CHARACTERIZATION OF SOILS THROUGH PROFILE STUDY OF NARASINGHPUR BLOCK IN CUTTACK DISTRICT OF ODISHA, INDIA

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

Master of Science (Agriculture)
in
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Submitted by
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I.D. No. 20412SAC005 2022 Enrolment No. 429475

Dedicated to

My Parents

Mr. Krushna Chandra Behera

Mrs. Tilottama Dei

&

Advisor

Dr. Ramawatar Meena

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Through: The Head,
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Institute of Agricultural Sciences, Banaras Hindu University,
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Dear Sir,

I have great pleasure in forwarding the thesis **"Characterization of soils through profile study of Narasinghpur Block in Cuttack District of Odisha, India** submitted by ***Mr. Lilan Kumar Behera*** **(I.D. No. 20412SAC005),** in partial fulfilment of the requirements for the degree of **Master of Science (Agriculture) in Soil Science and Agricultural Chemistry**, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi.

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

Thanking you,

Forwarded by

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Date*:*

Place*: Varanasi* ***(Lilan Kumar Behera)***

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LIST OF SYMBOLS AND ABBREVIATIONS

%	:	Per cent
˚F	:	Degree Fahrenheit
$\mu g\ L^{-1}$	:	Micro gram per liter
μgg^{-1}	:	Micro gram per gram
^{0}C	:	Degree centigrade
BC	:	Before Christ
bdl	:	Below detection limit
$CaCO_3$	:	Calcium carbonate
CEC	:	Cation exchange capacity
cm	:	Centi meter
cmol(p+) kg^{-1}	:	Centimole (proton) per kilogram
dSm^{-1}	:	Desi Siemen per meter
DTPA	:	Diethylene Triamine Penta Acetate
e.g.	:	For example,
EC	:	Electrical conductivity
ESP	:	Exchangeable Sodium Percentage
et al.	:	And others
Fig.	:	Figure
FYM	:	Farm Yard Manure
g	:	Gram
g kg^{-1}	:	Gram per kilogram
g cm^{-3}	:	Gram per cubic centimeter

GIS	:	Geographic Information System
g mol^{-1}	:	Gram per mole
GPS	:	Global Positioning System
hrs	:	Hours
i.e.	:	Which is to say, in other words
kg	:	Kilogram(s)
kg ha^{-1}	:	Kilogram per hacter
Km^2	:	Square kilometer
KVK	:	Krishi Vigyan Kendra
m	:	Metre
M	:	Molarity
meq l^{-1}	:	Milli equivalent per liter
mg kg^{-1}	:	Milli gram per kilogram
Mg m^3	:	Mega gram per meter cube
mL	:	Milliliter
MLD	:	Million liter per day
mm	:	millimeter
MT $year^{-1}$	:	Million tonne per year
N	:	Normality
ng L^{-1}	:	Nano gram per liter
No.	:	Number
OC	:	Organic carbon
PC	:	Principal components
pH	:	Puissance de hydrogen

ppm	:	Parts per million
r	:	Correlation coefficient
rpm	:	Revolution per minute
S.D.	:	Standard deviation
SOM	:	Soil organic matter
SOC	:	Soil organic carbon
SAP	:	Soil available phosphorous
SAK	:	Soil available potassium
v/v	:	Volume by volume
viz	:	That is to say
WHO	:	World Health Organization

Chapter I

INTRODUCTION

Soil is considered as the integral part of earth and their characteristics are largely governed by landforms in which they are developed. The information on their characteristic, classification, location and distribution, is required for any developmental planning in particular area. Soil is one of the most vital and precious natural resource. Social and economical development of people depends on soil that sustains life on the earth **(Kanwar, 2000).**

Soil is a natural body developed by natural forces acting on rocks and minerals. It is usually classified into different horizons from mineral matter and organic constituents at various depths which differ from the parent material in morphology, physical, chemical and biological characteristics. Systematic study of chemical properties and taxonomy of soils gives information on nature and type of soil and their constraints. Knowledge of vertical distribution of plant nutrients in soil is useful as roots of most of the crop plants go beyond the surface layer and draw part of their nutrient requirements from the sub surface layer **(Mishra, 2005).** Soils are applied solely to those superficial horizons of rocks, that have been more or less modified naturally by the interaction of water, air and various kinds of organisms, either living or dead; this being reflected in a certain manner in composition, structure and colour of such formations. Where this conditions are absent, there are no natural soils, but either artificial mixtures or rocks **(Dockuchaiev, 1900).**

Soil consists of four major components such as mineral matter, organic matter, water and air. These components cannot be separated because they are present very intimately mixed with each other. Soil solids mostly consists of mineral matter and a very small fraction is occupied by organic matter. Soil pore spaces are occupied equally by air and water.

Soil can be characterized by its texture, colour, structure, porosity and abundance of roots, rocks and carbonates. These characteristics allow scientists to interpret how the ecosystem functions and make recommendations for soil use that have a minimal impact on the ecosystem. Soil characterization is a critical step in determining the kind and level of contamination in a given soil. Not only it is necessary to evaluate the areal distribution of contamination across a land surface, but the depth of soil contamination is also key to understanding how that contaminant is distributed in three-dimensional space. Depth characterization also provides a key parameter in determining volumes of contaminated soil. Understanding how contamination is distributed vertically requires a method that not only provides a reasonable estimate of contamination, but also elucidates the depositional and post depositional processes responsible for the distribution of contamination with depth (**Michael *et al.*, 2010**).

Formation of soil in a region can occur within a certain period of time depending on the geological materials, successive climates, topography and biological and human activities of the region **(Joffe, 1949).** The effects of these elements are influenced by the type of the rock and the formations that have evolved from it, as well as landscape relief and the mitigation of particles in solution or suspension in water **(Arnold, 2006).**

Soil profile may be defined as a vertical section through a soil. It represents the sequence of horizons or layers differentiated from one another but genetically related and included to the parent material from which the soil profile is developed. Road cuts and other ready- made excavation can expose soil profiles and serve as windows to the soil. In an excavation open for some time, horizons are often obscured by soil material that has been washed by rain from upper horizons to cover the exposed face of lower horizons. A soil profile is an historic record of all the soil forming processes and it forms the unit of study in pedological investigations. Practically, soil profile is an important tool for soil classification which is applicable for thorough understanding the soils **(Zhang *et al.*, 2018)**.

The soil profile is an important tool in nutrient management. By examining a soil profile, soil fertility can be assessed. The profile of soil changes as the soil weathers or organic matter decomposes. A highly weathered infertile soil usually contains a light coloured layer in the sub-surface soil from which nutrients have leached away, while a highly fertile soil often has a deep surface layer that contains high amount of organic matter **(Das, 1996).**

Horizons within a soil may vary in thickness and have somewhat irregular boundaries, but generally they parallel the land surface. This alignment is expected since the differentiation of the regolith into distinct horizons is largely the result of influences, such as air, water, solar radiation and plant material, originating at the soil-atmosphere interface. In some soil profiles, the component horizons are very distinct in colour, with sharp boundaries that can be seen easily by even novice observers. In other soils, the colour changes between horizons may be very gradual and the boundaries more difficult to locate.

Soil profile study shall play crucial role in precision agriculture in area of all type of farming and rainfed areas, conservation agriculture and in contaminated soil diagnosis and remediation. Soil characteristics in relation to evaluation of soil fertility of area are important aspect in context to sustainable agriculture production. Because of imbalance and inadequate fertilizer application coupled with low efficiency of other inputs. The efficiency of chemical fertilizers nutrients has decline tremendously in intensive agriculture in day by day since last decades. The capacity of specific kind of soil to formation with in natural or managed ecosystem boundaries to substation Plant and animal productivity, maintain or enhance water and air quality as well as support human health and habitation (**More, 2010**).

Soil profile characteristics as conditioned by different processes and factors of soil formation have great influence on soil fertility and crop productivity. Detailed and scientific study of soil profiles is immensely essential for understanding the prevailing soil forming (soil genesis) factors and processes, without a knowledge of which soil characteristics cannot be clearly interpreted (**Vedadri and Naidu, 2018**). The crop productivity cannot be boosted further without judicious use of macro and micro nutrient fertilizers to overcome the existing deficiencies. Hence, a clear cut understanding of vertical distribution of plant nutrients in soil is highly necessary to suggest appropriate fertilizer schedule for different crops to obtain optimum yield. Variations in topography greatly influence the availability and distribution of plant nutrients, both in surface as well as subsurface soils (**Dorji et al., 2014**).

The application of fertilizer by farmers in the field without knowledge of soil fertility status and nutrient requirement of different crops usually leads to adverse effect on soil as well as crops creating nutrient deficiency or toxicity due to excess use or inadequate use of fertilizers. Finally these results in loss of farmers' financial resources and reduces the soil productivity and accelerates the soil quality degradation in long run. So use of balanced fertilizer dose in the agricultural field is the most important agricultural input for increasing crop production. Soil testing is now considered as an important method for recommending fertilizers doses for different crops in India.

Narasinghpur is a block of Cuttack district which is situated 100 km far from the capital of Odisha and 120 km far from its district headquarters Cuttack. Global positioning of Narasinghpur block is at 20.467N Latitude and 85.083E Longitude. One side of Narasinghpur is painted by the perennial giant Mahanadi River, where as the other side is escorted by the vast forest area with many mountains called Satakosia Wildlife Sanctuary. This place is connecting to districts like Nayagarh district, Angul district and to its own Cuttack district. Narasinghpur is named after its discoverer Narasingh who was later overthrown by Sri Mandardhar Harichandana Mohapatra.

Narasinghpur block is situated in mid central table land agro climatic zone of Odisha. The climate of the block is hot and moist sub-humid. Average annual rainfall of the block is 1421mm whereas the mean maximum summer temperature is 38.7^{0}C and mean minimum temperature of the block is 14^{0}C. The climate and rainfall of the block is different from the district headquarter because district headquarter is situated in east and south eastern coastal plain agro climatic zone. Commonly alluvial, red, lateritic, mixed red and black soils are found in the block.

Total number of villages in this block is 166. Sex ratio of Narasinghpur block is 912 females per 1000 of males. Total population of the block in 2022 is 1,24,959. 5.90% of the total population of Narasinghpur block is agricultural farmers, out of these 5.43% is male and 0.47% is female farmers. Most of the farmers of this block are small and marginal farmers. Paddy is the chief produce of this block during kharif season. In rabi season farmers produce groundnut, green gram, black gram like crops. Some farmers grow vegetables like cabbage, cauliflower during winter season. Sometimes farmers face drought like situation due to inadequate rainfall.

The present research work was undertaken with the following objectives;

- To characterize the soil profile of Narasinghpur block.
- To ascertain the fertility status of Narasinghpur block through soil profile.
- To study the correlation between physico- chemical properties and available nutrients in the soils of Narasinghpur block.

Chapter II

REVIEW OF LITERATURE

Agriculture is the major source of livelihood for the people in a region which is dependent on the soil of that region. The land and topographical conditions vary and physical aspects of the region presents a variety of landscapes and agricultural problems. Generally soils of an area have not been studied well while there is a wide variation in soil types. Different land use systems have different capacity to change the soil chemical properties. So that information about the soil chemical properties is important for best management practices to avoid negative impact of it for sustainable development.

The most significant aspect of enhancing crop production is the management of soil fertility. The characteristics of the soil profile, which is determined by various processes and factors of soil formation, have a significant role on soil fertility. Awareness of the vertical distribution of plant nutrients in soil is again helpful as the roots of most crop plants go beyond the surface layer and draw from the sub-surface layers part of their nutrient requirement **(Mishra, 2005).** "Topography" plays a vital role in deciding various soil properties within a small geographical area, among all the factors of soil formation.

Therefore, the review of literature for the present study is being discussed under the following sections.

2.1 Vertical distribution of soil properties

2.2 Variation in soil formation

2.3 Soil fertility status

2.1 Vertical distribution of soil properties

Natrajan and Renukadevi (2003) conducted an experiment on vertical distribution of forms of potassium in major soil series of Tamil Nadu, they found that the exchangeable K varied from 45 to 684 ppm and was positively related to organic carbon. Ammonium acetate-K ranged from 15 to 298 ppm. Soil properties like clay, silt, $CaCO_3$ and organic matter were found to be positively correlated with available K.

Singh *et al.* (2006) examined horizon wise samples from nine pedons from the state of Manipur. The soils were found to be acidic in reaction (pH 4.1 to 6.2), the organic carbon content ranged from 1.0 to 35 g/kg, the CEC ranged from 4.30 to 20.80 [cmol (p^+) kg^{-1}]. The clay content varied from 9.8 to 70.3 %. The total K percentage ranged from 2.01 to 4.85 %.

Sarade and Prasad (2008) examined horizon-by-horizon samples of six pedons of guava-growing soils in Maharashtra's Bhandara District. In different horizons of pedons, the clay content ranged from 15.2 to 60.3 percent. The bulk density varied from 1.35 to 1.79 mg m^{-3}, and rose with depth in general. The soils' pH ranged from 6.2 to 8.4. On the exchange complex, exchangeable Ca was shown to be the major cation, followed by Mg. The soils had CECs ranging from 8.8 to 40.5 [cmol (p^+) kg^{-1}]. The base saturation of the soils ranged from 69 to 97.5 percent.

Mishra *et al.* (2009) investigated the vertical distribution of available potassium in some soils of the West Central Tableland Catena in Odisha, and discovered that the organic carbon status was higher (11.2 to 14.1 g kg^{-1}) within the surface horizons, owing to large accumulations of organic matter and incorporation of massive quantities of stubbles left after paddy harvest. CEC and percentage base saturation values were discovered to be growing in a vertically downward trend. Because of the increase in clay percentage and decrease in organic matter content with depth, the available phosphorus reduced below the Ap horizon. The available potassium concentration increased with depth, and clay content and CEC were both positively correlated.

Kumar *et al.* (2012) contemplated the vertical distribution of plant available nutrients in soils of Jharkhand and found that increase in the soil pH and calcium carbonate with increase in the soil depth of profiles. On the other hand decrease in the soil organic carbon with increase in the depth. Higher values of CEC in sub- surface horizons were positively related with the amount of clay.

Dorji *et al*. (2014) concentrated on soils of Eastern Himalayas and found that the soil organic carbon found to be decreasing with increase in depth. The grassland

SOC was found to be highest followed by forests, shrub land and agricultural land. The distribution of SOC was found to be more homogenous in agricultural land.

Saini and Grewal (2014) investigated the vertical distribution of several types of potassium in Haryana soils and its correlations with various soil characteristics. They discovered that the distribution of various kinds of potassium in these soils, such as water soluble, exchangeable, non-exchangeable, and total potassium, ranged from 8 to 58 kg ha^{-1}, 127 to 263 kg ha^{-1}, 442 to 828 kg ha^{-1}, and 1.18 to 1.92 percentage, respectively. In these soils, there was no discernible trend in the various potassium forms with respect to depth. Different potassium forms were discovered to be positively and significantly connected to soil silt and clay concentration, but negatively associated to soil sand content.

Rajeswar and Ramulu (2016) researched on distribution of available macro and micronutrients vertically in soil profiles of Ganapavaram pilot area of Nagarjuna Sagar left canal command area of Andhra Pradesh and found that the soil pH and EC to be showing increasing trend with soil depth within the soil profiles which of decreasing trend with reference to macro nutrients like N, P, K, S and micro nutrients like Fe, Mn, Cu and Zn.

Dash (2018) investigated the vertical distribution of nutrients in three topographic positions in KVK, Dhenkanal: upland, middle land, and low land. The OC concentration was found to be highest in the surface of all land types and declined downwards. The pH was determined to be lowest at the surface and gradually raised as you went deeper. CEC increased up to a depth of 67cm in upland soils, up to the final part of B horizon in medium land soils, and up to the last part of B horizon in low land soils. The maximum N and P concentration was observed on the surface in all three topographic positions, and it dropped as depth increased. The K content increased in the middle and low land.

Khanday *et al.*, (2018) studied on soil profiles of Ganderwal District of Kashmir valley and found that the organic carbon content was more in the surface horizons than the sub-surface horizons. Soil reaction was found to be slightly acidic to alkaline and the soluble salt concentration was found to be negligible. The available nutrients like nitrogen, phosphorus, potassium and sulphur were medium in range and were found to be decreasing with increase in the depth and similar trend was also found to be followed in micronutrients like Fe, Mn, Cu and Zn.

Sethy (2018) investigated the vertical distribution of nutrients in three topographic situations in the Deogarh district of Odisha: foothill, upland, and medium land. From the surface horizon downward, the clay percentage gradually rose and was determined to be maximum within the C horizon. In all land types, the pH was lowest at the surface and increased with depth. The maximum concentration of OC was detected near the surface and reduced as deep increased. With increasing depth in all profiles, the CEC rose. The saturation of the base followed a similar pattern. Surface horizons of all terrain types had the maximum available N, P, and S, which decreased with depth. On the other hand, the accessible K content was lowest at the surface and rose as you went deeper.

Huiping *et al.* (2019) explain the spatial variation of soil organic carbon in Juniper plantation and the influence of environmental factors on organic carbon. Soil samples of 0-80 cm profile depth were sampled and they measured the soil organic carbon and other soil properties, analysed the vertical distribution of soil organic carbon and the relationship between them. The results showed that soil organic carbon content (36.01%), organic carbon density (34.83%) and available nitrogen content (47.06%) in the 0-20cm soil layer were all relatively large. Soil organic carbon content was significantly positively correlated with soil organic carbon density and soil available nitrogen content. Soil bulk density and soil pH value were negatively correlated with soil organic carbon, while soil total porosity, capillary water holding capacity and capacity and field water holding capacity were positively correlated. The vertical distribution of carbon content in the soil profile of the whole forestland shows a pattern of first steep drop and then gradual decrease. Soil fertility can be improved by changing stand structure and replanting broad-leaved trees.

Kafle (2019) conducted an experiment in Kankali community forest, Chitwan, Nepal, to quantify the vertical distribution of soil organic carbon (SOC) and nitrogen in 1 m soil profile depth. This community forest represents a tropical ***Shorea robusta*-**dominated community forest. It was found that the soil had 122.36 t/ha SOC and

12.74 t/ha nitrogen in 1 m soil profile in 2012, with 0.99% soil organic matter and 0.10% nitrogen concentration in average. Carbon and nitrogen ratio (C/N ratio) of the soil was found to be 9.90. Both bulk density and C/N ratio were found increasing with increase in soil depth. The SOC and nitrogen were found significantly different across different soil layers up to 1 m soil profile depth. The average pH of the forest soil was found to be 5.3.

Mishra *et al.* (2019) conducted an experiment to analyse the distribution of available plant nutrients and to examine the relationships between soil properties and available nutrient status in soil profiles of Eastern India. Three soil profiles were exposed under three different topographic positions. In all the pedons, soil pH and EC increased and soil organic carbon content decreased with increasing soil depth. The status of available N, P, K and S in surface soils ranged from 223 to 321, 11 to 36, 305 to 354 and 4.6 to 12 kg ha^{-1}, respectively.

Pattanaik (2019) studied the 3 pedons i.e. upland, medium land, lowland of KVK, Anugul situated at mid-central table land agro climatic zone of Odisha and found that organic carbon showed a decreasing pattern on increasing in depth, % base saturation showed a increasing pattern down the depth and all the macronutrients like N, P, K and micronutrients showed a decreasing pattern down the depth.

Patra (2019) studied 3 pedons of KVK, Keonjhar of north central plateau agro climatic zone of Odisha and found that OC and exchangeable acidity along with macro and micronutrients showed a decreasing pattern while cation exchange capacity and % base saturation showed an increasing pattern down the depth of profile.

Hoque *et al.* (2020) carried out an experiment with seven soil samples with seven land use types to observe the effect of soil depth on soil properties under various land use systems. Soil pH, electrical conductivity (EC), organic matter, available phosphorus (P), available sulphur (S) and different forms of potassium (K) such as water soluble, exchangeable and non-exchangeable were determined from the soil samples collected from four depths (viz. 0-10, 10-20, 20-30 and 30-40 cm). Soil pH varied from 6.30-7.39 irrespective of depths and land uses and it increased with increasing soil depth. Electrical conductivity of the soils ranged from 42-310 μS cm^{-1}

and organic matter status of most of the soils was very low to medium. Both EC and organic matter content decreased with the increase in soil depth. Available P concentration showed no specific changing trend with soil depth whereas available S concentration under different land use systems decreased with increasing soil depth. The concentrations of water soluble, exchangeable and non-exchangeable K in soils varied from 12.30-39.60, 20.90-53.16 and 163.30-684.30 mg kg^{-1}, respectively and showed no specific changing pattern with soil depth.

Munny *et al.* (2021) conducted an experiment to investigate of different land-use on soil organic carbon stock and selected soil properties in soil profiles in saline soils of Debitola and Fultola village near the salinity research center of Batiaghata Upazilla in Khulna, Bangladesh. He collected soil samples at 0-15, 15-30, 30-45, 45-60, 60-75, 75-90 and >90 cm depths in three different locations under different cropping patterns(Rice-Vegetable, Rice-Fallow and Rice-Shrimp) with three replicates and analysed. Results showed that the SOC content and SOC stock increased with depth increments in Rice-Vegetables land-use system while it decreased with depth in Rice-Fallow land-use system.

Tian *et al.* (2021) investigated the vertical variations in soil available phosphorus (SAP) and soil available potassium (SAK) in the critical zone on the Loess Plateau (50–200 m), China, by using classical statistical and geostatistical methods. The soil samples were collected from the top of the soil profile down to the bedrock by soil core drilling at five typical sites. SAP decreased throughout the profile. Whereas the SAK exhibited an increasing trend at all sites. The mean SAP concentration ranged from 0.94 to 32.56 mg kg^{-1} at the sampling sites and the SAK concentration ranged from 44.51 to 229.31 mg kg^{-1}. At all of the sampling sites, SAK was significantly positively correlated with the depth and clay content, but there was a significantly negative correlation between the SAK and the sand content.

2.2 Variation in soil formation

A variety of principles have often been discussed through a method of soil analysis, one of which is the notion of toposequence. To demonstrate its functional connexion with land use and land use planning, many soil scientists have examined many toposequence. Some of the relevant studies are discussed below on India's toposequence.

Catena is a unit of soil mapping that, despite falling widely apart due to fundamental and morphological differences in a natural system of classification, is still connected by topographical conditions in its occurrence and is repeated in the same relationships with each other where the same conditions are met, according to **Milne (1935).**

Materials are moved well away from the bigger portions of the slope during the soil forming phase, according to **Jenny (1941)**, and then sublimated on the bottom sections. The shortened profiles allude to the total disappearance of the A horizons, leaving the exposed horizon towards the ridges, and were often visible in young, ploughed slopes.

Biswas and Gowande (1962) employed the catenary notion in Madhya Pradesh's Chhattisgarh basin to examine the formation of soils. They pointed out that the series is made up of four soil types: Bhata, Matasi, Dorsa, and Kanhar, which are locally known as red planet, yellow planet, brown earth, and black earth, respectively. The red soil was discovered on top of the mounds, followed by yellow and brown soils down the slopes, and finally black dirt within the valleys. The change in soil colour and moisture state was discovered to play a role in the slope. The depth of the solum increased as the soil reaction changed from acidic to alkaline, the structure changed from less to blocky, and the texture changed from sandy loam to clayey.

Nayak (1980) did a research work on toposequence soils of Regional Research Station located at Keonjhar which is situated at Northern Plateau Zone of Odisha. He found that comparatively young soils were found on the foot hills where the soils were subjected to continuous erosion; transitional soils were found to be formed on the toe slope and upper valley of upland position. Comparatively matured soils were found to be formed on the gently sloping uplands. Soil depth, percentage clay, soil pH, CEC and percentage base saturation were found to be increasing along the toposequence from foot hills towards the toe slope.

Mishra (1981) did study on the morphological characteristics and classification of soils in the Hirakud command region of Odisha and discovered that physiography has a significant impact on soil properties. Chakuli, Mahulpali, and Kalamati were the three transects he inferred. Due to increased moisture regimes and restricted drainage conditions in lower topographic positions, the soil color in the Chakuli transect became yellower down the slope, both on the surface and in the majority of the sub-soil. The surface and subsurface soil textures became thicker as the slope progressed. Clay percentage, CEC, ESP, and pH all increased along the slope, which could be attributed to the transfer of finer soil particles and bases down the slope.

Mishra (1987) discovered that the clay substance in the B horizon increased from the ridge top to the lower valley land while investigating a toposequence in soils of sisal (Agave sisalana) growing zones of Sambalpur District in Odisha. The increase in CEC in the B layer was closely linked to the increase in clay content. The appearance of red soils in the ridge and yellower soils in the valley was attributed to the later land types' higher moisture regime as a result of their lower inclines. Subangular blocky structures were discovered in the ridge top soils, while crumb structures were discovered in the valley bottom soils. Udic Paleustalfs were the taxonomy classification for ridge top soils.

In the Ganjam District of Odisha, which is part of the North Eastern Ghat Region of Odisha, **Sahoo (1993)** looked at four pedons representing various physiographic units of a watershed. Upper pediment, pediment with bunding, unbunded upland, and lower pediment were the physiographic units found in the research area. In the respective pedons, pedons were found to be grouped under the orders Entisols, Entisols, Inceptisols, and Entisols. Except for the 4th pedon, all of the soils were found to have moderate to severe soil erosion, owing to high slopes, heavy rainfall, and barren areas with overgrazing. The soil texture became finer as the micro relief and slope decreased. Upper pediments had lower CEC values, while lower pediments had greater CEC values.

Das (1994) researched soil profile features along the toposequence in five physiographic units: foot hills, upper ridges, mid upland, mid medium land, and medium valley land in a watershed in Kandhamal District, Odisha. From the higher ridges down the hill, the soil colour changed from reddish brown to reddish yellow. The foothills' surface texture was determined to be sandy, changing to sandy clay loam and loam as it progressed down the slope. The soils of the research area's foothills, higher ridges, mid upland, and mid medium land were categorised as Haplustalfs, while those in the medium valley were classed as Ustochrepts.

Moharana (1995) focused on the toposequence of the Regional Research Station, G.Udayagiri, in Odisha's Kandhamal District. The pediment slope's surface texture was discovered to be loamy sand, which gradually changed to loam, sandy loam, sandy clay loam, clay loam, clay loam, and clay as it progressed down the slope. X-ray diffraction and petrographic study of the mineralogy of fine sand fractions revealed that quartz predominated in all soil profiles, followed by goethite or olivine, orthoclase, and silimanite. Other refractory minerals such as anatase, gibbsite, and hematite were also found, indicating that the soil had been heavily worn. Minerals such as quartz, feldspar, silimanite, muscovite, and others indicated the rocks' Khondalitic composition.

Nayak (1998) examined the soils of the OUAT's Central Research Station, he discovered a sand mineralogy research that revealed quartz to be the most abundant mineral in all pedons, followed by orthoclase, feldspar, mica, chlorite, biotite, garnet, zircon, muscovite, and rutile. The presence of identical minerals in all of the profiles suggested that the soil was derived from similar parent material.

Parida (2000) conducted a soil research at RRTTS, Bhawanipatna in Odisha's Western Undulating Agro Climatic Zone, and looked at five pedons along the toposequence that were made up of different physiographic units. Along the hill, he discovered that % clay, percentage porosity, soil response, organic carbon, electrical conductivity, and CEC values all increased.

Rao *et al.* (2004) did a research work on the soils of South-Coastal Andhra Pradesh and found that *Inceptisols* were formed on very gently to gently sloping uplands with a slope of 0 to 1 per cent and were very deep, sandy loam to sandy clay loam, well drained and that of *Vertisols* were formed in low land were very deep, clayey and moderately well drained.

Mishra (2005) investigated the Malipali transect of Sambalpur, which is located in Odisha's West Central Table Land Agro Climatic Zone, and discovered that the physiography has a significant impact on soil characteristics. From upland to lowland, the depth of the B horizon rose. pH, exchangeable bases, CEC, percentage base saturation, and organic carbon all showed a downward trend. The bulk density was discovered to be decreasing down the hill, owing to an increase in organic materials and smaller particles. The availability of macro and micro nutrients was also shown to be increasing down the slope, owing to increased organic matter content, runoff, and basic cation leaching.

Mishra (2008) showed that quartz was the most common mineral in all pedons in the Kanchinala smaller scale watershed of the Mahanadi delta of Odisha, followed by orthoclase and plagioclase. Higher feldspar content in the pedons indicated that clay formation had not progressed far enough. Garnet, muscovite, biotite, and hornblende were among the minerals identified.

Nagendran and Angayarkanni (2010) concentrated on a toposequence in Cumbum Valley of Tamil Nadu and found that water retension was emphatically related with rate of clay substance.

Sharma and Jassal (2013) investigated availability and total micronutrient variability in a toposequence from Punjab's wet sub humid Siwalik Agro-Ecological Sub Region. On steep slopes, the toposequence revealed the least developed soils, with only an A–C horizon sequence, and on moderate slopes, a well-formed profile with an argillic horizon. The soils were discovered to have a range of minerals, putting them in the mixed mineralogy category. Because of their interaction with organic matter through chelation and adsorption, the surface horizons have larger quantities of DTPA-extractable micronutrients than the subsurface horizons.

Sharma *et al.* (2013) conducted the experiment to analyse the macro and micronutrient contents of the alluvial plains of Kothari River, which is the tributary of Banas and situated in Eastern Rajasthan Upland with the aim to sustain better productivity and sustainability. Twelve pedons were selected for the experiment and soils were classified as coarse loamy, mixed hyperthermic Typic Haplustepts on higher elevations and fine loamy, mixed hyperthermic Typic Haplustepts on lower part of landform. Soils were analyzed for the status of available nitrogen, phosphorus, potassium, iron, manganese, zinc and copper content in vertical as well as in horizontal direction. Nitrogen, phosphorus and zinc content decreased in horizontal direction from higher elevation to lower elevation while iron and copper showed a reverse trend. Almost all nutrient elements showed a decreasing pattern in vertical direction of the pedons except copper.

Gandhi and Savalia (2014) investigated mustard soil-site suitability in calcareous soils of the Girnar toposequence in Gujarat's Southern Saurashtra region. The adaptability of five typical pedons to Indian mustard ***Brassica juncea* (L.)** in soils of various land types was investigated. Lower pediment soils belonging to Typic Haplusterts were found to be highly suitable for Indian mustard **(*Brassica juncea*)** cultivation, whereas hill slope land belonging to Lithic Ustorthents, upper pediment soils belonging to Lithic Haplustepts, upper coastal plain soils belonging to Typic Haplustepts, and coastal depression land type belonging to Typic Ustifluvents were found to be unsuitable.

Sarkar *et al*. (2014) did their study on soils of a toposequence in Chotanagpur Plateau of West Bengal. They examined the soil maturity sequence derived from Weathering Index (WI) based upon soil inorganic phosphorus fractions. They found the soils of moderately sloping upland as most matured which was followed by pediment and valley. The hill side slope was found to be least matured.

Veersh (2014) concentrated on soil formation along a toposequence over a Schist landscape and found that the important pedogenic processes seemed to be associated with the upper slope member (red pedon) were leaching, decalcification, desilicification, laterization and kaolinization under well drained condition; that of the lower slope members (brown and black pedons) were formed by the pedogenic processes of calcification and silicification under poor drainage condition. Red, brown and black pedons were classified as *Typic Haplustalf*, *Vertic Haplustepts* and *Lithic Calciustert* at sub group level, respectively.

Giri *et al.* (2017) while examining on soils of two toposequence found in Bazargaon plateau of Maharashtra, found that organic carbon content in toposequence-I ranged from 3.10 to 18.77 g kg^{-1} and in an increasing trend from upland to medium land; while in toposequence-II, it ranged from 1.55 to 12.77 g kg^{-1} and gradually decreased with depth. Exchangeable cations were found to be following the order of: Ca^{2+} >Mg^{2+} >K^{+} >Na^{+} in all the pedons of both the toposequence indicating the dominance of calcium bearing minerals in the parent material. Cation Exchange Capacity in toposequence-I varied from 35.6 to 69.0 cmol (p+) kg^{-1} while in toposequence-II, it varied from 37.8 to 67.2 cmol (p+) kg^{-1}.

Hakla *et al.* (2017) conducted field experiment on the Gir Madhuvanti toposequence of South Saurashtra region of Gujarat and reported variations in taxonomic classification along the toposequence. They found that soils of lower piedmont belonged to *Vertic Haplusterts*; that of plain area to *Typic Haplusterts*; that of depression area to *Sodic Haplusterts*; that of soils of hill slopes to *Lithic Ustorthents*; that of upper piedmont to *Lithic Ustorthents* and that of upper coast belong to *Fluventic Calciustepts*.

Rehman *et al.* (2017) were examined nine representative soil profiles in different toposequences of Puluwama District for various attributes. On foot hills, low hill plateaus, and land valleys, the soils were observed to vary in terms of degree of soil profile development from A-C, A-Bw-C, and A-Bt-C layers. Entisols, Molisols, and Alfisols were used to classify the soil profiles of foothills, low hill plateaus, and inland valleys.

Khanday *et al.* (2018) conducted field study of soil profiles of Ganderwal District of Kashmir valley reported that the soils were shallow to deep with profile development from A-C, A-Bw-C to A-Bt-C in Foot hills, Low hill plateaus and Inland valley, respectively.

Patra (2019) studied three pedons from KVK, Keonjhar in Odisha's north central plateau agro-climatic zone and discovered that pedon 1 belonged to the order Entisols, suborder Orthents, great group Ustorthents, and subgroup Typic Ustorthents, while pedon-2 and pedon-3 belonged to the same order Alfisols and Subgroup Ustalfs but different great groups due to different times of development Pedons 2 and 3 belonged to the Udic Haplustalfs and Udic Paleustalfs suborders, respectively.

Hegde *et al.* (2020) investigated the vertical distribution of physical and chemical properties of soils of Ramapura-1 micro watershed of Yadgir taluk and district of Karnataka, India by using digitalized cadastral map and satellite imagery. The soil texture varied from loamy sand to sandy clay loam in surface and sandy clay loam to clay in subsurface. The per cent moisture distribution was varied from 3.89 to 54.94 per cent and it was increase with depth. The soils under the study were slightly acidic to alkaline (5.57 to 10.32) and non-saline in reaction. The organic carbon content was low to high (0.12 to 1.16 %) and decreased with depth.

Awoonor *et al.* (2021) conducted an investigation for the assessment of soil variability along a toposequence in the tropical moist semi-deciduous forest of Ghana. Soil variability assessment along a toposequence was carried out on Bekwai-Nzima/Oda compound association. Soil samples were taken at two depths (0 - 20 and 20 - 50 cm). As shown by the coefficient of variation, topsoil (0 - 20 cm) had the highest variation compared to the subsoil (20 - 50 cm). The variations observed in most soil attributes (clay, silt, pH, CEC, SOC and TN) for the 0 to 20 and 20 to 50 cm depths were between eroded (summit and upper slopes) and depositional (lower slope and valley bottom) zones. The highly variable soil attributes were silt, TN, Av. P, and Av. K. However, bulk density and sand were the least variable irrespective of soil depth or toposequence. Pearson correlation analysis indicated a significant correlation ($p < 0.05$) between most soils attribute at the 0 - 20 and 20 - 50 cm depths at different slope positions. Principal component (PC) analysis indicated that the first four PCs explained more than 80% and 70% of the total variation for the 0 - 20 and 20 - 50 cm soil depths, respectively.

Pant *et al.* (2021) conducted an investigation on vertical distribution of different pools of soil organic carbon under long term fertilizer experiment on rice-wheat sequence in mollisols of North India. The soil at the experimental site was an Aquic Hapludoll consisting of a poorly drained silty clay loam (1–1.5 m deep) overlying loamy to sandy sediments. Over 42 years, application of 100% NPK+ FYM (Farm Yard Manure) was the most effective management system in increasing organic C up to 0 to

60 cm soil depths under rice-wheat sequence. Hence, application of FYM along with NPK resulted in a significant positive building up of all pools in the treatment at all four depths. Therefore, balance fertilization is important for sustaining improved soil health with balanced organic status and production potentiality of the soil for rice-wheat cropping sequence.

Novak (2022) investigated on the vertical distribution of basic soil characteristics and taxonomic status of sodic soil affected by afforestation. He found that afforested soils showed lower pH in the depth at 0–100 cm, and slightly higher SOC content in subsoil (20–100 cm). CaCO3 content was significantly different (higher) only at the depth of 50–100 cm in afforested soils. Remarkable differences in ESP values were measured. Afforestation had in almost every layer (0–20, 20–50, 50–100 and 150–200 cm) a significant lower ESP value than grassland soil samples from the same depths.

2.3 Soil fertility status

Aich *et al.* (2014) focused on study of the soils of organic farms at College of Agriculture, Pune. The content of available Fe, Mn, Zn, Cu and B in organic farm were found to be ranging from 5.96 to 11.70, 5.62 to 16.68, 1.06 to 3.68, 3.36 to 7.64 and 0.33 to mg kg^{-1} respectively. A positive relationship between organic carbon and Fe, Mn, Cu and Zn was observed based upon the coefficient of determination between micronutrients and soil properties.

Mishra *et al.* (2014) prepared GPS and GIS based soil fertility maps of Dhenkanal district and the soil reaction in all the blocks were found to be varying from pH of 4.33 to 7.83. The highest pH was found in Odapada block. The soils were safe for crop production in terms of Electrical Conductivity. The SOC of the District was found to be ranging between low to very high range (0.06-2.19 %). The available N in all the blocks were seen to be low to medium range (71-396 kg ha^{-1}); that of available P was in low to medium in all the blocks (0.2-51 kg ha^{-1}); that of available K ranged between low to very high (26.8 to 1004 kg ha^{-1}); that of the mean available S was found to be medium in range(12.3 to 17.8 mg kg^{-1}) ; that of available B ranged between deficient to sufficient range (0.13-1.47 mg kg^{-1}).

Kadam (2015) prepared GPS-GIS based soil fertility map of College of Agriculture farm, Karad, Maharashtra and found the SOC content of soils of Mundhe farm to be categorized as moderately high to very high with mean of 0.32% and for Saidapur farm categorized as medium to high which ranged from 0.72 to 1.03%. The available N was found to be of low to medium in status which ranged from 185.2 to 289.16 kg/ha. The available P for Mundhe farm was categorised as low to high which ranged from 11.30 to 50.10 kg/ha; that of Saidapur farm was categorised as low to high in status which ranged from 11.22 to 42.50 kg ha^{-1} with mean value 26.62 kg/ha. The available K in Mundhe farm was categorized as of medium status which ranged from 217.5 to 274.51 kg/ha and for Saidapur it was categorised as of medium status which ranged from 200 to 255.65 kg/ha. The available S in soils of Saidapur farm ranged from 10.36-30.0 mg kg^{-1} which were categorized as, medium to high.

Behera *et al.* (2016) did a research work on soil fertility status of some villages under East and South Eastern Coastal Plain Agro Climatic Zone of Odisha and observed the soil textural class to be varying from loamy sand to clay loam. The SOC content was found to vary from low to very high in status with a mean value varying from 1.1 to 22.6 g kg^{-1} and the values were found to be increasing from upland to lowland. The available N content fluctuated from low (87.5 kg ha^{-1}) to medium (337.5 kg ha^{-1}); that of available P fluctuated from low to very high (12.4-293.6 kg ha^{-1}); that of available K varied from low to very high (73.9- 510.7 kg ha^{-1}); that of available S fluctuated from low to high in range(0.97 to 76.4 mg kg^{-1}).

Khadka *et al.* (2016) studied to determine soil fertility status of the Agriculture Research Station, Belachapi, Dhanusha, Nepal. They found the pH of soils was acidic (5.61±0.14). The available sulphur (0.73±0.09 ppm) status was very low, whereas organic matter (1.34±0.07%), available boron (0.56±0.10 ppm), available zinc (0.54±0.22 ppm) and available copper (0.30±0.01 ppm) were low in status. The extractable potassium (95.52±13.37 ppm) and extractable calcium (1264.8±92.80ppm) exhibited medium in status. In addition, available phosphorus (33.25±6.97 ppm), available magnesium (223.20±23.65 ppm) and available manganese (20.50±2.43 ppm) were high in status. Furthermore, available iron (55.80±8.89 ppm) status was very high.

Mishra *et al*. (2016) studied GPS and GIS based soil fertility maps of Nayagarh District, Odisha and found that soils were acidic in reaction (pH 5.50 to 6.40) and low to medium in organic carbon status (4.5 to 6.83 g/kg). The mean available N content was seen as fluctuating between 129 to 171 kg/ha; that of available P content between 6.1 to 12 kg/ha; that of available K status between 159 to 258 kg/ha; that of available S between 17 to 26 mg/kg and that of available B status from 0.38-0.74 mg/kg. The soils were found to be deficient in available N and P, medium in available K, medium to high for available S, sufficient in available B content.

Nahak *et al.* (2016) prepared GPS and GIS based soil fertility maps of KVK Farm, Ranital and found that 41% of soils were neutral in soil reaction and 59% of soils were slightly alkaline. The SOC was found to vary from 2.4 to 13.8 g/kg. The mean available N, P, K and S were found to be 106.7, 15.8, 42.68 kg/ha and 2.345 mg/kg respectively. The mean hot water soluble boron, DTPA extractable Fe, Mn, Cu and Zn were found to be 1.12, 29.82, 4.31, 0.91 and 0.16 mg/kg respectively.

Barik *et al*. (2017) contemplated soil fertility status of some villages in Astaranga block of Puri District, Odisha and found the soil pH value to be lying in between 5.1 to 6.6. Clay content in the soils fluctuated from 8.8 to 30.8 percent. The SOC ranged between 2.5 to 11 g/kg. The mean available N content was found to be low (88 to 188 kg/ha); that of available P between 3.3 to 259 kg/ha; that of available K content varied from 59.1 to 446 kg/ha; that of available S was deficient (0.43 to 8.53 mg/kg) and that of hot water soluble B was found to range in between 0.12 to 7.6 mg/kg.

Denish *et al.* (2017) conducted a detailed soil survey in Bogur micro watershed in Karnataka with the aim of evaluating the fertility status of soils using nutrient index approach. A total of 118 surface samples were collected on grid basis with an auger from a depth of 0-20 cm and analyzed for pH, electrical conductivity, organic carbon, available nitrogen, P2O5 and K2O, available sulphur and available micronutrients (Zn, Mn, Fe & Cu) using standard analytical methods. Based of fertility ratings, pH of soils was acidic to alkaline. Electrical conductivity was normal. Soil organic carbon was low to high, with more than 70% of study area falling in the high category. Exchangeable Ca and Mg contents were low to high. Available macronutrient status (N, P, K, & S) were low to high. The availability of micronutrients was highly variable. Zinc (Zn) was low to medium, iron (Fe) was low, while manganese (Mn) and copper (Cu) were low to high.

Mishra *et al*. (2017) prepared GPS and GIS based soil fertility maps of Bhadrak District of Odisha and found that all the blocks were acidic in soil reaction and medium to high in organic carbon content (6.1 to 9.4 g kg^{-1}). The mean available soil N was found to be low (149 to 191 kg ha^{-1}); that of available P was found to be low to medium (3.8 to 17.8 kg ha^{-1}); that of available K was medium to high (179 to 484 kg ha^{-1}); available sulphur was found to be deficient in some blocks and sufficient in other blocks (8 to 33 mg kg^{-1}) and that of hot water soluble B was found to be above critical limit (0.57 to 1.03 mg kg^{-1}).

Patil *et al.* (2017) prepared GIS-GPS based soil fertility maps of Agriculture College farm, Kadegaon District, Maharashtra and found that the pH of soil varied from 7.09 to 8.21 while EC varied from 0.200 to 0.980 dSm^{-1}. The SOC contents in soils were found to vary between 0.13 to 0.91 percent. The available N, P and K ranged from 91 to 637, 5.2 to 34.7 and 109 to 559 kg ha^{-1} respectively. Soils of Agriculture College farm Kadegaon were very low to high in available nitrogen, very low to high in available phosphorus and low to very high in available potassium status.

Priyadarshini *et al.* (2017) concentrated on study of soil fertility status of some villages of Salepur block of Cuttack District of Odisha and found the soil textural class to be fluctuating from sandy loam to clay loam and the soil colour varied between brown to yellow. The SOC content was observed to be varied from low to very high range with a mean value varying from 2.8 to 10.6 g kg^{-1} and the values increased from upland to lowland. The available N was found to be low and varied from 113 to 238 kg ha^{-1}; the available P varied widely from 4 to 147 kg ha^{-1}; that of available K varied from low to high 32 to 376 kg ha^{-1}; that of available S varied from deficient to sufficient range 0.95 to 10.9 mg kg^{-1} and that of available B ranged between 0.06 to 2.28 mg kg^{-1}.

Dash *et al.* (2018) examined fertility status of RRTTS and KVK farm, Dhenkanal and they found that the texture of the soil varied from sandy to sandy clay; pH ranged between 4.13 to 5.97 and the SOC ranged between 5.1 to 15.9 g kg^{-1}. The available N content varied from 209 to 358 kg ha^{-1}; the available P (Bray's) varied from 5 to 39 kg ha^{-1}; the available K varied from 239 to 698 kg ha^{-1}; the available S varied from 3.6 to 15.5 kg ha^{-1} as far as the micronutrients were concerned the available Fe varied from 31.1 to 99.9 mg kg^{-1}; the available Mn varied from 10.2 to 40.6 mg kg^{-1}; available Cu varied from 0.6 to2.9 mg kg^{-1}; available. Zn varied from 0.6 to 1.6 mg kg^{-1} and available B varied from 0.63 to 1.28 mg kg^{-1}.

Desavathu *et al.* (2018) conducted an experiment on soil fertility status Paderu Mandal, Vishakhapatnam district of Andhra Pradesh using Geospatial techniques. They collected 82 soil samples from different land cover systems such as agriculture, forest, built up area, scrubland and plantation at a depth of 0–30 cm, analyzed for soil pH, electrical conductivity (EC) and presence of nitrogen (N), phosphorous (P) and potassium (K). It is observed that soil pH varies between 4.8 and 7.5; showing nearly 83% of the study area is acidic in nature. The EC varies from 0.04 to 0.87 ds/m with a mean of 0.21 ds/m and non-saline in condition. The available N content varied between 62 kg/ha to 284 kg/ha; the available P varied between 5kg/ha to 240 kg/ha and the available K varied between 22 kg/ha to 363 kg/ha.

Dhanve *et al.* (2018) conducted a research on assessment of soil fertility status of Agricultural Research Station, Badnapur, Maharashtra. They collected 100 soil samples from 0-15cm depth from Agricultural Research Station, Badnapur and grouped into 5 blocks. They found that the available nitrogen of soils was ranged from 137.9 to 269.6, 149.2 to 236.6, 153.6 to 235.6, 150.5 to 268.9 and 137.9 to 269.6 kg ha^{-1}, with an average 203.83, 192.9, 194.6, 209.7 and 203.75 kg ha^{-1}, respectively. The available phosphorus content of soil depicted ranged from 10.75 to 21.09, 20.60 to 27.29, 12.64 to 25.7, 15.71 to 23.74 and 17.16 to 25.32 kg ha^{-1} with an average 15.92, 23.94, 19.17, 19.72 and 21.24 kg ha^{-1}, respectively. The available potassium content of soil varied between 450.24 to 686.88, 630.56 to 673.12, 540.96 to 722.4, 596.96 to 769.4 and 552.16 to 679.84 with an average 568.56, 651.84, 631.6, 683.2 and 616.0 kg ha^{-1}, respectively. The available Sulphur content of soil varied between 8.6 to 18.27, 13.25 to 14.3, 10.82 to 18.98, 9.09 to 17.32 and 11.69 to 18.65 with an average 13.43, 13.82, 14.65, 13.20 and 15.17 kg ha^{-1}, respectively.

Digal (2018) investigated the soil fertility status of certain villages in Kandhamal district's Phiringia block and found that the pH of the soil ranged from 4.9 to 6.1, the EC was less than 2 dS/m, and the SOC was 4.6 to 9.7 g/kg. The available N content ranged from 88 to 213 kilogramme ha^{-1}, while available P ranged from 9 to 40 kg ha-1 and available K ranged from 184 to 429 kg ha-1. The available S and B levels were found to range from 7.3 to 11.2 ppm and 0.63 to 0.96 ppm, respectively.

Nayak (2018) focused on the study of the fertility status of four villages of Sundargarh district and found that the pH ranged between 5.48 to 7.14; the SOC ranged between 3.5 to 17.4 gm/kg; the available N content ranged from 75.26 to 225.81 kg ha^{-1}; the available P ranged between 2.28 to 17.07 kg ha^{-1} and the available K ranged between 48.36 to 433.2 kg ha^{-1}.

Sethy (2018) contemplated the fertility status of Deogarh district and KVK Deogarh of Odisha and found that the texture of the soil varied from loamy sand to sandy loam; pH varied between 5.5 to 6.9 and the SOC content ranged from 3.1 to 9.1 gm/Kg. The available soil N content found to vary between 87.5 to 212.5 kg/ha; the available P (Bray's) found to vary between 8 to 55 kg/ha and the available K content found to vary between 281 to 607 kg/ha.

Swain (2019) tested the fertility of various villages in Khordha and Bhubaneswar and discovered that clay content ranged from 2.42 to 34 percent, pH ranged from 4.24 to 6.93, and SOC concentration ranged from 1.1 to 11.6 gm/kg. The available N content of soils ranged from 50 to 225 kg/ha, while the available P content was 11.3 to 23.26 kg/ha, the available K content was 37.6 to 458.3 kg/ha, the available S content was 2.17 to 11.0 ppm, and the available B content was 0.91 to 2.68 ppm. Upland soils had all of the figures in the lower range, while lowland soils had all of the higher values for all of the characteristics.

Pattanaik (2019) investigated the fertility status of KVK, Anugul, and discovered that the soil texture ranged from sandy loam to sandy clay, while soil organic carbon varied between 4.3 and 14.6 g/kg of soil, and available N, P, and K content varied between 156 kg/ha and 340 kg/ha, 5 kg/ha to 34 kg/ha, and 289 kg/ha to 546 kg/ha, respectively. Available sulphur and boron in soil ranged from 3.6 to 15.3 kg ha^{-}

^{1} with a mean of 7.4 kg ha^{-1} and 0.66 to 1.25 mg kg^{-1} with a mean of 0.93 mg kg^{-1}, respectively.

Patra (2019) evaluated the fertility status of RRTTS and KVK, Keonjhar, in an experiment. He discovered that soil texture ranged from sandy loam to sandy clay loam, while soil organic carbon varied from 3.8 to 14.6 g/kg with an average value of 8.9 g/kg, available N, P, and K content varied from 87.5 kg/ha to 162.5 kg/ha, 8 kg/ha to 44 kg/ha, 110 kg/ha to 462 kg/ha, and S status varied from 3.8 mg/kg to 14.8 mg/kg. Available sulphur and boron were found to range from 3.8 to 15.4 mg/kg with a mean of 7.7 mg/kg and 0.68 to 1.30 mg kg-1 with a mean of 0.99 mg/kg, respectively.

Chhetri *et al.* (2020) conducted the study to assess the fertility status using soil nutrient index in three land use systems in Bhutan. Soil samples were collected from three different land uses between July 2013 to December 2018, and analysed, interpreted for pH, organic carbon, organic matter, primary nutrients, carbon/nitrogen ratio, total exchangeable bases, cation exchange capacity and base saturation. The results revealed that soil reaction in three different land uses varied from strongly acidic to slightly alkaline with pH values varying from 4.04 to 8.20. Soil fertility with respect to organic matter was high in dryland and medium in others. In all the land uses, status of nitrogen was low, organic carbon in medium and CN ratio in good category. The level of available phosphorous and cation exchange capacity was medium in dryland and orchard but low in wetland. Available potassium and exchangeable bases were medium in dryland and low in others. Base saturation was in low category in orchard and medium in other two land uses. A positive and significant correlation of organic matter was found with nitrogen, potassium and cation exchange capacity while significant negative correlations existed between soil pH and nitrogen, organic matter and cation exchange capacity.

Debroy *et al.* (2020) investigated on the vertical distribution of cationic micro nutrients across landscape positions on Meghalayan plateau in the North Eastern region of India. Cationic micronutrients and their fractions varied with soil depth and landscape positions in the study area. DTPAextractable Fe, Mn, Zn and Cu content was higher in surface layer as compared to the sub surface and found in higher amount in valley as compared to the other landscape positions. Zinc is the most limiting cationic micronutrient found in the study area, whereas poor availability of Mn was also observed in few sub-surface samples. Residual fraction was the largest fraction of cationic micronutrients in soil and varied from 58.4 to 71.0, 33.8 to 64.9, 66.0 to 84.1 and 30.1 to 65.6% of total Fe, Mn, Zn and Cu, respectively in the study area. Soluble and exchangeable fraction is the most labile pool of cationic micronutrients in the study area though its content was less. Organically complexed fraction contributed in large to the availability of Fe, Zn and Cu. Whereas, amorphous and crystalline Fe oxide occluded fractions of Zn and Cu and crystalline oxide occluded fractions of Mn were also found to contribute the availability of respective cationic micronutrients as an indirect source.

Saini *et al.* (2020) conducted an experiment for the evaluation of nutrient index using Mn as a measure of fertility status of soils under different cropping systems of Punjab in North-Western India. A total of 150 surface soil samples were collected from various blocks of three districts of Punjab located in the north-western region of India from major cropping systems viz., rice-wheat (Ludhiana district), maize-wheat (Ropar district) and cotton-wheat (Mansa district). These samples were analyzed for pH, electrical conductivity (EC), soil organic carbon (SOC), cation exchange capacity (CEC), sand, silt, clay, DTPA-extractable manganese (DTPA-Mn) and different Mn fractions of variable solubility. Among all the Mn fractions, the residual-Mn (RES-Mn) fraction comprised the largest (65-71%) and OM-Mn fraction comprised the lowest (0.3-0.8%) proportion of total-Mn in all DTPA-Mn categories. Based on fertility ratings, SOC concentration in soils with DTPA-Mn categories (5.0 mg kg-1 soil), respectively. The EC was low in all DTPA-Mn categories. Organic carbon status was medium in all soils with different DTPA-Mn categories.

Eze *et al.* (2021) carried out an experiment on the soil cationic relationships, structural and fertility assessment within selected active dumpsites in Nigeria. Results showed that the soils were of high potassium and calcium concentrations with the following order Ca > K > Mg > Na. The pH and SOM ranged from 7.0 ± 0.89 to 7.60 ± 0.26 and from 4.50 ± 0.26 to $12.60 \pm 0.21\%$ respectively. Correlation analysis with the cations showed the SOM had stronger positive relationship ($r > 0.5$) except for

K in comparison with pH. Ca, K and Na strongly correlated with the CEC ($r > 0.9$) while they also exhibited positive relationship between them in most dumpsites.

Ojobor *et al.* (2021) carried out an experiment for the amendment of soil fertility through regular nutrient assessment is a necessary intervention for sustainable crop production in Ovu, Nigeria. Cassava, oil palm and plantain farms were randomly selected in the six community and 118 representative soil samples were taken. Soil pH, organic carbon, total nitrogen, available phosphorus content of soil and exchangeable bases were measured. The cassava, oil palm and plantain farms were slightly acidic mean values of 6.4±0.38, 6.5±0.31 and 6.4±0.30, respectively indicating slight acidity. Organic carbon was low to high while total nitrogen was high except at Okoemaka that was moderate (0.19±0.04 %). Available phosphorus content was low to medium while exchangeable potassium and calcium were medium to high, exchangeable magnesium was low to medium. Nutrient index showed that soil pH was moderate and while total nitrogen was high.

Singh *et al.* (2021) carried out an investigation for Characterization of soils of Sagarpali and Chitbadagaon village of Ballia District (U.P.). Depth wise soil samples were collected from two selected village viz. Sagarpali and Chitbadagaon. From both Sagarpali and Chitbadagaon pedons soil sample were collected from 0 - 20, 20 - 41, 41 - 61, 61 - 81, 81 - 101, 101 - 127, 127 - 152 and 152 - 177 cm depths and in this respect a soil profile was opened in each village. Standard method was followed for analysis of physico-chemical parameter of soil. Results revealed that pH of soil found to be slightly acid to slightly alkaline where EC was in normal range. Bulk density of soil found be 1.40 - 1.54 Mg m^{-3} and water holding capacity 36.89 - 47.79%. Organic carbon content varied from 0.13 - 0.71%. The soil was slightly moderately calcareous (0.36 - 2.34 $CaCO_3$ %). Available N, P, K, and S content in soil varied from 106.62 - 304 kg ha^{-1}, 6.81 - 11.10 mg kg^{-1}, 240.8 - 403.2 kg ha^{-1} and 4.32 - 8.35 mg kg^{-1} respectively. The texture of soil was found to be clayey to clay loamy.

Chapter III

MATERIALS AND METHODS

3.1 District at a glance

Cuttack is the former capital and second largest city in the state of Odisha. The name of the city is an anglicised form of *Kataka* which literally means *The Fort,* a reference to the ancient Barabati Fort around which the city initially developed. Cuttack is known as the *Millennium City* as well as the *Silver City* due to its history of 1000 years and famous silver filigree works. It is considered as the judicial capital of Odisha as the Orissa High Court is located here. It is the commercial capital of Odisha which hosts many trading and business houses in and around the city. Cuttack is famous for its Durga puja which is one of the most important festival of Odisha. Cuttack is also the birthplace of Netaji Subhas Chandra Bose. The city is categorised as a Tier-II city as per the ranking system used by Government of India.

3.1.1 Geography

The geographical location of the district is 20.517^0 N latitude and 85.726^0 E longitude. The district covers an area of 3,932 km^2 and has average elevation of 25m. It is bordered by Angul, Dhenkanal, Nayagarh and Khurda districts to the west while its southern and eastern boundaries touch Puri, Jagatsinghpur, Kendrapada and Jajpur districts. The district is located in the coastal part of the state and its administrative headquarters are located in the city of Cuttack. Cuttack is second most populous district of Odisha after Ganjam as per 2011 Census.

3.1.2 Topography

The district has two distinct geographic regions. First, the Sadar subdivision mostly consists of the alluvial delta formed by the river Mahanadi and its distributaries. The land is mostly flat and intersected by numerous channels, active and abandoned, of the Mahanadi system. Second, the Athagad and Banki subdivisions consist of broken hill country on either side of the Mahanadi river. Most of the hills are low height and present a rounded appearance reaching a maximum of around 2500 feet along the border with Hindol. Substantial forested tracts are still to be found in the Damapada block and Narasinghpur block while Athagad, Tigiria and Badamba blocks are largely agricultural. A Thick layer of sandstone underlies these subdivisions while occasional laterite stone outcrops can be seen at many places.

3.1.3 Physiography

Physiographically the district can be divided into two distinct units viz-deltaic plain and lateritic uplands and hilly tract. The lateritic uplands and hilly tract is seen in the western part of the district. The Laterite upland bordering the hilly tract is characterized by moderately undulating topography supporting some vegetation. The hilly tract consists of a series of detached hill range s of Pre- Cambrian and upper Gondwana formation. The average altitude varies from 50 to 100 m. above msl with the maximum of 337m. above mean sea level. The deltaic plains occupy the eastern part of the district which is formed under the fluvial environment. The area is characterized by parallel to radial drainage pattern. It forms the most fertile part of the district.

3.1.4 Rainfall and Climate

The district is characterized by tropical monsoon climate having three distinct seasons in a year, viz. winter, summer and rainy seasons. Winter commences from late November and continues till end of February. Winter is followed by the summer season, which extends up to mid-June. During the period between April and May, 3 to 4 cyclonic rains generally occur in the district. The rainy season sets in the district at the advent of the southwest monsoon, generally from the middle of June and continues till end of September. Lowest and the highest temperatures recorded for the district are 7.5^0 C and 42.0^0 C respectively. The December and January are the coldest and May is the hottest month. The normal annual rainfall is 1501.3 mm (1950 – 1991) with the average of 1587.4mm. The mean annual wind velocity is 3.4 km/hr. The wind speed during cyclonic storms becomes very high and ranges from 70 to 100 km/hr or even more. Major direction of wind is from south and southwest. The relative humidity, on an average, varies from 41 to 84% during the year and during monsoon it is much more where as in winter it is less. The mean monthly potential evapo-transpiration varies from 57 mm during January to 320 mm during May.

3.1.5 Soils

As per agro climatic classification, the district falls under North Eastern Coastal plain. Three orders of soils, viz. Alfisols, Ultisols and Entisols occur in the district. Alfisols can be further sub-divided in to red loamy soils, red sandy soils, older alluvial soils and deltaic alluvial soils .The red soils are found in the hilly area in the western part of the district and older alluvial soils are found in minor pockets in northern part. The deltaic soil are found in major parts of the district. Ultisols include laterite and lateritic soils, which are found in pockets and characterized by compact to vesicular mass in subsoil horizon composed essentially of a mixture of the hydrated oxide of allumina and iron. Entisols include younger alluvial soils occurring along the course of Mahanadi river mainly in western part and central part of the district. These soils are deficient in nitrogen, phosphoric acid and humus, but not in potash and lime.

3.1.6 Rivers

Main city is located at the apex of the Mahanadi river delta. Apart from Mahanadi, four of its distributaries also run through the city. The distributaries include Mahanadi, Kathajodi, Kuakhai and Birupa where Kathajodi further has two distributaries; the right being Devi while the left is Biluakhai. Mahanadi runs through the city on the northern side separating the main city from the Jagatpur Industrial Area. The Kathajodi river forms a riverine island of Bayalis Mouza (42 Wards) after separating the main city from Gopalpur. The Kuakhai river separates the southern part of the city into two-halves, namely Pratap Nagri and the new township of Naranpur. The Kuakhai runs throughout the south of the city along Phulnakhara before entering Bhubaneswar. The Birupa river runs through the north of Jagatpur Industrial Area separating it from Choudwar. There are numerous ponds known as (*pokharis*) in the city that store rain water. The Mahanadi provides much of the drinking water to the city. Recent growth of the city has resulted in expansion across the Kathajodi River and a newer township towards the head of the delta formed between the tributary Kathajodi river and the main river.

3.2 The study area - Narasinghpur Block, Cuttack

3.2.1 General Description

There are 37 gram panchayats and 166 villages in Narasinghpur block. Narasinghpur population in 2022 was 124,959. According to 2011 census of India, total Narasinghpur population is 97,624 people are living in this block, of which 51,055 are male and 46,569 are female. 39,527 male and 29,966 female are literate people out of 69, 493 of Narasinghpur block. Total workers are 38,596 depends on multi skills out of which 29,273 are men and 9,323 are women. Total 5,760 cultivators are depended on agriculture farming out of them 5,302 men and 458 women are engaged in farming. 11,008 people works in agricultural land as a labour in Narasinghpur (9,657 are men and 1,351 are women).

Major enterprise of Narasinghpur block is agriculture. Narasinghpur block is in the agro climatic zone of Mid Central Table Land zone, its annual precipitation is 1421mm and climate is hot and moist sub humid. Most of the farmers are small and marginal and they depend on the monsoon for irrigation. The major field crops grown in this block are paddy, black gram and green gram, while major vegetable crops are brinjal, cauliflower, tomato and mango. Mainly alluvial, red, lateritic and mixed red soils are observed.

3.2.2 Location and Extent

The study area is located in Mid Central Table Land Agro climatic zone of Odisha. It is situated between 20.467^0 N latitude and 85.083^0 E longitude with average summer temperature 45^0 C and average winter temperature 10^0 C. The study area covers a total area of 471 km^2. There are about 165 villages in Narasinghpur block. Most of the lands are cultivated for paddy production.

3.2.3 Climate

The climate condition of the block is generally hot with high humidity during April and May and cold during December and January. The monsoon generally starts late in June and endures until September. The region’s average annual precipitation is 1421 mm which varies from year to year. 90% rainfall of the region is reported from June to September. August is the month with more rainy days. There are wide range of temperature during day and night. Mean maximum summer temperature of the region is 38.7^0 C whereas mean minimum winter temperature of the region is 14^0 C. The summer begins in mid-March and in May temperature is maximum which is around 45^0 C. With the onset of monsoon in 2nd week of June, temperature drops and the weather remains cool during the monsoon. Whereas December is the coolest month as 12^0 C is reported as the mean daily temperature of this month.

3.3 Methods of study

3.3.1 Methods of soil sample collection

Fifteen villages of the block were selected for the soil collection. One soil profile represents of each village. Soil samples were taken from four different depths (0-15cm, 15-30cm, 30-60cm and 60-90cm) by digging the soil profile. The samples were collected with the help of Khurpi. The information like name of the farmer, type of land, name of the present crop and previous crop grown, longitude and latitude of the village were collected (Table 3.3.1). These samples were taken and transported to Institute of Agricultural Sciences, BHU for further study. Then the samples were processed at soil processing lab of the Department of Soil Science and Agricultural Chemistry.

Table 3.3.1: General information about the soil profile of Narasinghpur block

Sl. No	Village Name	Longitude	Latitude	Farmer Name	Type of land	Cropping Pattern
1	Adheigundi	85^0 08’ 109” E	20^0 46’ 75” N	Ajaya Kumar Sahoo	Cultivated	Paddy- Blackgram
2	Balijhari	85^0 08’ 112” E	20^0 46’ 84” N	Bhim Nayak	Cultivated	Paddy- Groundnut
3	Champeswar	85^0 08’ 110” E	20^0 46’ 78” N	Dillip Sethy	Cultivated	Paddy- Fallow
4	Ekadal	85^0 08’ 107” E	20^0 46’ 77” N	Chaitanya Gochi	Cultivated	Paddy- Groundnut
5	Fulapada	85^0 08’ 123” E	20^0 46’ 81” N	Pratap Behera	Cultivated	Paddy- Blackgram
6	Jaymangala	85^0 08’ 117” E	20^0 46’ 80” N	Dibakar Mallik	Cultivated	Paddy- Greengram
7	Kakudia	85^0 08’ 113” E	20^0 46’ 81” N	Basudeb Behera	Cultivated	Paddy- Redgram
8	Kamaladiha	85^0 08’ 131” E	20^0 46’ 86” N	Lokanath Sahoo	Cultivated	Paddy- Blackgram
9	Kanpur	85^0 08’ 111” E	20^0 46’ 76” N	Pitabas Sahoo	Cultivated	Paddy- Groundnut
10	Kokalaba	85^0 08’ 128” E	20^0 46’ 85” N	Matia Nayak	Cultivated	Paddy- Groundnut
11	Nuapatna	85^0 08’ 114” E	20^0 46’ 83” N	Jatindra Panda	Cultivated	Paddy- Blackgram
12	Padamala	85^0 08’ 107” E	20^0 46’ 77” N	Gayadhar Nayak	Cultivated	Paddy- Brinjal
13	Paikabarabati	85^0 08’ 109” E	20^0 46’ 75” N	Pankaj Biswal	Cultivated	Paddy- Blackgram
14	Paikapadapatana	85^0 08’ 103” E	20^0 46’ 73” N	Sudam Panda	Cultivated	Paddy- Groundnut

15	Sagar	85^0 08’ 116” E	20^0 46’ 79” N	Umakanta Sahoo	Cultivated	Paddy- Greengram

3.3.2 Processing of soil samples

The collected soil samples were air dried in the soil processing lab, samples were grinded with a wooden roller and passed through a 2mm sieve. Then the samples were stored in polythene bags, labelled and kept for further analysis.

3.4 Methods of soil analysis

3.4.1 Physical analysis

a) Mechanical analysis: The particle size analysis was carried out by Bouyoucos Hydrometer method **(Piper, 1950)**. Using USDA Textural Triangular diagram Textural classes were determined. For this 50gm soil was taken into a beaker and 50 ml of 6% H_2O_2 was added. The beaker was covered with a watch glass and placed on a water bath until the organic matter gets oxidized; the beaker was removed and allowed to cool. Then the soil suspension was transferred to a 1L measuring cylinder. Then 400ml of distilled water and 10 ml of sodium hexametaphosphate was added to it and the volume made up to 1L. The suspension was stirred for 20-25 times with a plunger. The hydrometer was inserted into the suspension and the reading was taken at 4 minutes. The temperature of the suspension was also recorded. The suspension was allowed undisturbed and a second hydrometer reading was recorded after 2 hours.

$$\% \text{ (Silt + Clay)} = \frac{(S-B)+CF}{wt\ of\ sample\ (gm)} \times 100$$

$$\% \text{ Clay} = \frac{(s-b)+CF}{wt\ of\ sample\ (gm)} \times 100$$

$$\% \text{ Sand} = 100 - (\% \text{ Silt + Clay})$$

b) Bulk density: Bulk densities of collected samples were analysed by Pycnometer method. First pycnometers were filled with soils and weighed and their weights were noted down. Then soils are removed and pycnometers are filled with water to measure the volume and volume of pycnometers was noted down. B.D of soils was calculated by the following formula.

$$\text{BulK density } \left(\frac{\text{Mg}}{\text{m3}}\right) = \text{Weight of Soil/Volume of pycnometer}$$

c) Particle density: Particle densities of the soils were determined by specific gravity bottle or pycnometer bottle **(Chopra and Kanwar, 1986).** In the process we had used water as the displacing liquid since the soils were a salt free and non-swelling type. Care was taken to remove all entrapped air by gentle tapping and allowing the displacing liquid to stand for some time. Particle density was calculated from the ratio of the oven dry weight of the soil to the volume of soil solid particles.

$$\text{Particle Density}\left(\frac{\text{Mg}}{\text{m3}}\right) = \frac{\text{Weight of soil solids}}{\text{Volume of soil solids}}$$

d) Porosity: The total pore space was estimated from the measurements of bulk density and particle densities.

$$\text{Porosity (\%)} = \left(1 - \frac{B.D}{P.D}\right) \times 100$$

3.4.2 Methods of chemical analysis

a) Soil pH: The pH of soil samples were determined in 1:2.5 soil: water suspension using a glass electrode digital pH meter **(Jackson, 1967)**.

b) Electrical conductivity (EC): The soil water suspension prepared for the determination of pH was used to estimate the electrical conductivity of the soil. The soil suspension was allowed to settle till supernatant become clear. Electrical conductivity was measured with the help of an EC meter and expressed as dSm^{-1} **(Jackson, 1967).**

c) Organic carbon: The organic carbon content of soil samples was determined by **Walkley and Black's** rapid titration method **(1934)**. 1 g of 2 mm ground soil sample was taken in 500 ml of the dry conical flask. After that 10 ml of 1N $K_2Cr_2O_7$ solution was added in the conical flask and then mixed it. Afterwards, 20 ml of concentrated H_2SO_4 was added in the flask. Then the flask was swirled 2-3 times and then stands for 30 minutes to on an asbestos sheet for the reaction in a dark place. The suspension was diluted with 200 ml of distilled water. Afterwards, a pinch of sodium fluoride and 1 ml of DPA indicator were added and titrated against the solution of 0.5N Ferrous Ammonium Sulphate (FAS) till the colour changed from violet to bright green end point. A blank titration was also carried out without taking a soil sample.

$$\text{Organic Carbon (\%)} = \frac{10(B-S)}{B} \times 0.003 \times \frac{100}{\text{wt.of sample(gm)}}$$

3.4.3 Available macronutrients

a) Available nitrogen: Available nitrogen of the profile samples were determined by alkaline permanganate method as outlined by **Subbiah and Asija (1956)** by nitrogen semi auto analyser. For this, 5gm soil was transferred to a distillation flask, a few glass beads were added to prevent bumping and then 25 ml of 0.32% potassium permanganate solution was added along with 25 ml of 2.5% NaOH solution. The distillate was collected in a 250 ml conical flask containing 20 ml of 2% boric acid with a mixed indicator. The collected ammonia was titrated against N/50 sulphuric acid and from titrated value, the available nitrogen content in the soil was calculated.

$$\text{Available N in soil (kg/ha)} = (S\text{-}B) \times 31.36$$

b) Available phosphorus: As the soil reactions were neutral to alkaline, available phosphorus in soil was determined by Olsen's method and estimated with spectrophotometer with a wavelength of 660 nm **(Olsen *et al*., 1954)**. For this 2.5gm of soil was taken in 100 ml conical flask, a pinch of Darco G-60 and 50 ml of Olsen's reagent was added. Then solution was shaken for 30 minutes on a mechanical shaker and filter through Whatman No.1 filter paper. 5 ml of filtrate was transferred into a 25 ml volumetric flask. 5 ml of ammonium molybdate solution containing 400 ml of 10N HCl was added drop by drop. After that the solution was shaken to drive out the CO_2 evolved. 1 ml of freshly diluted $SnCl_2$ was added and the intensity was measured at 660nm wavelength.

A standard curve was prepared by using standard working solution. 0, 0.5, 1.0, 1.5, 2.0, and 2.5 ml of standard work solution was taken and 5 ml of Olsen's extractant was added. $SnCl_2$ was added to develop blue colour and blue colour intensity was measured to draw a standard curve.

$$\text{Available P (kg/ha)} = \frac{Q \times V \times 2.24}{A \times S}$$

c) Available potassium: It was determined by extracting the soil with Ammonium acetate solution and was estimated by flame photometer **(Hanway and Heidel, 1952)**. For this, 5g soil was transferred to a 100 ml conical flask. Then 25 ml of 1N ammonium acetate solution was added to it, after that it was shaken for 5 minutes. The suspension was filtered through Whatman No. 1 filter paper and potassium concentration in the filtrate was measured using a flame photometer. A standard curve was drawn by recording the flame photometer readings for each of the working standards of K after adjusting blank to zero and plotting the readings against K concentrations.

$$\text{Available K (kg/ha)} = C \times 11.2$$

d) Available sulphur: Sulphur was determined by extracting the soil with 0.15% Calcium chloride solution followed by adding barium chloride to develop turbidity and was estimated by spectrophotometer with a wavelength of 420nm **(Chesnin and Yien, 1950).**

Standard curve was prepared by using standard S solution (0.5434g K_2SO_4 was dissolved in distilled water and diluted to 1L). 0.25, 0.50, 1.0, 2.5 and 5.0 ml of standard S solution was taken in 25 ml of volumetric flask and 10ml of extracting solution was added to each flask. For blank 10 ml of extracting solution was taken in a 25ml of volumetric flask. 1g of $BaCl_2$ crystals was added to each flask and swirled to dissolve the crystals. 1ml of gum acacia was added and volume was made up to 25ml by adding distilled water. Turbidity was measured at 340nm wavelength in a Spectrophotometer to draw the curve.

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

3.4.4 Available micronutrients

Available iron, manganese, copper, zinc: The available micronutrients (Fe, Mn, Cu and Zn) in the soil samples were determined by extracting the soil with DTPA **(Lindsay and Norvell, 1978)** and measured by Atomic Absorption Spectrophotometer. For this 10 g soil was taken in 100 ml conical flask, then 20 ml of DTPA extractant was added and shaking was done for 2 hours on a mechanical shaker. Filtrate was collected through Whatman No. 42 filter paper and was estimated by AAS by feeding the standard working solutions according to the micronutrient extracted. Standard curves were prepared for each micronutrient i.e Fe, Zn, Cu and Mn by feeding the standard working solution of each nutrient.

$$\text{Available Micronutrient in soil (mg/kg)} = A \times 2$$

3.4 Statistical Analysis

A statistical analysis was carried out to determine the maximum, minimum, average and standard deviation of the physico- chemical properties of soil. Correlation between physico-chemical properties of soils of Narasinghpur block was carried out also.

Plate 3.1: Soil profile of the studied area

Plate 3.2: Collection of soil samples from the soil profile

Plate 3.3: Particle density analysis by pycnometer bottle method

Plate 3.4: Soil texture analysis of the studied area by Bouyoucous hydrometer method

Plate 3.5: Collection of information from farmers in the studied area

Chapter IV

RESULTS AND DISCUSSION

The present experiment **"Characterization of soils through soil profile study of Narasinghpur Block in Cuttack District of Odisha, India"** was carried out at Narasinghpur Block, Cuttack, Odisha by digging up soil profile and analyse the sample at the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, to establish an understanding about the physico - chemical properties of soils through the soil profile study. It is very important to study the soil properties of a soil profile. Different soil properties were determined and statistical analysis was carried out to establish a relation between the physico – chemical properties of soils of the profile with the nutrient status of soil. The results of the experiment are presented below

1. Vertical distribution of soil physical properties such as particle size, bulk density, particle density and total porosity.
2. Depth wise vertical distribution of chemical properties like pH, Electrical Conductivity (EC) and organic carbon.
3. Distribution of macro nutrients and micro nutrients according to depth of the profile.

4.1 Vertical distribution of the soil physical properties

4.1.1 Particle size distribution and textural class

The particle size distribution means relative proportion of sand, silt and clay content present in the soil and that determines the texture of soils. Sand content of the studied area ranged between 64.3 and 68.1% with average 66.68% and S.D 1.03. Silt content of studied area ranged between 10.5 and 15.3% with average 13.5% and S.D 1.42. Clay content of studied area ranged between 17.8 and 23.3% with average 19.9% and S.D 1.72. Soil samples of studied area were found to be sandy loam and sandy clay loam **(Table 4.1.1)**.

Clay content of the soils can be increased with increase in organic manure application and reducing excessive tillage. Similarly decrease in sand content can be observed as we move down the soil profile. **Dash (2018)** and **Mishra (1981)** obtained similar types of findings during their experiments on the soil of KVK, Dhenkanal and Hirakud command area in Odisha.

Table 4.1.1: Particle size distribution and textural class of soils of Narasinghpur block

Village	Sand (%)	Silt (%)	Clay (%)	Textural Class
1	67.4	14	18.6	sandy loam
2	66.6	13.4	20	sandy clay loam
3	64.3	12.7	23	sandy clay loam
4	65.8	15.3	18.9	sandy loam
5	66.2	10.5	23.3	sandy clay loam
6	65	14.8	20.2	sandy clay loam
7	67.2	15	17.8	sandy loam
8	68.1	12.3	19.6	sandy loam
9	66.8	13.2	20	sandy clay loam
10	67.5	14	18.5	sandy loam
11	67.3	13.9	18.8	sandy loam
12	66.4	12.4	21.2	sandy clay loam
13	67.7	14.4	17.9	sandy loam
14	67.4	11.2	21.4	sandy clay loam
15	66.5	15	18.5	sandy loam
Maximum	68.1	15.3	23.3	
Minimum	64.3	10.5	17.8	
Average	66.68	13.50	19.90	

S.D	1.03	1.42	1.72	

4.1.2 Bulk Density

Bulk density is the indicator of soil compaction and soil health. It is the ratio of dry weight soil and volume of soil. Bulk density of 0-15cm depth soils ranged between 1.12 and 1.23 Mg/m^3 with average 1.17 Mg/m^3 and S.D 0.037. Bulk density of 15-30cm depth soils ranged between 1.18 and 1.29 Mg/m^3 with average 1.24 Mg/m^3 and S.D 0.033. Bulk density of 30-60cm depth soils ranged between 1.23 and 1.37 Mg/m^3 with average 1.31 Mg/m^3 and S.D 0.041. Bulk density of 60-90cm depth soils ranged between 1.31 and 1.45 Mg/m^3 with average 1.38 Mg/m^3 and S.D 0.049 **(Table 4.1.2).**

Bulk density increased with profile depth due to changes in organic matter content, porosity and compaction. **Chaudhuri *et al.* (2013)** conducted similar study on on soils of Coimbatore and found the increase in B.D with increase the depth of soil profile.

Table 4.1.2: Depth wise variation in the bulk density of the studied area

Village	Bulk density (Mg/m^3)			
	0-15 cm	**15-30 cm**	**30-60 cm**	**60-90 cm**
1	1.21	1.27	1.34	1.42
2	1.22	1.29	1.37	1.44
3	1.17	1.22	1.29	1.33
4	1.19	1.25	1.31	1.35
5	1.18	1.25	1.32	1.37
6	1.2	1.27	1.36	1.45
7	1.22	1.26	1.31	1.39
8	1.16	1.22	1.28	1.34
9	1.23	1.29	1.36	1.43
10	1.16	1.21	1.27	1.33
11	1.12	1.18	1.23	1.32
12	1.14	1.19	1.24	1.31
13	1.17	1.26	1.33	1.41
14	1.12	1.26	1.32	1.44
15	1.12	1.24	1.32	1.41
Maximum	1.23	1.29	1.37	1.45
Minimum	1.12	1.18	1.23	1.31
Average	1.17	1.24	1.31	1.38
S.D	0.037	0.033	0.041	0.049

4.1.3 Particle Density

Particle density is the mass of a unit volume of sediment solids. It is expressed in the ratio of the total mass of the solid particles to their total volume, excluding pore spaces between particles. Particle density of 0-15 cm depth soils ranged between 2.3 and 2.45 Mg/m^3 with average 2.38 Mg/m^3 and S.D 0.047. Particle density of 15-30 cm soils ranged between 2.38 and 2.58 Mg/m^3 with average 2.48 Mg/m^3 and S.D 0.065. Particle density of 30-60 cm soils ranged between 2.44 and 2.68 Mg/m^3 with average 2.56 Mg/m^3 and S.D 0.071. Particle density of 60-90 cm soils ranged between 2.53 to 2.74 Mg/m^3 with average 2.64 Mg/m^3 and S.D 0.07 **(Table 4.1.3).**

Particle densities of studied area increased with increase in depth of soil profile due to decrease in organic matter content and porosity down the profile.

Table 4.1.3: Depth wise variation in particle density of the studied soil profile

Village	**Particle density (Mg/m^3)**			
	0-15 cm	**15-30 cm**	**30-60 cm**	**60-90 cm**
1	2.4	2.58	2.62	2.69
2	2.33	2.38	2.44	2.53
3	2.38	2.43	2.47	2.55
4	2.3	2.4	2.46	2.53
5	2.4	2.46	2.53	2.61
6	2.45	2.49	2.57	2.64
7	2.38	2.42	2.51	2.59
8	2.44	2.57	2.63	2.71
9	2.36	2.48	2.57	2.65
10	2.42	2.55	2.63	2.72
11	2.32	2.45	2.56	2.67
12	2.41	2.54	2.65	2.73
13	2.33	2.41	2.54	2.63
14	2.40	2.46	2.57	2.66
15	2.45	2.55	2.68	2.74
Maximum	2.45	2.58	2.68	2.74
Minimum	2.30	2.38	2.44	2.53
Average	2.38	2.48	2.56	2.64
S.D	0.047	0.065	0.071	0.070

4.1.4 Total Porosity

Soil porosity is the fraction of the total soil volume that is taken up by the pore space **(Nimmo, 2004)**. Porosity of soils from 0-15 cm depth ranged between 47.6 and 54.2% with average 50.7% and S.D 2.08. Porosity of 15-30 cm depth soils ranged between 45.8 and 52.7% with average 49.4% and S.D 1.93. Porosity of 30-60 cm depth soils ranged between 43.8 to 52.1% with average 48.61% and S.D 2.23. Porosity of soils from 60-90 cm depth soils ranged between 43.1 and 51.4% with average 47.56% and S.D 2.37 **(Table 4.1.4).**

Total porosity through the depth of soil profile up to 90 cm decreased due to reduction of soil organic matter. Significant relationship obtained by **Dash (2018)** and **Pattanaik (2019)** during their experiments.

Table 4.1.4: Total porosity of depth wise soil samples of Narasinghpur block

Village	**Porosity (%)**			
	0-15 cm	**15-30 cm**	**30-60 cm**	**60-90 cm**
1	49.5	49.1	48.8	47.2
2	47.6	45.8	43.8	43.1
3	50.8	49.8	47.8	47.7
4	48.2	47.9	46.8	46.6
5	50.8	49.2	47.8	47.5
6	51.02	49.0	47.1	45.05
7	48.7	47.9	47.8	46.3
8	52.4	51.6	51.3	50.5
9	47.9	47.5	47.1	46.03
10	52.1	51.7	51.2	50.8
11	51.7	51.2	50.8	50.5
12	53.1	52.7	52.1	51.4
13	49.8	47.8	47.6	46.4
14	53.3	48.8	48.4	45.9
15	54.2	51.3	50.8	48.5
Maximum	54.2	52.7	52.1	51.4
Minimum	47.6	45.8	43.8	43.1
Average	50.70	49.40	48.61	47.56
S.D	2.08	1.93	2.23	2.37

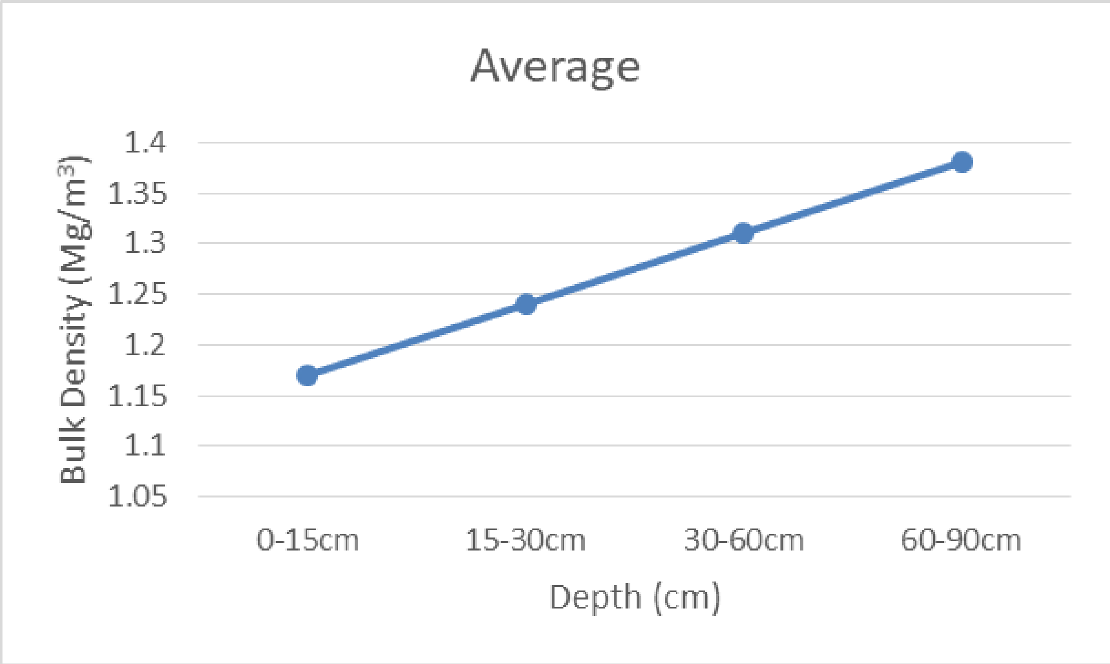

Fig. 4.1: Status of bulk density in soils of Narasinghpur block in Cuttack district

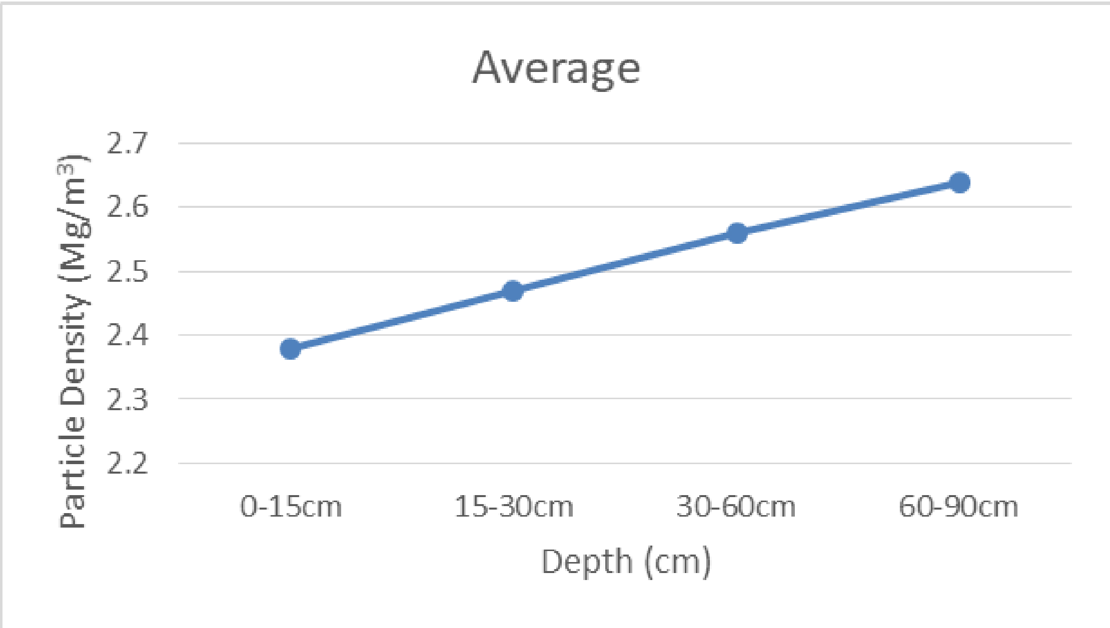

Fig. 4.2: Status of particle density in the soils of Narasinghpur block in Cuttack district

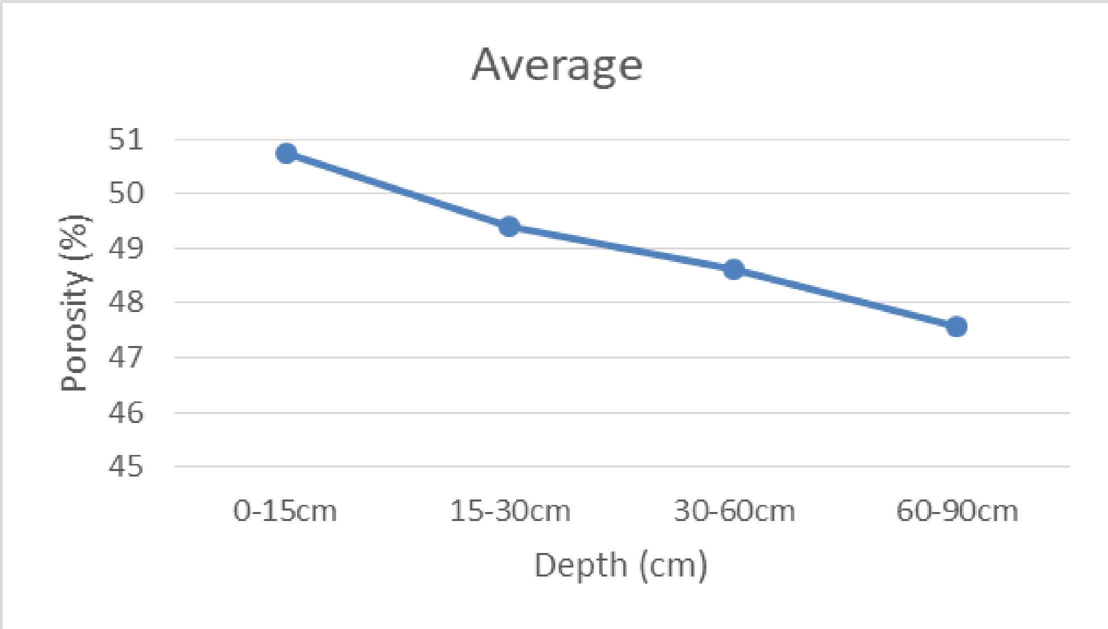

Fig. 4.3: Status of porosity in the soils of Narasinghpur block in Cuttack district

4.2 Vertical Distribution of Chemical Properties

4.2.1 Soil pH

The pH of the soils from 0-15 cm depth ranged between 6.29 and 7.49 with average 6.86 and S.D 0.44. The pH of 15-30 cm depth soils varied from 6.55 to 7.77 with average 7.16 and S.D 0.39. The pH of 30-60 cm depth soils ranged between 6.94 and 8.2 with average 7.46 and S.D 0.40. While the pH of 60-90 cm depth soils ranged between 7.15 and 8.25 with average 7.67 and standard deviation 0.37 **(Table 4.2.1).**

pH of the soils of studied area increased with increasing depth of profile because during rainfall the basic cations are leached down to the profile from upper horizons which favours more acidification in upper surface of the layer. This type of result has also been observed by **Sethy (2018)** and **Pattanaik (2019).**

Table 4.2.1: pH of the different depth of profile soil samples of Narasinghpur block

Village	pH			
	0-15 cm	**15-30 cm**	**30-60 cm**	**60-90 cm**
1	6.29	6.55	6.94	7.15
2	6.35	6.63	7.06	7.23
3	7.1	7.39	7.49	7.66
4	6.44	7.09	7.32	7.51
5	6.29	6.73	7.19	7.43
6	6.51	6.89	7.24	7.73
7	7.13	7.26	7.47	7.64
8	7.19	7.48	7.73	7.96
9	6.70	7.18	7.21	7.29
10	6.59	6.74	7.11	7.37
11	6.8	7.04	7.16	7.38
12	7.49	7.53	8.2	8.25
13	7.16	7.59	7.92	8.07
14	7.45	7.77	8.05	8.22
15	7.46	7.67	7.91	8.18
Maximum	7.49	7.77	8.2	8.25
Minimum	6.29	6.55	6.94	7.15
Average	6.86	7.16	7.46	7.67
S.D	0.44	0.39	0.40	0.37

4.2.2 Electrical Conductivity

Electrical conductivity measures the total soluble salts concentration in the soils. Electrical conductivity of soils of the studied area from the depth of 0-15 cm ranged between 0.025 and 0.066 dS/m with average 0.042 dS/m and S.D 0.013. Electrical conductivity of the soils from 15-30 cm depth ranged between 0.031 and 0.072 dS/m with average 0.052 dS/m and S.D 0.012. Electrical conductivity of 30-60 cm soils of the studied area ranged between 0.041 and 0.08 dS/m with average 0.061 dS/m and S.D 0.012. Electrical conductivity of 60-90cm depth soils ranged between 0.046 and 0.086 with average 0.070 and S.D 0.011 **(Table 4.2.2).**

Electrical Conductivity was found to be <1 dS/m which is beneficial for crops. EC of studied area increased with depth of profile due to leaching of soluble salts during intensive rainfall period. This type of observation also obtained by **Mishra (2005)** during his experiment.

Table 4.2.2: Electrical Conductivity of soil profile of the studied area

Village	**Electrical conductivity (dS/m)**			
	0-15 cm	**15-30 cm**	**30-60 cm**	**60-90 cm**
1	0.036	0.062	0.074	0.079
2	0.025	0.031	0.06	0.070
3	0.029	0.036	0.043	0.068
4	0.026	0.042	0.061	0.068
5	0.025	0.036	0.041	0.046
6	0.035	0.039	0.043	0.047
7	0.048	0.057	0.059	0.064
8	0.066	0.072	0.080	0.086
9	0.051	0.062	0.070	0.073
10	0.045	0.054	0.06	0.064
11	0.052	0.058	0.065	0.072
12	0.066	0.068	0.079	0.086
13	0.036	0.047	0.059	0.068
14	0.046	0.058	0.064	0.074
15	0.045	0.059	0.069	0.074
Maximum	0.066	0.072	0.08	0.086
Minimum	0.025	0.031	0.041	0.046
Average	0.042	0.052	0.061	0.070
S.D	0.013	0.012	0.012	0.011

4.2.3 Organic Carbon

Organic carbon is the indicator of organic fractions in soils which is formed due to decomposition of residues by microorganisms. Organic carbon of the studied area from depth 0-15 cm ranged between 0.41% and 0.66% with average 0.51% with S.D 0.070. Organic carbon of soils from the depth 15-30 cm ranged between 0.35% and 0.55% with average 0.41% and S.D 0.062. From 30-60 cm depth the organic carbon of soils ranged between 0.26% to 0.45% with average 0.33% and S.D 0.051. While organic carbon of 60-90 cm depth soils ranged between 0.16% and 0.38% with average 0.26% and S.D 0.063 **(Table 4.2.3).**

Maximum organic carbon was found on the surface horizon because of accumulation of crop residues and formation of humus on the surface horizon forever. Organic carbon content decreased from upper to the lower horizon of the profile of the studied area. My result was found similar to the findings of **Kumar *et al.* (2012)** and **Khanday *et al.* (2018)**.

Table 4.2.3: Depth wise variation in soil organic carbon of the studied area

Village	Organic Carbon (%)			
	0-15 cm	**15-30 cm**	**30-60 cm**	**60-90 cm**
1	0.59	0.35	0.29	0.20
2	0.41	0.37	0.33	0.26
3	0.56	0.41	0.34	0.27
4	0.45	0.37	0.31	0.23
5	0.58	0.44	0.32	0.23
6	0.47	0.35	0.29	0.21
7	0.49	0.39	0.32	0.21
8	0.52	0.46	0.37	0.31
9	0.54	0.45	0.34	0.29
10	0.66	0.51	0.45	0.38
11	0.48	0.39	0.26	0.21
12	0.44	0.37	0.31	0.28
13	0.43	0.35	0.28	0.25
14	0.47	0.35	0.27	0.16
15	0.57	0.55	0.41	0.38
Maximum	0.66	0.55	0.45	0.38
Minimum	0.41	0.35	0.26	0.16
Average	0.51	0.41	0.33	0.26
S.D	0.070	0.062	0.051	0.063

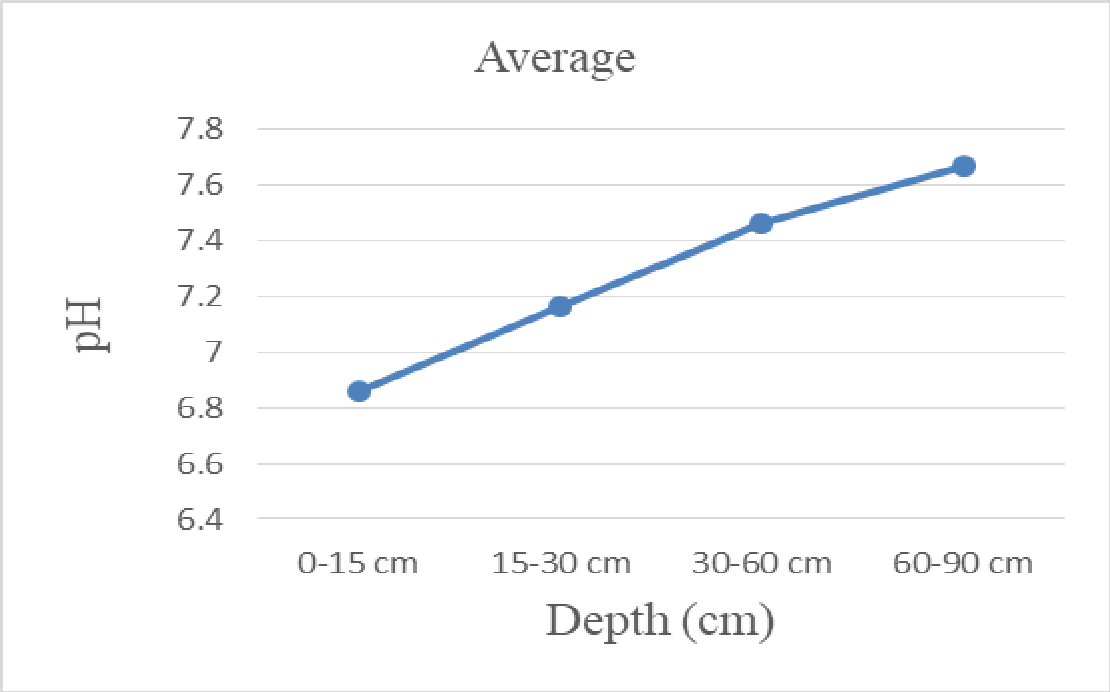

Fig. 4.4: pH status in the soils of Narasinghpur block in Cuttack district

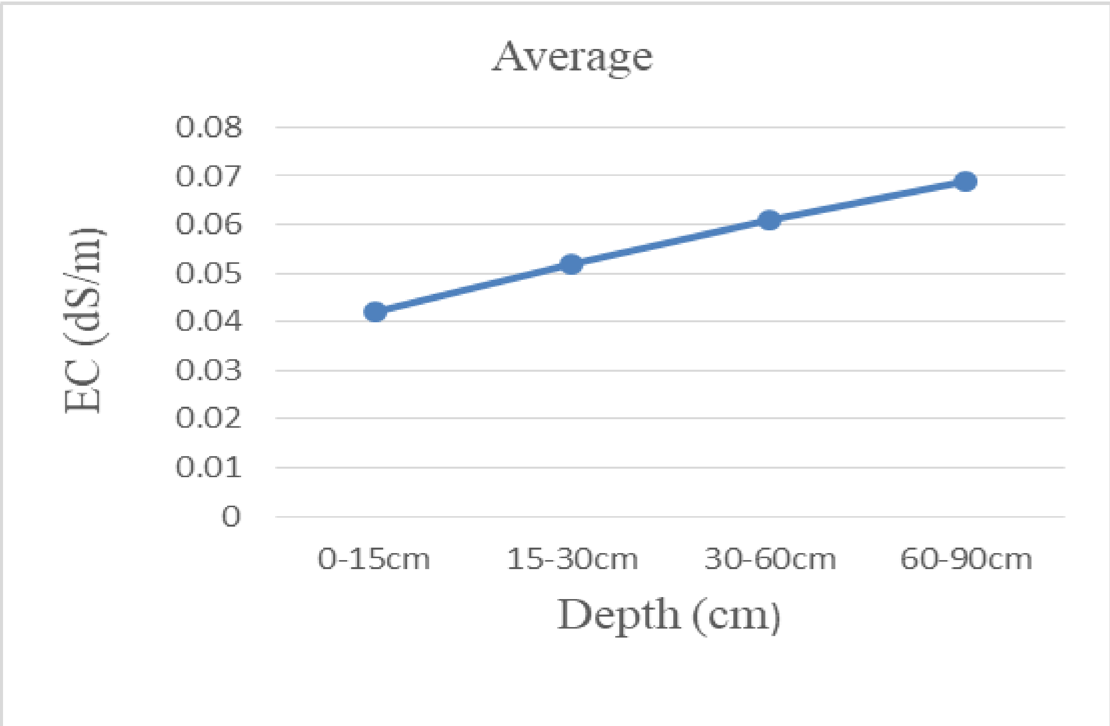

Fig. 4.5: Status of electric conductivity in the soils of Narasinghpur block in Cuttack district

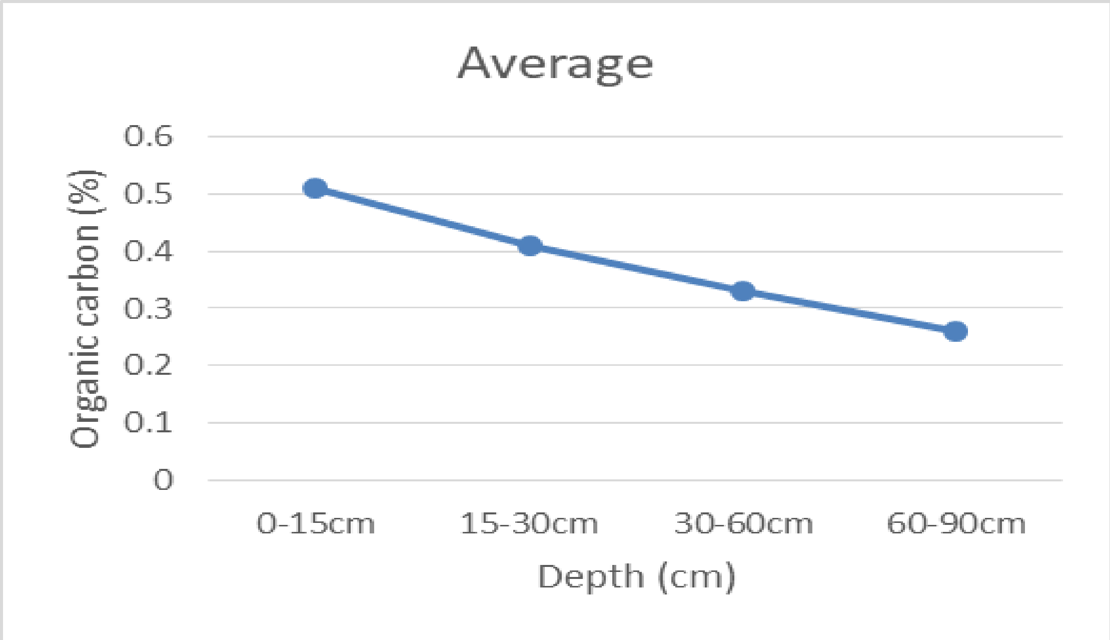

Fig. 4.6: Organic carbon status in the soils of Narasinghpur block in Cuttack district

4.3 Distribution of macro nutrients and micro nutrients depth wise in soil profile of Narasinghpur block

4.3.1 Available Nitrogen

The available nitrogen content was estimated by alkaline permanganate method. The available nitrogen content in 0-15 cm depth soils ranged between 271.20 kg/ha and 363.70 kg/ha with average 313.38 kg/ha and S.D 26.62. Soils from depth 15-30 cm was available nitrogen content ranged between 243.4 kg/ha and 313.6 kg/ha with average 277.9 kg/ha and S.D 18.92. The available nitrogen content of soils from depth 30-60 cm ranged between 213.4 kg/ha and 263.43 kg/ha with average 239.04 kg/ha and S.D 15.53. Available nitrogen content of the soils from 60-90 cm ranged between 163.07 kg/ha and 213.4 kg/ha with average 190.53 kg/ha and S.D 15.85 **(Table 4.3.1).**

Maximum N content was found on the top soils because of higher availability of organic matter on the surface soils. Nitrogen content decreased with increasing depth along with reduction of organic matter. Similar type of findings was obtained by **Mishra (2005).**

Table 4.3.1: Available nitrogen content in the depth wise soils of Narasinghpur block

Village	**Nitrogen (Kg/ha)**			
	0-15 cm	**15-30 cm**	**30-60 cm**	**60-90 cm**
1	351.2	288.5	263.4	213.2
2	284.3	253.9	215.9	188.2
3	301.4	276.15	250.88	212.52
4	363.7	313.6	225.7	163.07
5	271.2	243.4	225.7	175.6
6	319.04	281.2	245.9	188.2
7	291.6	263.7	238.7	213.4
8	294.1	268.8	253.4	200.7
9	328.8	271.2	231.05	185.7
10	289.2	266.4	228.7	193.9
11	299.2	267.9	213.4	176.8
12	326.4	306.9	263.43	169.4
13	307.4	283.6	239.5	195.8
14	334.12	295.4	246.7	201.05
15	339.04	288.14	243.24	180.5
Maximum	363.7	313.6	263.43	213.4
Minimum	271.2	243.4	213.4	163.07
Average	313.38	277.9	239.04	190.53
S.D	26.62	18.92	15.53	15.85

4.3.2 Available Phosphorous

The available phosphorous content was measured by Olsen's reagent because soils of studied area were neutral to alkaline in nature. The range of available phosphorous content in the soils from 0-15 cm depth was found in between 17.6 kg/ha and 25.3 kg/ha with average 21.43 kg/ha and S.D 2.38. The available phosphorous content of soils from 15-30 cm depth was found to be in the range between 13.2 kg/ha and 20.35 kg/ha with average 17.36 kg/ha and S.D 1.95. The available phosphorous content of the soils from 30-60 cm depth ranged between 9.35 kg/ha and 17.6 kg/ha with average 13.46 kg/ha and S.D 2.26. The available phosphorous content of soils from 60-90 cm depth ranged between 6.6 kg/ha and 12.65 kg/ha with average 9.92 kg/ha and S.D 1.91 **(Table 4.3.2).**

Available phosphorous content decreased with increasing depth due to decrease in organic matter content and increase in pH as phosphorous is more available at neutral pH. Such type of results have also been observed by **Pattanayak (2016)**.

Table 4.3.2: Depth wise available phosphorous content in the soils of Narasinghpur block

Village	Phosphorous (Kg/ha)			
	0-15 cm	**15-30 cm**	**30-60 cm**	**60-90 cm**
1	23.59	17.60	11.55	9.35
2	18.70	15.95	12.10	9.90
3	21.45	18.15	13.75	10.45
4	22.55	19.80	13.75	8.80
5	20.90	16.50	13.20	11.0
6	21.45	17.60	14.30	9.90
7	23.81	20.07	15.07	11.71
8	23.29	17.70	15.78	12.26
9	24.75	20.35	17.6	12.65
10	18.70	13.20	10.45	7.70
11	20.35	17.05	14.30	8.25
12	17.60	14.85	11.55	6.60
13	19.80	15.95	9.35	7.15
14	25.30	18.70	16.50	12.10
15	19.25	17.05	12.65	11.0
Maximum	25.30	20.35	17.60	12.65
Minimum	17.60	13.20	9.35	6.60
Average	21.43	17.36	13.46	9.92
S.D	2.38	1.95	2.26	1.91

4.3.3 Available Potassium

Available potassium of soil profiles in studied area was measured by neutral normal ammonium acetate. The available potassium content of soils in the depth of 0-15 cm was found to be in the range between 204.8 kg/ha and 286 kg/ha with average 246.82 kg/ha and S.D 22.96. The available potassium content of soils from 15-30 cm depth ranged between 184 kg/ha and 262 kg/ha with average 222.12 kg/ha and S.D 20.90. The available potassium content of the soils from 30-60 cm depth ranged between 157.2 kg/ha and 252 kg/ha with average 23.53 kg/ha and S.D 23.53. While available potassium content of soils from 60-90 cm depth ranged between 143.2 kg/ha and 238.8 kg/ha with average 174.36 kg/ha and S.D 23.02 **(Table 4.3.3).**

Available Potassium content was decreased with increase in depth of profile of studied area. Similar results obtained by **Sethy (2018)** during his experiment.

Table 4.3.3: Available potassium content in soil profile of the studied area

Village	**Potassium (Kg/ha)**			
	0-15 cm	**15-30 cm**	**30-60 cm**	**60-90 cm**
1	286	262	252	238.8
2	263.2	228.4	198	168.8
3	258.4	236	214.4	178.6
4	236	218.4	180.8	169
5	272.1	247.2	216.8	177.6
6	259.2	222.8	174	156
7	263	239.6	218.4	193.4
8	216.8	184	157.2	146
9	261.6	232	204.8	172
10	228.8	194.8	180	163
11	204.8	192.4	171.2	143.2
12	232.8	218.4	196.4	171
13	261.6	221.8	192	178
14	226.4	210	185.6	164.4
15	231.6	224	203	195.6
Maximum	286	262	252	238.8
Minimum	204.8	184	157.2	143.2
Average	246.82	222.12	196.30	174.36
S.D	22.96	20.90	23.53	23.02

4.3.4 Available Sulphur

Available sulphur content of studied area was measured by 0.15% $CaCl_2$. The available sulphur content of the soils from 0-15 cm depth ranged between 10.96 ppm and 15.30 ppm with average 13.12 ppm and S.D 1.30. Available sulphur content was found from 15-30 cm depth ranged between 8.41 ppm and 13.52 ppm with average 10.83 ppm and S.D 1.36. Available sulphur content of 30-60 cm depth soil from 6.63 ppm to 10.45 ppm with average 8.52 ppm and S.D 0.98. Available sulphur content of 60-90 cm depth soils found between 4.6 ppm and 8.16 ppm with average 6.49 ppm and S.D 1.14 **(Table 4.3.4).**

Maximum available sulphur was found on the surface layer due to the maximum availability of organic carbon on the surface horizon. Available sulphur has a positive relationship with organic carbon content. Similar results have been obtained by **Giri *et al.* (2017).**

Table 4.3.4: Depth wise available sulphur content in the soils of Narasinghpur block

Village	**Sulphur (ppm)**			
	0-15 cm	**15-30 cm**	**30-60 cm**	**60-90 cm**
1	10.96	9.44	7.39	5.35
2	11.98	10.45	8.92	7.39
3	14.79	11.73	8.41	7.65
4	13.01	11.22	8.16	7.14
5	14.28	12.5	9.18	6.88
6	14.03	10.96	8.67	6.12
7	13.26	10.45	8.41	7.39
8	12.5	10.71	8.16	5.61
9	15.30	13.52	10.45	8.16
10	14.28	11.22	8.92	5.61
11	11.98	9.69	7.90	5.86
12	13.52	10.96	9.69	6.88
13	11.47	8.41	6.63	4.84
14	13.77	12.24	9.43	7.90
15	11.73	8.92	7.39	4.59
Maximum	15.30	13.52	10.45	8.16
Minimum	10.96	8.41	6.63	4.59
Average	13.12	10.83	8.52	6.49
S.D	1.30	1.36	0.98	1.14

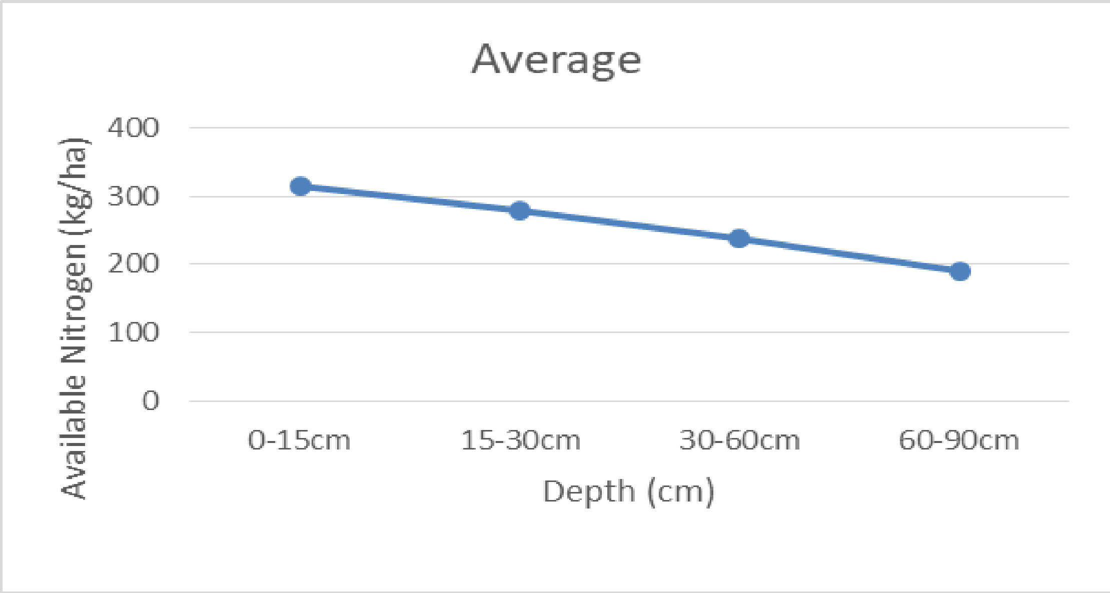

Fig. 4.7: Status of available nitrogen in the soils of Narasinghpur block in Cuttack district

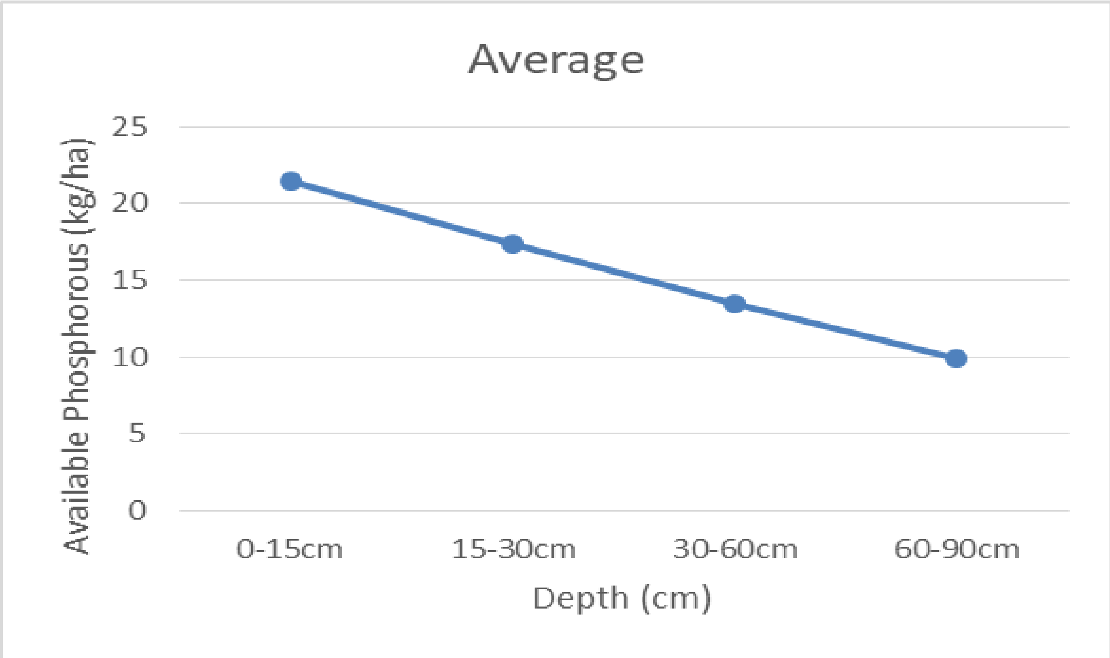

Fig. 4.8: Status of available phosphorous in the soils of Narasinghpur block in Cuttack district

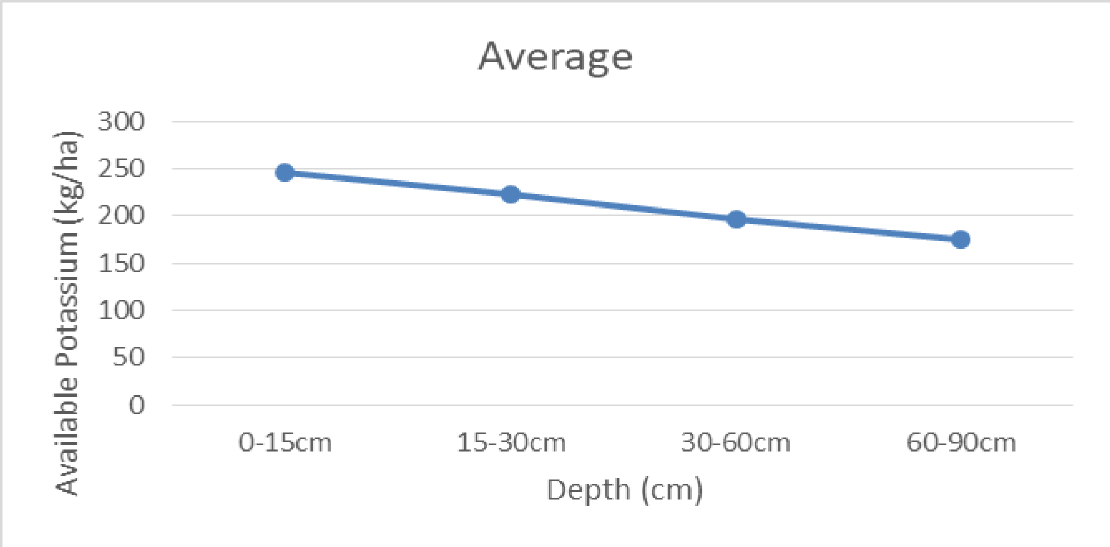

Fig. 4.9: Status of available potassium in the soils of Narasinghpur block in Cuttack district

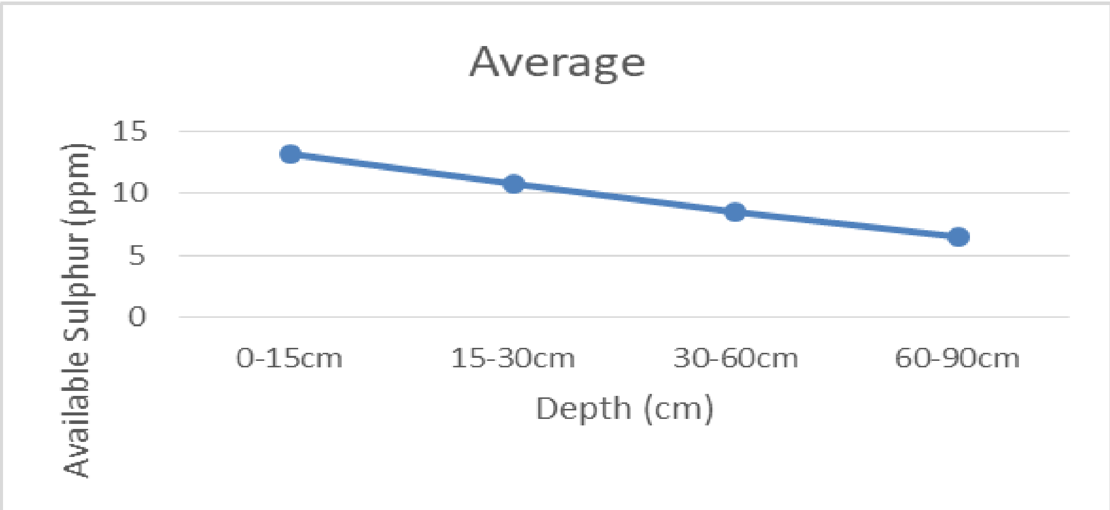

Fig. 4.10: Status of available sulphur in the soils of Narasinghpur block in Cuttack district

4.3.5 Available Micro nutrients

Available micro nutrients were estimated by DTPA method.

4.3.5.1 Available Iron

Available iron content of soils from 0-15 cm depth was found between 4.57 and 5.40 ppm with average 4.96 ppm and S.D 0.28. Iron content of 15-30 cm depth soils ranged between 3.20 and 4.90 ppm with average 4.19 ppm and S.D 0.50. Iron content of soils from 30-60 cm depth ranged between 2.40 and 4.23 ppm with average 3.40 ppm and S.D 0.51. Iron content of 60-90 cm depth soils found between 1.89 and 3.70 ppm with average 2.54 ppm and S.D 0.55 **(Table 4.3.5.1).**

Available iron showed positive relation with organic carbon and negative relation with pH. Iron content decreased with increase in depth of profile due to increase in pH of soils towards the lower horizon. My experiment was similar to the findings of **Sharma** and **Jassal (2013).**

Table 4.3.5.1: Iron content in soils of Narasinghpur block

Village	**Iron (ppm)**			
	0-15 cm	**15-30 cm**	**30-60 cm**	**60-90 cm**
1	5.2	4.7	3.8	2.9
2	4.8	4.3	3.4	2.2
3	5.4	4.6	3.9	2.7
4	4.6	3.8	3.2	2.1
5	5.03	4.1	3.5	2.5
6	5.02	4.4	3.1	2.08
7	4.7	3.2	2.4	1.9
8	5.4	4.9	4.2	3.7
9	4.9	4.3	3.6	2.7
10	4.73	4.14	3.54	2.87
11	4.82	3.91	3.13	2.37
12	5.37	4.61	4.23	3.65
13	5.14	4.76	3.24	2.19
14	4.57	3.34	2.62	1.89
15	4.75	3.92	3.16	2.43
Maximum	5.40	4.90	4.23	3.70
Minimum	4.57	3.20	2.40	1.89
Average	4.96	4.19	3.40	2.54
S.D	0.28	0.50	0.51	0.55

4.3.5.2 Available Zinc

Available zinc content of soils from 0-15 cm depth ranged between 0.44 and 0.63 ppm with average 0.51 ppm and S.D 0.05. Zinc content of 15-30 cm depth soils ranged between 0.38 and 0.54 ppm with average 0.44 ppm and S.D 0.048. Zinc content of soils from 30-60 cm depth ranged between 0.28 and 0.43 ppm with average 0.36 ppm and S.D 0.049. Zinc content of 60-90 cm depth soils was found between 0.22 and 0.39 ppm with average 0.29 ppm and S.D 0.054 **(Table 4.3.5.2).**

Available Zn content decreased towards the lower horizon of profile due to decrease in organic carbon content with depth. Similar findings were obtained by **Sharma** and **Jassal (2013).**

Table 4.3.5.2: Available zinc content in soils of Narasinghpur block

Village	Zinc (ppm)			
	0-15 cm	**15-30 cm**	**30-60 cm**	**60-90 cm**
1	0.63	0.54	0.42	0.37
2	0.52	0.43	0.31	0.26
3	0.55	0.47	0.38	0.32
4	0.49	0.41	0.32	0.27
5	0.46	0.41	0.33	0.24
6	0.51	0.45	0.38	0.29
7	0.56	0.49	0.41	0.37
8	0.47	0.4	0.34	0.3
9	0.61	0.52	0.43	0.36
10	0.44	0.38	0.28	0.22
11	0.48	0.42	0.33	0.26
12	0.53	0.47	0.43	0.39
13	0.54	0.48	0.41	0.32
14	0.45	0.39	0.31	0.23
15	0.5	0.42	0.35	0.28
Maximum	0.63	0.54	0.43	0.39
Minimum	0.44	0.38	0.28	0.22
Average	0.51	0.44	0.36	0.29
S.D	0.05	0.048	0.049	0.054

4.3.5.3 Available Copper

Available copper content of 0-15 cm depth soils was found between 0.19 and 0.32 ppm with average 0.24 ppm and S.D 0.036. Copper content of soils from depth of 15-30 cm ranged between 0.14 and 0.24 ppm with average 0.18 ppm and S.D 0.032. Copper content of 30-60 cm depth soils ranged between 0.09 and 0.19 ppm with average 0.13 ppm and S.D 0.031. Copper content of soils from 60-90 cm depth ranged between 0.05 and 0.13 ppm with average 0.088 and S.D 0.024 **(Table 4.3.5.3).**

Copper showed a positive relationship with organic carbon and negative relationship with pH of the studied area. Copper content was found maximum in soils of 0-15 cm depth. This type of experimental findings was obtained by **Mishra (2008).**

Table 4.3.5.3: Available copper content in soil profile of Narasinghpur block

Village	Copper (ppm)			
	0-15 cm	**15-30 cm**	**30-60 cm**	**60-90 cm**
1	0.23	0.17	0.12	0.09
2	0.32	0.24	0.19	0.13
3	0.27	0.21	0.18	0.11
4	0.21	0.14	0.09	0.05
5	0.24	0.18	0.13	0.1
6	0.25	0.21	0.15	0.08
7	0.19	0.14	0.1	0.07
8	0.22	0.17	0.11	0.09
9	0.2	0.15	0.11	0.06
10	0.23	0.19	0.11	0.07
11	0.25	0.2	0.13	0.1
12	0.29	0.22	0.17	0.13
13	0.26	0.2	0.14	0.08
14	0.28	0.22	0.15	0.1
15	0.21	0.14	0.09	0.06
Maximum	0.32	0.24	0.19	0.13
Minimum	0.19	0.14	0.09	0.05
Average	0.24	0.18	0.13	0.088
S.D	0.036	0.032	0.031	0.024

4.3.5.4 Available Manganese

Available manganese content of soils from 0-15 cm depth ranged between 4.62 to 5.69 ppm with average 4.99 ppm and S.D 0.28. Manganese content of 15-30 cm depth soils ranged between 3.84 and 5.14 ppm with average 4.41 ppm and S.D 0.37. Manganese content of soils from depth 30-60 cm found between 3.33 and 4.57 ppm with average 3.80 ppm and S.D 0.39. Manganese content of 60-90 cm depth soils ranged between 2.47 and 3.91 ppm with average 3.23 ppm and S.D 0.47 **(Table 4.3.5.4).**

Manganese content decreased with increasing depth due to higher pH with depth of soils. Manganese had a positive relationship with organic matter and negative relation with pH. Such type of relationship study is in close conformity with relationship study of **Pattanaik (2019).**

Table 4.3.5.4: Available manganese content in different depth of soil of Narasinghpur block

Village	Manganese (ppm)			
	0-15 cm	**15-30 cm**	**30-60 cm**	**60-90 cm**
1	5.15	4.71	4.17	3.89
2	5.69	5.14	4.57	3.91
3	5.38	4.94	4.23	3.85
4	4.76	4.11	3.53	3.12
5	4.82	4.1	3.36	2.47
6	4.69	4.09	3.35	2.67
7	5.11	4.73	4.27	3.75
8	4.91	3.84	3.33	2.9
9	4.87	4.32	3.49	2.82
10	5.23	4.68	3.95	3.27
11	5.04	4.72	4.19	3.77
12	4.97	4.43	3.71	3.14
13	4.62	4.07	3.63	2.91
14	4.79	4.2	3.51	2.98
15	4.84	4.17	3.76	3.1
Maximum	5.69	5.14	4.57	3.91
Minimum	4.62	3.84	3.33	2.47
Average	4.99	4.41	3.80	3.23
S.D	0.28	0.37	0.39	0.47

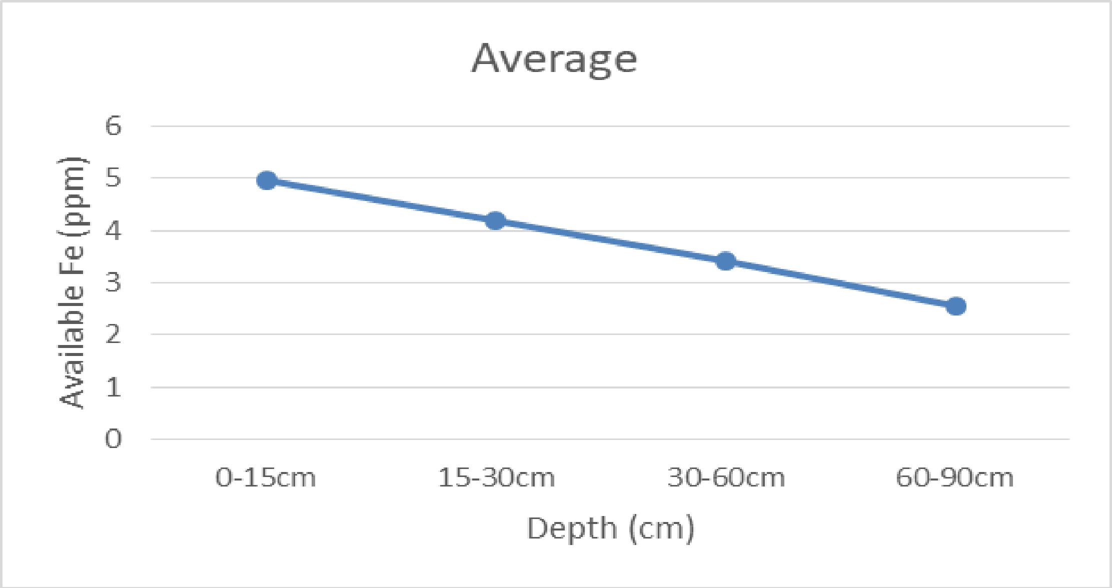

Fig. 4.11: Status of available iron in the soils of Narasinghpur block in Cuttack district

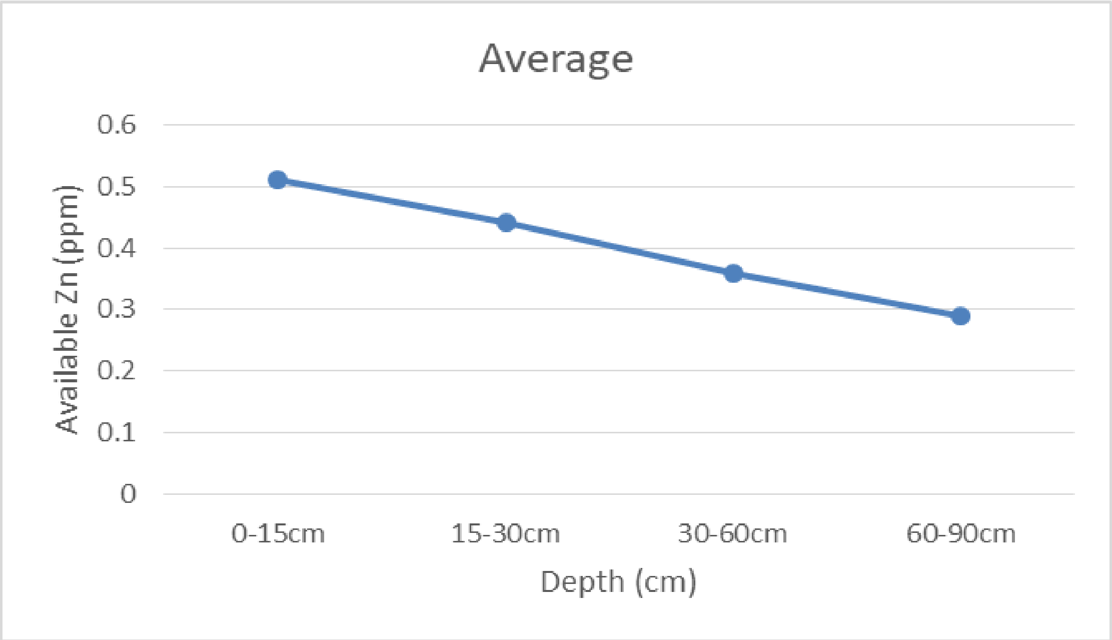

Fig. 4.12: Status of available zinc in the soils of Narasinghpur block in Cuttack district

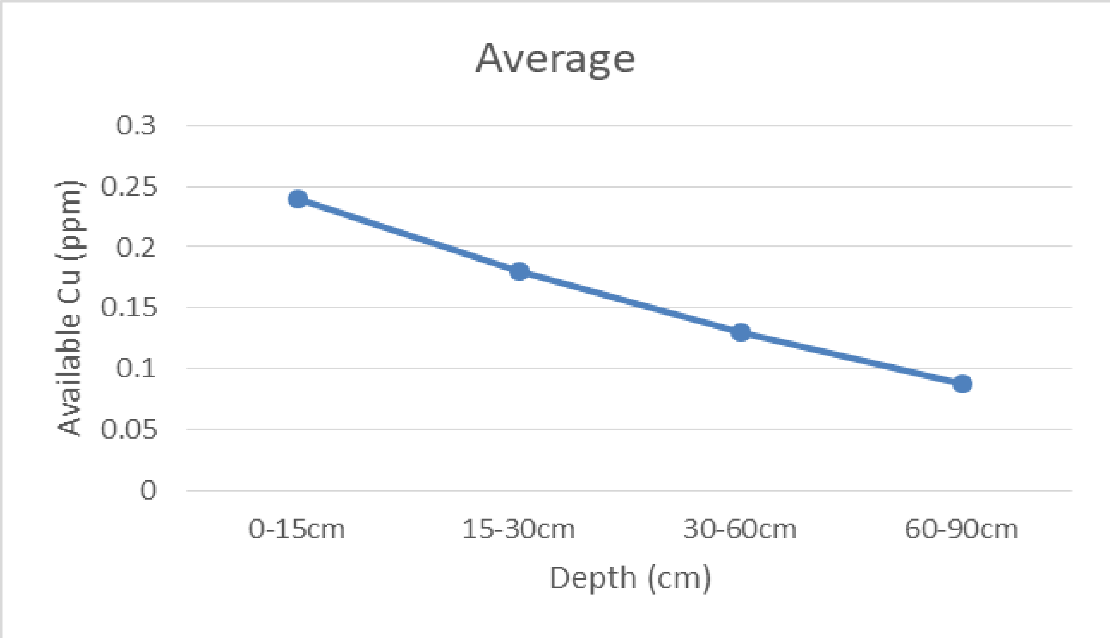

Fig. 4.13: Status of available copper in the soils of Narasinghpur block in Cuttack district

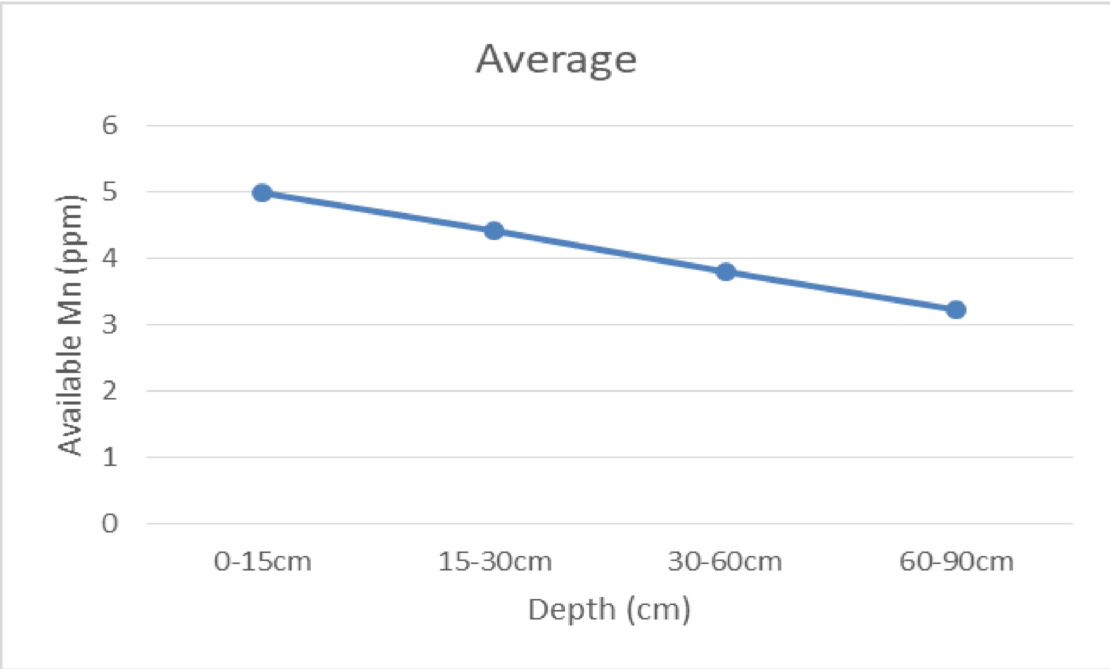

Fig. 4.14: Status of available manganese in the soils of Narasinghpur block in Cuttack district

4.3.6 Correlation between physico-chemical properties of soils of Narasinghpur block

Bulk density has a significant correlation of 0.685 at 0.01 level with particle density, 0.439 at 0.01 level with pH and 0.467 at 0.01 level with EC and non-significant correlation with rest of the physico-chemical properties. Particle density has a significant correlation of 0.685 at 0.01 level with bulk density, 0.624 at 0.01 level with pH and 0.754 at 0.01 level with EC and non-significant correlation with other properties of soils of Narasinghpur block. Porosity has a significant correlation of 0.012 at 0.05 level with EC, 0.580 at 0.01 level with organic carbon, 0.473 at 0.01 level with nitrogen, 0.330 at 0.05 level with phosphorous, 0.173 at 0.05 level with potassium, 0.378 at 0.01 level with sulphur, 0.587 at 0.01 level with iron, 0.326 at 0.05 level with zinc, 0.414 at 0.01 level with copper and 0.351 at 0.01 level with manganese and non-significant correlation with other properties **(Table 4.3.6)**.

pH has a significant correlation of 0.439 at 0.01 level with bulk density, 0.624 at 0.01 level with particle density and 0.655 at 0.01 level with EC and non-significant correlation with other physico-chemical properties of soils of Narasinghpur block. EC has a significant correlation of 0.467 at 0.01 level with bulk density, 0.754 at 0.01 level with particle density. 0.012 at 0.05 level with porosity and 0.655 at 0.01 level with pH and non-significant correlation with other physico-chemical properties of soils of the studied area. Organic carbon has a significant correlation of 0.580 at 0.01 level with porosity, 0.735 at 0.01 level with nitrogen, 0.738 at 0.01 level with phosphorous, 0.630 at 0.01 level with potassium, 0.765 at 0.01 level with sulphur, 0.796 at 0.01 level with iron, 0.667 at 0.01 level with zinc, 0.650 at 0.01 level with copper and 0.717 at 0.01 level with manganese and non-significant correlation with other properties of the studied area **(Table 4.3.6)**.

Nitrogen has a significant correlation of 0.473 at 0.01 level with porosity, 0.735 at 0.01 level with organic carbon, 0.861 at 0.01 level with phosphorous, 0.742 at 0.01 level with potassium, 0.809 at 0.01 level with sulphur, 0.827 at 0.01 level with iron, 0.842 at 0.01 level with zinc, 0.796 at 0.01 level with copper and 0.778 at 0.01 level with manganese and non-significant correlation with other properties of soils of the studied area. Phosphorous has a significant correlation of 0.330 at 0.05 level with porosity, 0.738 at 0.01 level with organic carbon, 0.861 at 0.01 level with nitrogen, 0.718 at 0.01 level with potassium, 0.878 at 0.01 level with sulphur, 0.756 at 0.01 level with iron, 0.802 at 0.01 level with zinc, 0.727 at 0.01 level with copper and 0.735 at 0.01 level with manganese and non-significant correlation with other properties of soils of the studied area. Potassium has a significant correlation of 0.173 at 0.05 level with porosity, 0.630 at 0.01 level with organic carbon, 0.742 at 0.01 level with nitrogen, 0.718 at 0.01 level with phosphorous, 0.698 at 0.01 level with sulphur, 0.699 at 0.01 level with iron, 0.852 at 0.01 level with zinc, 0.673 at 0.01 level with copper and 0.768 at 0.01 level with manganese and non-significant correlation with other properties of soils of the studied area. Sulphur has a significant correlation of 0.378 at 0.01 level with porosity, 0.765 at 0.01 level with organic carbon, 0.809 at 0.01 level with nitrogen, 0.878 at 0.01 level with phosphorous, 0.698 at 0.01 level with potassium, 0.787 at 0.01 level with iron, 0.761 at 0.01 level with zinc, 0.815 at 0.01 level with copper and 0.774 at 0.01 level with manganese and non-significant correlation with other properties of soils of the studied area **(Table 4.3.6)**.

Iron has a significant correlation of 0.587 at 0.01 level with porosity, 0.796 at 0.01 level with organic carbon, 0.827 at 0.01 level with nitrogen, 0.756 at 0.01 level with phosphorous, 0.699 at 0.01 level with potassium, 0.787 at 0.01 level with sulphur, 0.824 at 0.01 level with zinc, 0.838 at 0.01 level with copper and 0.756 at 0.01 level with manganese and non-significant correlation with other physico-chemical properties of soils of Narasinghpur block. Zinc has a significant correlation of 0.326 at 0.05 level with porosity, 0.667 at 0.01 level with organic carbon, 0.842 at 0.01 level with nitrogen, 0.802 at 0.01 level with phosphorous, 0.852 at 0.01 level with potassium, 0.761 at 0.01 level with sulphur, 0.824 at 0.01 level with iron, 0.738 at 0.01 level with copper and 0.779 at 0.01 level with manganese and non-significant correlation with other properties of soils of the studied area. Copper has a significant correlation of 0.414 at 0.01 level with porosity, 0.650 at 0.01 level with organic carbon, 0.796 at 0.01 level with nitrogen, 0.727 at 0.01 level with phosphorous, 0.673 at 0.01 level with potassium, 0.815 at 0.01 level with sulphur, 0.838 at 0.01 level with iron, 0.738 at 0.01 level with zinc and 0.840 at 0.01 level with manganese and non-significant correlation with other properties of soils of the studied area. Manganese has a significant correlation of 0.351 at 0.01 level with porosity, 0.717 at 0.01 level with organic carbon, 0.778 at 0.01 level with nitrogen, 0.735 at 0.01 level with phosphorous, 0.768 at 0.01 level with potassium, 0.774 at 0.01 level with sulphur, 0.756 at 0.01 level with iron, 0.779 at 0.01 level with zinc and 0.840 at 0.01 level with copper and non-significant correlation with other properties of soils of the studied area **(Table 4.3.6)**.

Table 4.3.6: Correlation between physico-chemical properties of soils of Narasinghpur block

		Bulk density	Particle density	Porosity	pH	EC	Organic carbon	Nitrogen	Phosphorous	Potassium	Sulphur	Iron	Zinc	Copper	Manganese
Bulk density	Pearson Correlation	1													
	Sig. (2-tailed)														
	N	60													
Particle density	Pearson Correlation	.685**	1												
	Sig. (2-tailed)	.000													
	N	60	60												
Porosity	Pearson Correlation	-.763**	-.064	1											
	Sig. (2-tailed)	.000	.627												
	N	60	60	60											
pH	Pearson Correlation	.439**	.624**	-.026	1										
	Sig. (2-tailed)	.000	.000	.842											
	N	60	60	60	60										
EC	Pearson Correlation	.467**	.754**	.012	.655**	1									
	Sig. (2-tailed)	.000	.000	.928	.000										
	N	60	60	60	60	60									
Organic carbon	Pearson Correlation	-.789**	-.582**	.580**	-.526**	-.492**	1								
	Sig. (2-tailed)	.000	.000	.000	.000	.000									
	N	60	60	60	60	60	60								
Nitrogren	Pearson Correlation	-.820**	-.743**	.473**	-.490**	-.544**	.735**	1							
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000								
	N	60	60	60	60	60	60	60							
Phosphorous	Pearson Correlation	-.741**	-.788**	.330*	-.543**	-.574**	.738**	.861**	1						
	Sig. (2-tailed)	.000	.000	.010	.000	.000	.000	.000							
	N	60	60	60	60	60	60	60	60						
Potassium	Pearson Correlation	-.559**	-.673**	.173	-.633**	-.620**	.630**	.742**	.718**	1					
	Sig. (2-tailed)	.000	.000	.187	.000	.000	.000	.000	.000						
	N	60	60	60	60	60	60	60	60	60					
Sulphur	Pearson Correlation	-.784**	-.793**	.378**	-.583**	-.604**	.765**	.809**	.878**	.698**	1				
	Sig. (2-tailed)	.000	.000	.003	.000	.000	.000	.000	.000	.000					
	N	60	60	60	60	60	60	60	60	60	60				
Iron	Pearson Correlation	-.852**	-.648**	.587**	-.534**	-.474**	.796**	.827**	.756**	.699**	.787**	1			
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000				
	N	60	60	60	60	60	60	60	60	60	60	60			
Zinc	Pearson Correlation	-.697**	-.703**	.326*	-.522**	-.487**	.667**	.842**	.802**	.852**	.761**	.824**	1		
	Sig. (2-tailed)	.000	.000	.011	.000	.000	.000	.000	.000	.000	.000	.000			
	N	60	60	60	60	60	60	60	60	60	60	60	60		
Copper	Pearson Correlation	-.810**	-.791**	.414**	-.530**	-.636**	.650**	.796**	.727**	.673**	.815**	.838**	.738**	1	
	Sig. (2-tailed)	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000		
	N	60	60	60	60	60	60	60	60	60	60	60	60	60	
Manganese	Pearson Correlation	-.780**	-.798**	.351**	-.668**	-.565**	.717**	.778**	.735**	.768**	.774**	.756**	.779**	.840**	1
	Sig. (2-tailed)	.000	.000	.006	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	
	N	60	60	60	60	60	60	60	60	60	60	60	60	60	60

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Chapter V

SUMMARY AND CONCLUSION

Summary

The studied area is located in mid central table land Agro-climatic zone of state Odisha. The present experiment characterization of soils through profile study of Narasinghpur Block in Cuttack District of Odisha was anlysed at Department of Soil science and Agricultural chemistry, Institute of Agricultural Sciences, BHU, Varanasi during the year 2020-2022. As the name of the experiment suggested, fifteen profile were exposed in fifteen villages of studied area. These soil samples were taken to BHU for analysis. Soils were collected from four different depths i.e. 0-15 cm, 15-30 cm, 30-60 cm and 60-90 cm and analysed in the laboratory and the results were summarized below

1. The texture of the studied area was determined by Bouyoucous Hydrometer method. The texture of the studied area were found to be sandy loam and sandy clay loam. The average sand content was found to be 66.68%, the silt content was found to be 13.5% and average clay content was found to be 19.90%. Maximum sand content was found in Kamaladiha village, whereas maximum silt content was found in Ekadal village and clay content was found to be maximum in **Fulapada village**.
2. The bulk densities of the studied area was determined by Pycnometer method. The average bulk density of surface soil was found to be 1.17, bulk density of 15-30 cm depth was found to be 1.24, bulk density of 30-60 cm depth was found to be 1.31 and bulk density of 60-90 cm depth was found to be 1.38 Mg/m^3. Bulk density of the studied area increased with depth due to decrease in organic carbon and pore space. Maximum bulk density was found in **Kamaladiha village**.
3. The particle densities of studied area was determined by Pycnometer method. Average particle density of surface soil was found to be 2.38 Mg/m^3. Below the

surface layer particle density of soils were 2.48, 2.56 and 2.64 Mg/m^3 respectively up to 90 cm depth. Particle density of **Sagar village** was found to be maximum, while minimum particle density was found in **Ekadal village**. Particle density of the studied area increased with depth. Particle density of surface soil is lower than sub surface soils due to decrease in organic matter content of sub surface soils.

4. Maximum porosity was found in surface soils of studied area. Porosity decreased with depth due to increase in compactness and decrease in organic matter content. Porosity of the studied area varied from 50.74% to 47.56% from surface soil up to 90 cm depth. Maximum porosity was found in **Sagar village**.
5. The soils of studied area were found to be neutral to slightly alkaline. pH increased with depth because acidification is most pronounced near the soil surface. Soil pH also increased due to downward movement of bases during intense rainfall time. Average pH of the surface soils of studied area was found to be 6.86 and below the surface layer pH of soils were 7.16, 7.46 and 7.67 respectively up to 90 cm depth. pH of **Padamala** village was found to be maximum.
6. Electrical conductivity of studied area was found <1 dS/m which is beneficial for plant growth. Electrical conductivity increased with depth due to downward movement of finer soil particles and soluble salts through runoff. EC of **Padamala** village was found to be maximum.
7. Organic carbon content was found to be maximum in surface soil due to significant accumulation of organic matter. Organic carbon content decreased with depth because crop residues are deposited more in surface soils. So that organic matter formation is more in surface soils than subsurface soils. Organic carbon of surface soil was found to be 0.51% which was reduced down the depth of profile up to 9 0cm from 0.51% to 0.26%. Maximum organic carbon was found in **Kokalaba village**.
8. Available nitrogen content of soils of studied area was found to be in medium range. Average N content of surface soils of studied area was found to be 313.38

kg/ha and it was reduced to 190.53 kg/ha at 90 cm depth of profile. Nitrogen content decreased with depth due to decrease in organic matter below the surface soils. Maximum nitrogen was found in **Ekadal village.**

9. Available phosphorous was found to be in medium range due to less application of phosphatic fertilizers by farmers in the studied area. Average phosphorous content of surface soils of the studied area was found to be 21.43 kg/ha which was decreased to 9.92 kg/ha at the 90 cm depth of profile. Phosphorous content decreased with depth due to decrease in organic matter content. Maximum phosphorous content was found in **Paikapadapatana village.**

10. The available potassium content was found maximum in surface soil which was in medium to slightly high range. Average potassium content of surface soils was found to be 246.82 kg/ha, below the surface layer potassium content was found to be 222.12 kg/ha, 196.30k/ha and 174.36 kg/ha respectively up to 90 cm depth. Potassium content decreased with increase in depth. Maximum potassium content was found in **Adheigundi village**.

11. Available sulphur content studied area was found to be in high range in surface soils of studied area. Average sulphur content of surface soils of studied area was found to be 13.12 ppm, below the surface soil sulphur content was found to be 10.83 ppm, 8.52 ppm and 6.49 ppm respectively up to 90 cm depth. However, sulphur content decreased with increase in depth of profile. Maximum sulphur content was found in **Jayamangala village**.

12. Soils of studied area were found to be deficient in micro nutrients. Average iron content of surface soils was found to be 4.96 ppm which was reduced to 2.54 ppm at 90 cm depth of profile. Average Zinc content of surface soils was found to be 0.51 ppm and it was reduced to 0.29 ppm at 90 cm depth. Average Copper content of surface soils was found to be 0.24 ppm and it was decreased to 0.08 ppm at 90 cm depth. Average Manganese content of surface soils was found to be 4.99 ppm and it was reduced to 3.23 ppm at 90 cm depth of profile. Micro nutrient content decreased with increase in depth of profile. Fe content was found to be maximum in **Champeswa**r and **Kamaladiha** village. Zn content

was found to be maximum in **Adheigundi village**. Cu content was found to be maximum in **Balijhari village** and maximum Mn content was found in **Balijhari village**.

Conclusion

Narasinghpur block is one among distinct geographical regions of Cuttack district. This present study includes the exposing of soils profiles of different villages, analysing physico-chemical properties of samples collected from four depths of a profile and establish a cor-relation between soil properties with available nutrients. The results showed the depth wise highest, lowest, average and standard deviation value of physico-chemical properties of soils i.e soil texture, B.D, P.D, porosity, pH, EC, organic carbon, available macro nutrients(N,P,K,S) and available micro nutrients(Fe, Zn, Cu, Mn).

Results showed that value of EC is less than 1 dS/m which is suitable for crop production. Organic carbon content can be increased by applying organic manures and FYM in the field. Available phosphorous content was found to be in medium range zone in surface soils and decreased below the profile which may be insufficient for deep rooted crops, so that phosphorous content can be increased by applying phosphatic fertilizers along with organic manures. Micro nutrient content of studied area was found to be low which may be not sufficient for crop requirements, so that micro nutrient content can be enhanced by applying micro nutrient fertilizers and organic manures to improve the status of micronutrients in the deficient soils.

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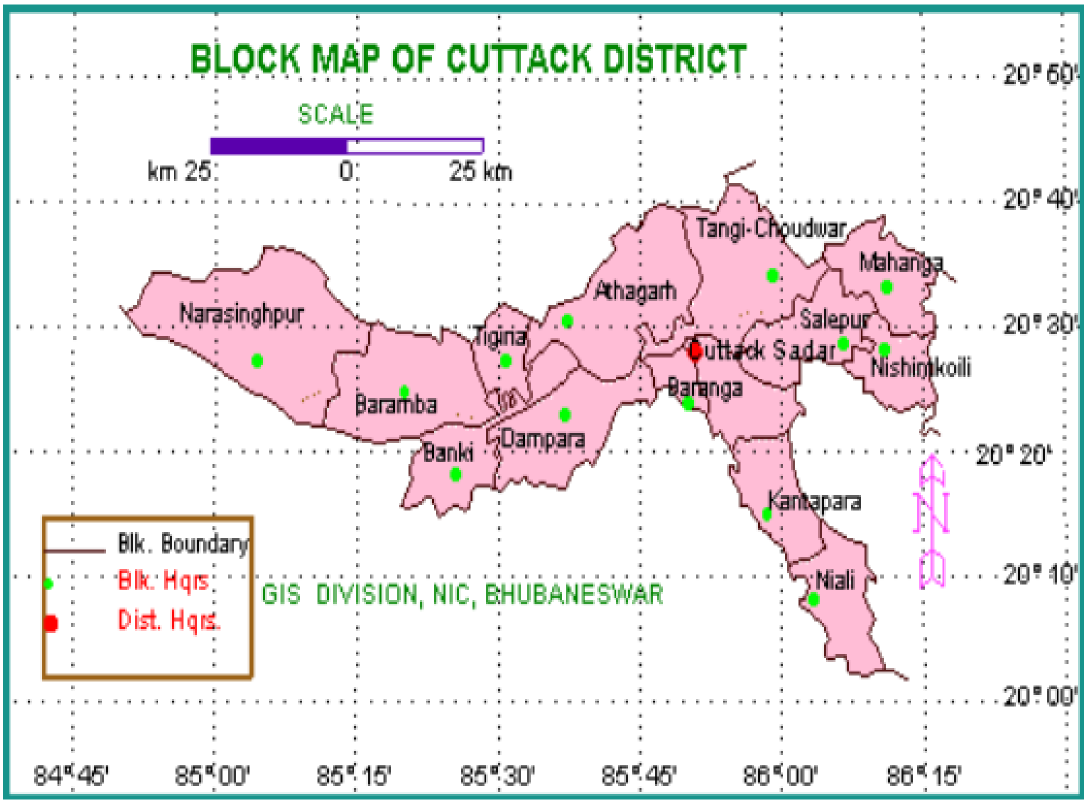
APPENDICES

Appendix 1: Block map of Cuttack district showing the studied area

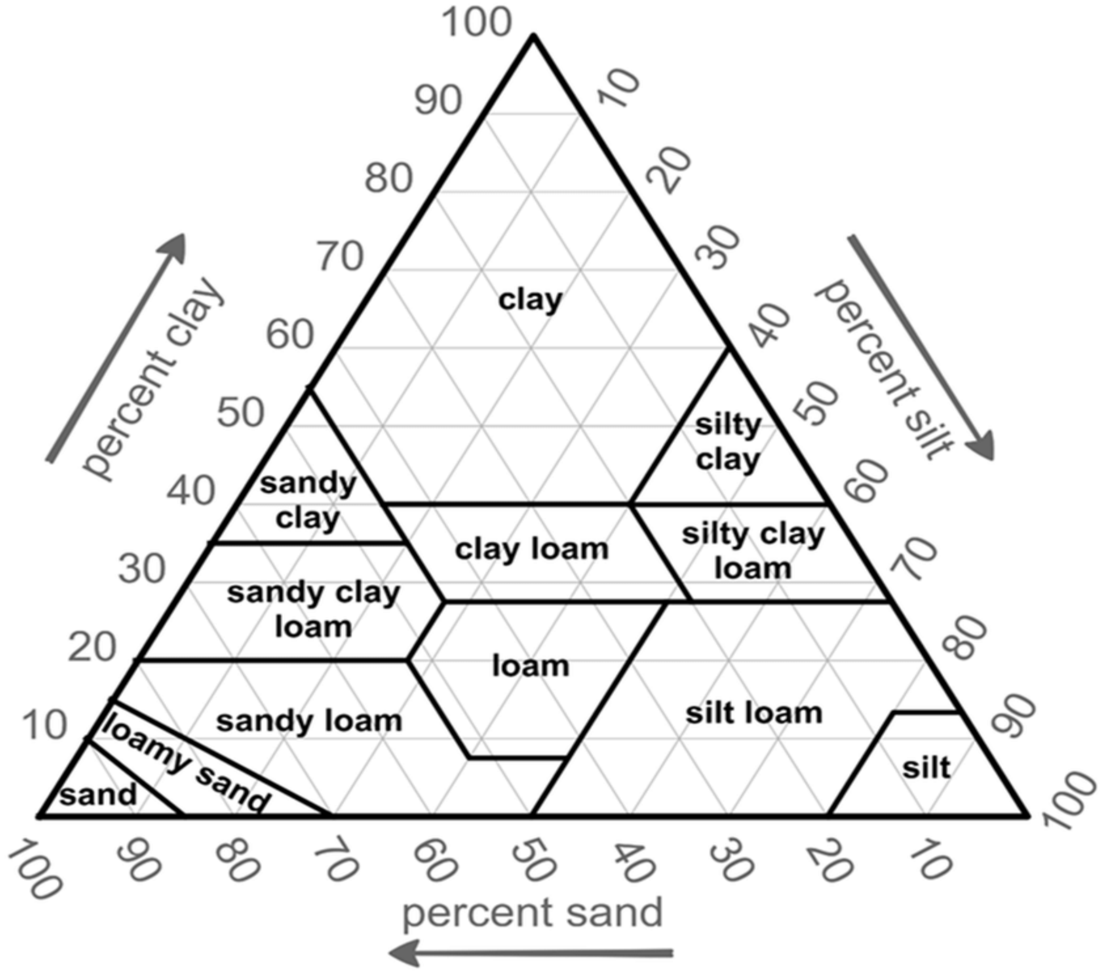


Appendix 2: List of agro climatic zones of Odisha

Agro climatic Zone in Odisha

Sl no	**Agroclimatic Zone**	**Agricultural Districts**	**Climate**	**Normal**			**Broad Soil groups**
				Mean annual rainfall (mm)	Mean maximum summer temp (°C)	Mean minimum winter temp (°C)	
1	North Western Plateau	Sundargarh, parts of Deogarh, Sambalpur & Jharsugud	Hot & moist sub-humid	1600	38.0	15.0	Lateritic, Red & Yellow, Mixed Red & Black
2	North Central Plateau	Mayurbhanj, major parts of Keonjhar, (except Anandapur & Ghasipura block)	Hot & moist sub-humid	1534	36.6	11.1	Red, Lateritic, Deltalc alluvial, Coastal alluvial & Saline
3	North Eastern Coastal Plain	Balasore, Bhadrak, parts of Jajpur & hatdihi block of Keonjhar	Moist subhumid	1568	36.0	14.8	Red, Brown forest, Red & Yellow, Mixed Red & Black
4	East & South Eastern Coastal Plain	Kendrapara, Khurda, Jagatsinghpur, part of Cuttack, Puri, Nayagarh & part of Ganjam	Hot & Humid	1577	39.0	11.5	Saline, Lateritic, Alluvial, Red & Mixed red & Black
5	North Eastern Ghat	Phulbani, Rayagada, Gajapati, part of Ganjam & small patches of Koraput	Hot & moist, sub-humid	1597	37.0	10.4	Brown forest, Lateritic Alluvial, Red, Mixed Red & Black
6	Eastern Ghat High Land	Major parts of Koraput, Nabarangpur	Warm & humid	1522	34.1	7.5	Red, Mixed Red & Black, Mixed Red & Yellow
7	South Eastern Ghat	Malkangiri & part of Keonjhar	Warm & humid	1710	34.1	13.2	Red, Lateritic, Black
8	Western Undulating Zone	Kalahandi & Nuapada	Hot & moist sub-humid	1352	37.8	11.9	Red, Mixed Red & Black and Black
9	Western Central Table Land	Bargarh, Bolangir, Boudh, Sonepur, parts of Sambalpur & Jharsuguda	Hot & moist sub-humid	1614	40.0	12.4	Red & Yellow, Red & Black, Black, Brown forest, Lateritic
10	Mid Central Table Land	Angul, Dhenkanal, parts of Cuttack & Jajpur	Hot & moist sub-humid	1421	38.7	14.0	Alluvial, Red, Lateritic, Mixed Red & Black

Appendix 3: Textural triangle for soil texture determination



Appendix 4: Soil test parameters

Sl No.	Test Parameter	Method Used	References
1	pH	Potentiometric titration method	**Jackson, 1967**
2	EC	Conductometric titration method	**Jackson, 1967**
3	Organic Carbon	Rapid titration method	**Walkley and Black, 1934**
4	Mechanical Composition	Bouyoucos hydrometer method	**Bouyoucos, 1927**
5	Available N	Alkaline potassium permanganate method	**Subbiah and Asija, 1956**
6	Available P	Olsen's method	**Olsen *et al.*, 1954**
7	Available K	Neutral normal ammonium acetate method	**Hanway and Heidel, 1952**
8	Available S	0.15% $CaCl_2$ extractable method	**Chesnin and Yien, 1950**
9	Available Fe	DTPA extractable method	**Lindsay and Norvell, 1978**
10	Available Zn	DTPA extractable method	**Lindsay and Norvell, 1978**
11	Available Cu	DTPA extractable method	**Lindsay and Norvell, 1978**
12	Available Mn	DTPA extractable method	**Lindsay and Norvell, 1978**