1.24**	**2.37**	**47.24**	**46.35**
Range	**1.16-1.44**	**2.0-2.6**	**34-53.6**	**40.14-54.66**
SD±	**0.74**	**0.35**	**5.51**	**2.93**
CV (%)	**59.92**	**14.87**	**11.67**	**6.33**

Appendix-7 Status of Available pH, EC and Organic carbon in soil of hilly areas

Sample No.	pH	EC (dSm^{-1})	Organic carbon (%)
S_{31}	5.8	0.070	0.49
S_{32}	5.3	0.066	0.94
S_{33}	6.4	0.070	0.70
S_{34}	5.4	0.085	1.18
S_{35}	6.7	0.111	0.55
S_{36}	4.9	0.111	0.85
S_{37}	4.7	0.100	1.15
S_{38}	5.9	0.098	0.49
S_{39}	6.7	0.188	1.33
S_{40}	5.4	0.064	0.67
S_{41}	6.0	0.113	0.75
S_{42}	5.1	0.094	0.73
S_{43}	5.5	0.095	0.31
S_{44}	5.8	0.082	0.49
S_{45}	5.7	0.119	0.15
S_{46}	5.8	0.098	0.54
S_{47}	5.8	0.152	1.11
S_{48}	6.1	0.094	0.23
S_{49}	5.5	0.065	0.76
S_{50}	5.7	0.126	1.02
S_{51}	5.8	0.042	0.61
S_{52}	5.6	0.140	1.47
S_{53}	5.7	0.108	0.96
S_{54}	6.3	0.247	0.49
S_{55}	5.9	0.080	0.33
S_{56}	5.8	0.124	1.30
S_{57}	5.8	0.041	0.78
S_{58}	5.6	0.067	0.51
S_{59}	5.7	0.085	0.55
S_{60}	5.2	0.075	1.24
Mean	**5.72**	**0.10**	**0.75**
Range	**4.7-6.7**	**0.041-0.247**	**0.15-1.47**
SD±	**0.45**	**0.041**	**0.348**
CV (%)	**7.41**	**41.81**	**45.92**

Appendix-8 Status of available Primary and Secondary macronutrients in soil of hilly areas

Sample No.	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)	Calcium (Meq/100g)	Magnesium (Meq/100g)	Sulphur (mg/kg)
S_{31}	175	12.3	134.4	3.9	1.40	0.12
S_{32}	265	13.1	224	2.6	0.60	0.14
S_{33}	230	15.9	67.2	1.8	2.02	0.17
S_{34}	400	17.3	145.6	2.9	1.10	0.17
S_{35}	195	12.8	123.6	8	1.82	0.15
S_{36}	250	18.1	190.4	1.3	1.30	0.16
S_{37}	345	16.2	257.6	1.1	0.82	0.17
S_{38}	175	13.6	156.8	4.7	1.40	0.14
S_{39}	300	15.9	145.6	7.2	0.61	0.14
S_{40}	200	15.7	190.4	6.3	0.12	0.16
S_{41}	230	15.3	112	9.2	0.24	0.14
S_{42}	230	16.3	100.8	10.3	0.65	0.15
S_{43}	167	15.7	78.4	4.9	0.13	0.14
S_{44}	175	18.1	156.8	7.2	0.10	0.11
S_{45}	100	13.8	246.4	6.5	1.80	0.12
S_{46}	195	15.9	67.2	5.1	0.21	0.18
S_{47}	320	15.4	190.4	11.7	0.62	0.12
S_{48}	115	15.9	168	6.2	0.23	0.13
S_{49}	230	14.6	201.8	5.1	0.51	0.13
S_{50}	285	13.3	123.2	6.5	0.33	0.14
S_{51}	200	13.6	112	6.6	0.18	0.16
S_{52}	320	15.5	100.8	6	0.35	0.15
S_{53}	265	16.2	168	7.4	0.31	0.16
S_{54}	175	13.3	179.2	10.5	0.41	0.16
S_{55}	167	13.6	212.8	5.3	0.22	0.14
S_{56}	300	18.3	180.8	7.8	0.53	0.16
S_{57}	230	16.1	89.6	5.7	0.80	0.11
S_{58}	195	12.7	190.4	6.4	0.12	0.11
S_{59}	195	15.7	145.6	5.4	0.78	0.14
S_{60}	285	17.02	156.8	5.7	0.33	0.14
Mean	**230.4**	**15.28**	**153.8**	**5.97**	**0.66**	**0.143**
Range	**100-400**	**12.3-18.3**	**67.2-257.6**	**1.1-11.7**	**0.10-2.02**	**0.11-0.18**
SD±	**67.94**	**1.69**	**50.36**	**2.55**	**0.55**	**0.19**
CV (%)	**29.48**	**11.05**	**32.73**	**42.77**	**83.23**	**9.84**