SOIL PROFILE MAPPING OF MIRZAPUR DISTRICT OF VINDHYAN REGION USING GEOSPATIALTECHNIQUES

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

Master of Science (Agriculture)

in

Soil Science – Soil and Water Conservation

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Submitted by
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Through: The Head,
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Dear Sir,

I have great pleasure in forwarding the thesis entitled ***"Soil Profile Mapping of Mirzapur District of Vindhyan region using Geo spatial Techniques"*** submitted by *Ms. Panneeru Vennela (ID. No. 19430SAC010, Enrolment No. 417403)*, in partial fulfilment of the requirements for the degree of **Master of Science (Agriculture)** in **Soil Science-Soil and Water Conservation**,from the Department of Soil Science & 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

(Prof. Nirmal De)

(Head)   **Supervisor**

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Date:
Place: Varanasi **(Panneeru Vennela)**

CONTENTS

LIST OF SYMBOLS AND ABBREVIATIONS

%	Per cent
Agri.	Agriculture
B.D	Bulk density
Ca	Calcium
cm	Centimeter
Cmol (P+) kg^{-1}	Centimol per kilogram
Cu	Copper
DSm^{-1}	Deci Siemen per meter
DTPA	Diethylene Triamine Penta acetic acid
EC	Electrical conductivity
EDTA	Ethylene di amine tetra acetic acid
Et al.	Et alia, and others
Fe	Iron
G kg^{-1}	Gram per kilogram
GIS	Geographic Information System
Ha.	Hectare
i.e.	Id est. that is
J	Journal
K	Potassium
Kg ha^{-1}	Kilogram per hectare
Meq $100g^{-1}$	Milli equivalents per 100 gram of soil
Mg kg^{-1}	Milligram per kilogram
Mg	Magnesium
Mha	Million hectare
Mm.	Millimeter
Mn	Manganese
N	Nitrogen
Na	Sodium
O.C.	Organic carbon
P	Phosphorus
P.D.	Particle density
pH	Puissance de hydrogen
Sq. km	Square kilometer
TEA	Tri ethanol Amine
viz.	Vide licet, name
Zn	Zinc

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Chapter I

INTRODUCTION

Soil is a dynamic living body which acts as the substrate of all living entities. The global agricultural situation and outlook is facing challenges in terms of increased production from a limited agricultural land due to increasing population and climate change. A report by Food and Agricultural Organisation states that the world population might increase up to 9.15 billion by 2050 and requires an increase in the food production up to 60% from the current status which calls for increased efficiency through high yielding crop varieties and efficient management of resources like soil, water, fertilizers etc., in crop production.

Soil nutrition management and its productivity is a key factor for the increased yields of crops. The productivity of soils is being seriously affected due to lack of proper management and monitoring. Climate change has also affected the soil health and quality exceedingly in recent times. According to IPCC (Intergovernmental Panel on Climate Change), the temperatures are expected to raise between 1.1 and 6.4 during the 21st century globally. This affects the rainfall patterns, nutrient cycles of Nitrogen and Phosphorus, declines the soil organic matter and carbon storage in the soil (Brievik, 2013).

This change in the nutrient cycles and organic matter shows a detrimental effect on the soil productivity which in turn ramifies the production. Evaluation and monitoring of agriculture resources and inputs has become a key factor as a single input is inter related with many other factors like temperature, precipitation, ground water availability, erosion pattern, deforestation and soil quality.

The farming plans require an updated data and information on cropping patterns, cultivable soil area, ground water level, floods and droughts, soil quality index for crop selection and cultivation in a season.

Considering the challenges today in agriculture sector it requires a potential technology for regular monitoring of the agricultural resources, to develop suitable models for future action of plan and to formulate the necessary policies by the Government.

In the past two decades remote sensing techniques have made major outbreak in the agricultural sector. The geo spatial technology is used to serves various purposes like soil survey, soil mapping, soil quality estimation, crop health assessment, Pest infestation rate, crop acreage estimation, cropping pattern assessment, Agro- meteorology, water management and atmospheric conditions with emphasis to crop yield.

The information generated from the remote sensing techniques is an interaction of incident radiation with the targeted object or the radiation emitted from the object which is captured by the sensor. The most used spectrums for geo spatial technology are visible spectrum, Near Infrared, Short wave infrared and Microwave radiation (Sinha *et al.,* 2015).

Remote sensing involves in three major processes, Data generation, Data acquisition and Data processing and interpretation.

Geo spatial technology provides numerous advantages over traditional methods like

- Repetitive coverage of an area useful in change detection
- Increased information or data through hyper spectral remote sensing
- Synoptic view
- High accuracy in data
- Potential for a faster survey
- Low in cost and less laborious.

The remote sensing techniques are prominently used in soil science field today, majorly for soil mapping and soil survey. Soil mapping through geo spatial technology provides an accurate and updated data of various soil parameters through geospatial information system by stacking the layers of bands of the spectrum. The predictive soil mapping helps in the soil quality estimation, soil water or moisture status, soil erosion rate, soil temperature, soil loss and drainage patterns in the soil system.

Geo Spatial Technology helps in obtaining large sets of data or information with high accuracy and high frequency of repetition. In this study the physical and chemical properties of the soil profile samples from various locations are analyzed and mapped using Geo Spatial techniques.

Soil profile analysis provides information on the physical and chemical characteristics of the soil. Soil profile is the vertical section of a soil showing distinctive horizons extending up to bedrock (concept of soil profile given by Nathanael Shaler). In the soils where the bedrock is absent due to complete weathering profile may extend up to tens of meters.

Profile analysis helps in determination the water holding capacity, porosity, permeability etc. Soil color describes about the fertility status of the soil. Highly weathered soil has lighter color in the subsurface horizons due to intensive leaching which are less fertile and fertile soils have darker color in the surface and subsurface soil due to the presence of organic matter (Slepetiene *et al.,* 2015).

The chemical and physical characteristic analysis from the profile gives a brief view on the soil formation, nutrient status and soil status if prone to continuous further use. The profile analysis does not only serve the farmers for cultivation (Presley *et al.,* 2008). It is also useful to ecologists to estimate the changes, soil engineers for determining the capacity of soil to withhold constructions, Hydrologists to study the ground water status, drainage patterns etc.

Mirzapur district covers a geographical area of 4522 sq.km and one of the Southernmost· district of Uttar Pradesh state with headquarters at Mirzapur. The district is located between 82.21’45” to 82.30’E longitude and 24.41’30” to 24.47’N latitude, bounded on the north by Bhadohi and Varanasi districts, on the east by Chandauli district, on south by Sonabadhra and on the north-west by Allahabad district lies in the Vindhayanchal region which is administratively divided into four tehsils. The Mirzapur district comprises the range of physiographic including hillocks, plateau and plains made by alluvial soils. Runoff rate is high in the hilly regions of the state which leads to considerable soil loss. The soils are mostly Red soil and Alluvial soils in the Ganga basin region. Agro ecologically the district is classified as Indo gangetic plain and Vindhyan region. More than 80% of the area lies in Vindhyan region and 20% of area lies under alluvial tract.

Major portion of the area is in Rocky areas so the underground water resources are undefined, uncertain and not explored fully for a potential agricultural production. The annual rainfall is 1100mm, erratic with uneven distribution. The area is under moisture stress in maximum part of the year resulting in increased degraded land. Only 40% of the land is cultivable with no proper irrigation methods.

Major constraints of the soil are confined to the plateau and hilly region of the district. The soils in the District are prone to erosion, low in Nutrient status, poor vegetation status, formation of gullies and submergence of cultivable land. The cumulative effect of primitive farming practices lies lopping, felling and over grazing leading to the constraints like Low soil productivity, Degraded soil fertility, Degradation of cultivable lands and extensive marginal - Sub marginal lands.

The crop production in the area is highly dependent on the precipitation pattern. The production is undulating and low over years due to the inadequate agricultural resources, primitive cultivation practices and rainfall dependent agriculture. The low productivity in the area is also due to the poor socio economic conditions, financial and managerial aspects, less technological awareness and gap between the farmers and Modern agricultural practices.

The soil profile mapping of the soil samples is done by analyzing various physical and chemical parameters of the soil like pH, Electrical conductivity, Porosity, Bulk density, Alkalinity (Carbonates and Bicarbonates), Organic Carbon, Total Organic Matter, Major nutrients N,P and K, Sodium levels and Micronutrients (Fe, Cu, Mn and Zn).

Considering the current challenges in soil management and agricultural management in the Mirzapur district, the study, **“Soil Profile Mapping of Mirzapur District of Vindhyan region using Geo Spatial Techniques”** is done to attain the following objectives,

1. Measuring the soil physical and chemical properties in the profile from 0-15cm to 45-60 cm depth.

2. Spatial Variability Mapping of physico- chemical properties of soil profile

3. Evaluation and correlation of the soil properties in the profile at various depths.

Chapter II

REVIEW OF LITERATURE

Soil is the vital component for the life functions of all the living organisms. It is a complex matter and comprises of soil organic matter, water and air. Soil physico chemical properties play a vital role in the sustainability of environment and productivity of soil. In the current study ***"Soil Profile Mapping of Mirzapur District of Vindhyan region using Geo Spatial Techniques"*** various soil physico-chemical parameters of the soil profile are analyzed through standard laboratory methods and interpreted through spatial variability mapping using GIS. The review of literature is discussed under following heads:

2.1 Remote sensing applications in soil science

2.2 Soil mapping using geo spatial techniques

2.3 Physico-chemical properties of soil

2.4 Geographic information system (GIS) in soil science

2.5 Spatial variability mapping techniques

2.1 Remote sensing applications in soil science

Remote sensing aids in identification of earth surface features and estimation of earth surface geo bio physical properties with the help of electromagnetic radiation as a medium for interaction. Spatial, spectral, temporal and signature are the main characteristics of the sensor or target that helps in the discrimination of the target object or phenomenon **(Navalgund *et al.*, 2007).**

Remote sensing has a great potential in the soil characterization. Various methodologies has been developed for the estimation of soil properties based on sensors and techniques (**Mulder *et al.*, 2019**). Optical remote sensing with a limited number of bands (SPOT, ASTER and LANDSAT etc.) is adapted for land use data and vegetative cover description. Soil texture is described using hyper spectral sensors, thermal infrared band is adapted for estimating soil temperature and microwave band is used for soil moisture and vegetation estimation. Scatterometer sensor is mostly used for global estimation and Synthetic Aperture Radar (SAR) with high spatial resolution is used for local and regional studies of soil parameters like moisture, roughness and texture etc.

For the soil parameters estimation three types of methodologies are adapted (**Zeribi *et al.*, 2012**);

- Empirical models based on ground and satellite data base
- Semi empirical models based on mixture of real data and physical modelling
- Physical models to analyze relation between remote sensing and soil parameters based on radioactive transfer physics.

Remote sensing techniques used in ocean study, water security, disaster management and mitigation, climate studies, infrastructure development, community centric applications and village resource centre etc. Remote sensing and GIS aids in the development of crop models for crop insurance product development, carbon auditing from agriculture lands, physiological process based models for crop condition assessment, food security system development, nutrient cycling in agro-ecosystems, farm variability and precision farming, impact of climate change in agriculture and livestock management which requires research and development on need basis.

It also contributes in crop acreage estimation, pest and disease monitoring, hydrological studies etc. Earth observation data through remote sensing has potential applications in agriculture sector. The data helps in achieving sustainability by identifying cultivable waste and marginal lands, improvised cropping practices by increased cropping intensity, creation of supportive infrastructure (Irrigation potential) (**Navalgund *et al.*, 2007**)

2.2 Soil mapping using Geo spatial techniques

Soil mapping gives a brief overview of area and its geography, description of the major soil types in the region, description of their physical, chemical properties, total area land use planning of that area, soil erodibility and crop production information about the area. Soil mapping is done to describe the area, and its various soil characteristics.

Soil mapping done through the different spatial techniques including the visual interpretation and satellite data provides more accurate and efficient soil mapping. The evaluation of soil profile properties which were done previously by rational deduction methods based on the experience. The usage of Geo Spatial technologies like remote sensing and GIS are the one of the non destructive methods that is capable of probing depth and methods of pertinent deductive reasoning using any form of reliable input data. The efficiency of time spent in mapping using geospatial techniques, Aerial photo interpretation and conventional method was in the ratio of 1:5:10 (**Karale *et al.*, 1983)**.

The spectral properties of the soil which is the key factor for the application of Geo Spatial technology is dependent on the soil mineralogy, thermal properties, soil biology and hydrological aspects. Soil profile study can be done by application of Ground Penetrating Radar which has a capacity ranging up to one meter in clay soils and nearly 25m in light textured soils **(Manchanda *et al.*, 2003**).soil properties like salinity, organic matter and iron content are strongly correlated with the soil albedo and the differences in the soil texture, soil moisture, organic matter and salinity is well observed in the spectral range of visible to shortwave infrared wavelength (**Nawar *et al.*, 2015).** The data obtained by soil survey is used for modelling of land use planning. Many geo-spatial models are made by soil forming factor covariate. Raster soil-landscape models are better soil survey program. For chestnut soil properties, probability distribution is obtained for evaluating the effect of soil forming factors on various soil properties. Long term ploughing, use of irrigation water containing high sodium bicarbonates are the reasons for poor land quality Remote sensing coupled with advanced geospatial techniques like ASTER imagery, NDVI, SMOS helps in the accurate interpretation and analysis of the properties (**Mulder *et al.*, 2019**).

Digital soil mapping is advanced in the recent times due to availability of hyper spectral remote sensing data, gamma radio metrics, reflectance spectroscopy etc. Soil mapping is used to predict various Physical and chemical soil properties. A review revealed that out of 90investigated soil mapping studies, 40% were focused on the basic soil properties like bulk density, soil texture and structure, 31% on soil organic carbon and climate change, 16% on hydrological properties and 15% were on soil taxonomy **(Grunwald, 2010)**. Future challenges in agriculture and land management will entail for the adaption of digital soil mapping to landscape settings and. temporal soil patterns. Physical parameters like soil colour, Bulk density, moisture content and Organic carbon when subjected to interpolation revealed the significant variability across the fields of low management and high management in surface and subsurface soil of soil profile **(Muzku *et al.*, 2005)**. Many linear regression models were developed for the estimation of soil moisture in soil profile of water shed regions using remote sensing data based on surface attributes and climatic factors. There exists a strong correlation exists between soil moisture and soil depth (**Venkatesh *et al.*, 2011).** The data analysis using classical statistics and geo statistical parameters like semivariogram and cross variogram analysis explained the interdependency of clay content and soil EC, calcium carbonate mineral content, organic matter content in both cross semivariogram and co-kriging prediction. Hence the co-kriging can be considered as the accurate method for spatial interpolation and soil properties evaluation **(Saleh, 2018).**

2.3 Physico chemical properties of soil

Soil physico-chemical properties determine the movement of air and water in the soil layers. They also influence the water and nutrient retention in the soil. The nutrient availability in the soil play a crucial role in the ecosystem sustainability and soil productivity and is controlled by the interaction of biotic, climatic and physico-chemical variables of the soil. The physical and chemical properties analyzed in this study are Soil Ph, Electrical Conductivity, porosity, bulk density, particle density, water holding capacity, organic carbon, available nitrogen, available phosphorous, available potassium, exchangeable calcium and magnesium, carbonates and bicarbonates, micronutrients(iron, copper, manganese and zinc).

In the soil profile, the affect of climate and topography was significant on the pH of A horizon where as in C horizon and B horizon pH was influenced mostly by the parent material and climatic factors. Soil parameters differ in various land use systems, studies revealed the pH ranges of soil in forest lands as 4.5 -7.2, in barren lands 6.1 to 7.9 and 5.4 - 7.5 in agricultural system. Highest pH value was recorded in barren land and lowest in forest soils **(Zhang *et al.*, 2019** and **Alawi, 2019)**. Electrical Conductivity models relate the bulk electrical conductivity of the soil particles, volumetric water content, and average EC of soil particles. The clay content, particle density, bulk density and proportion of macro and micro pores influence the electrical conductivity in the soil (**Rhodes and Corwin, 1990)**.

Bulk density values usually reflect the porosity status of the soil. Porosity contributes in the classification of soil structure and pore size distribution used in hydraulic conductivity estimation. Advanced techniques like Ultra High resolution X-ray tomography is used in the analysis of soil macro porosity **(Vidal *et al*., 1998).** The bulk density of the soil related to the type of soil particles, organic matter content, mineral type and soil microbial activity. A study revealed a high positive correlation of bulk density with sand content (r= 0.909) and a significant negative correlation with clay(r=0.633) and silt content (r=-0.734) (**Chaudary *et al.*, 2013).** The particle density may vary with the slope, clay mineralogy, tillage and presence of heavy metals. The particle density decreases across the soil profile with increasing depth due to the reduction in the organic matter and porosity **(Hao *et al.*, 2019)**. Soil particle density can be estimated by models using the values of soil organic matter. These methods explained that the combination of soil organic matter and clay content explain near the simple linear regression method the particle density value of 2.86 mg m^{-3} and the multiple linear regression about 92% variation in particle density measured (**Schjonning *et al.*, 2017)**.

Water holding capacity of the soil depends on soil organic matter and soil texture. Partial Least Squares Regression analysis is carried out for WHC modelling based on the statistical indices. The water holding capacity is positively correlated to clay content (r=0.88), bulk density (r= 0.62) and organic matter(r= 0.43)available soil moisture estimation using pedotransfer function is an indirect method for moisture estimation in soil. Pedotransfer function leverages the relation between available soil moisture and various soil attributes like texture, Bulk density and organic matter (**Bordoloi *et al*., 2018 and Blaschek *et al.*, 2019).** Soil colour is influenced by soil moisture, organic matter, soil texture, soil structure and iron compounds. It is statistically useful for the estimation of total nitrogen, total organic carbon and active iron in the soil. A study revealed that the L value (lightness) of the soil is negatively correlated with total carbon and nitrogen (R^2 values are 0.18** and 0.26**) and the yellowness value is positively correlated with the iron content in soil (R^2 = 0.59**) **(Moritsuka *et al*., 2014).**

Soil organic carbon and organic matter influences the soil physical and chemical properties, majorly soil nitrogen. Random forest based digital mapping technique was used to make a 250m map of Soil organic carbon stock using many data layers and data mining approaches of remote sensing (**Sreenivas *et al*., 2016**).studies revealed that organic matter in soil is related to rainfall rate where the rainfall had positive correlation with standing litter (r= 0.85), clay content (r= 0.69) and recalcitrant organic matter (r=0.73). The soil organic matter quality is characterized by thermal stability analysis which gives information on biogeochemical stability (**Fernandaz *et al.*, 2011 and Mani *et al.*, 2017).**

Soil organic matter and nitrogen content are interpreted by reclassified images are created using DEM (Digital Elevation Model). The IDW Inverse Distance Weighing interpolation was superior to Spline Interpolation to evaluate the soil organic matter and nitrogen content **(Bidadi *et al.*, 2012).** The nitrogen cycle and nitrogen status in the soil is affected by anthropogenic activities and climate change. There is a high nitrogen removal by the crop than inputs into soil. Geographical Information system (GIS) is used to estimate the nitrogen levels in the soil pool and atmosphere. The nitrogen available for absorption in the soil can be estimated by MANNER (Manure Evaluation Routine) model after calculating the losses due to leaching and volatilization **(Velmurugan *et al.*, 2008).** The decreased soil pH, increased aluminium concentration in the soil system affects the soil organic matter decomposition and mineralization processes. The nitrogen deposition under 90 kg ha^{-1} per year is seemed as the optimum level for soil nitrogen status and dynamics **(Varma and Sagar, 2020).**

Phosphorus content decrease with increase in the soil depth due to decreasing level of organic residues in the subsoil layers.(**Hasan, 1996)** According to Phosphorus content, the coastal alluvial strips, foothills and alluvium of northern region are of medium P fertility and sandy coastal alluvium, loams of sub humid regions are low in available phosphorus. the low potassium levels in the soil pool occurs due to leaching, removal by plant and microorganisms uptake and levels depend on the clay type in the soil **(Wolde, 2016)** The potassium becomes unavailable to plant access when fixed by clay, lack of moisture in the soil makes clay shrink and makes the potassium non exchangeable. Potassium availability is also dependent on other cations in the soil (**Nathan *et al.*, 2002)**. The mobility of the potassium in soil increases with the increase in soil moisture, a rise in the volumetric water content from 0.1 to 0.4 resulted in the increase in potassium diffusion coefficient by 10 (**Kuchenbuch *et al.*, 1986).**

Deficiency of micronutrients results in severe crop failure and whereas excess levels may lead to toxicity and health hazards. Hence it is crucial to determine the micronutrient levels in soil. The status of the micronutrients in the soil depend on the soil pH, oxidation state, stability of chelates, mycorrhizae, Adsorptive surfaces and organic matter. Concentrations of micronutrients may also vary by soil type, climate, topography and vegetative cover. The deficiency poses imbalance in the soil productivity, sustainability and stability of soils. The micronutrients which are associated with the organic fractions and oxides contribute more to the soil productivity than that of mineral fractions (**Sukeerthi *et al.*, 2020** and **Dhaliwal *et al.*, 2019).** A study on the micronutrients levels in the surface and subsurface layer of soil in slopes of Mount Kilimanjaro using mid infrared spectroscopy and wet analysis. Copper, Iron Manganese and zinc showed a medium correlation (r = 0.31 to 0.46) **(Mathyo *et al.*, 2016).**

2.4 Geographic Information System applications in soil science

Remote sensing and photogrammic techniques provide the digital representation of earth's surface that can be combined with the soil data in a geographic information system for an efficient storage and analysis of huge amount of data. IGIS is a modular package and other different modules are used to create geo spatial databases, editing, topologies creation, analysis, query, retrieval, map composition, coordinate transformation, data conversion tools, data validations, image restoration, image enhancements, image classification and geo processing etc.

Digital soil mapping (DSM) which is the creation of spatial soil information using field and laboratory observation methods combined with the spatial and non spatial inference system. GIS illustrates the relationship between soil properties and DEM derived topographic features, increases the availability of ancillary data for soil characterization, summarizes the non spatial and spatial techniques of pedometry in estimating and modelling soil properties and contributes in land use planning and soil protection (**Buttafuoco, 2018).** Geographic information system is an analytical tool which is used to create the soil database with attributes data of depth, drainage, runoff, pH, salinity, and alkalinity, erosion etc. and links with spatial data. Linking of the spatial data with non spatial data helps to generate the models. GIS technique is also used in the terrain mapping unit (TMU) which is used to integrate the existing maps and data interpreted from the satellite images. Terrain mapping unites are used for purposes like land suitability, estimated erosion rates, land cover use and accessibility information.

For evaluating the effect of soil forming factors on various soil properties probability distribution is obtained.GIS linked with land use land cover (LULC) is used to produce soil erosion risk maps and land degradation which may be caused by physical (Water, wind erosion, crusting, compaction, water logging etc), chemical(pollution, alkalization, salinization, acidification etc) or any biological process **(Grunwald 2010).**Soil survey is done to make decision and evaluate soil change it is a method of describing the characteristics of soil, classified them into different groups, publishing information about the soil and mapping of that area. The dynamic soil properties are changed as result of poor management and Soil resource management can be done by interpreting the soil properties and grouping them accordingly. Soil change can be used as a reference of soil health assessment. Uses of GIS extend to assess the soil salinity, identification of soil and vegetative type and estimation of recharge of ground water. ArcGIS, Quantum GIS and Arc view are the types of software used to generate the soil data base.

2.5 Spatial variability mapping techniques

The soil properties vary from region to region. The uncertainty in the soil parameters is described by the spatial variability mapping. This uncertainty in the physical and chemical properties of the soil occurs due to mineral composition and parent material in the soil. Each soil exhibit variation in the soil properties so digital soil mapping should be done to know the characteristics. The soil properties such as soil texture (sand, silt and clay), soil pH, electrical conductivity (EC), organic matter, mineral content are analyzed by classical and geo-statistical methods. Structural factors such as parent materials, topography, structural factors, topography and soil properties influences spatial distribution of soil properties. Geo-spatial analysis is carried out to demonstrate the spatial variability of soil properties by using GIS technology and interpolation of kriging (**Denton *et al.*, 2017**). Structural factors like parent materials, topography, structural factors, topography and soil properties are the influential factors of spatial distribution of soil properties. Geo-spatial analysis is done to demonstrate the spatial variability of soil properties by using GIS technology and interpolation of kriging. Co-kriging is the one of the most important, accurate and efficient method for spatial interpolation and evaluation of soil properties. Major application of Geo statistical methods in soil science is for the estimation of soil attributes and mapping in the unsampled areas. Soil properties analyzed using both classical and geo statistical methods that included descriptive statistics, semivariograms, cross-semivariograms spatial kriged and cokriged prediction maps and interpolation (**Saleh *et al.*, 2018**). For the spatial prediction of soil properties (sand, silt, clay, pH, organic carbon, Exchangeable Calcium, Exchangeable Magnesium, Available Potassium, Sodium, CEC, and electrical conductivity) in different layers MLR and scorpan-kriging (SK) are used.

MATERIALS AND METHODS

The research work entitled ***"Soil Profile Mapping of Mirzapur District of Vindhyan region using Geo Spatial Techniques"*** was undertaken focusing on the physico chemical characteristics of the soil profile samples taken from the Mirzapur block of Uttar Pradesh. The study was conducted to calculate the remote sensing indices and create spatial variability maps of the study site.

3.1 Study area

Mirzapur district covers a geographical area of 4522 sq.km and one of the Southernmost· district of Uttar Pradesh state with headquarters at Mirzapur. The district is located between 82.21'45" to 82.30'E longitude and 24.41'30" to 24.47'N latitude, bounded on the north by Bhadohi and Varanasi districts, on the east by Chandauli district, on south by Sonabadhra and on the North West by Allahabad.

Physiography

Mirzapur district is characterized by hard hilly rocks particularly at Vindhyan region and alluvial formations. According to geomorphology, the district can be divided into two characteristic units, the Residual hills/table lands and Marginal alluvial plain. River Ganga flows from west to east and changes in the direction at Chunar. The altitude of the area is about 100-300m at Mean Sea Level.

Climate

The climate of the Mirzapur district is Sub-Humid characterized with hot summers and moderate to cold winters. The temperatures ranges about 14.18˚C to 39.80˚C with the May as the hottest month of the year where the mean daily maximum temperature is 40.5˚C and mean daily minimum temperature is 9.0˚C.

The relative humidity of the area is about 85% with a monthly average RH of 41%. The Potential Evapotranspiration of the area is about 1456.7mm and the mean wind velocity is about 2 knots and the maximum wind speed is 4.5km/hr.

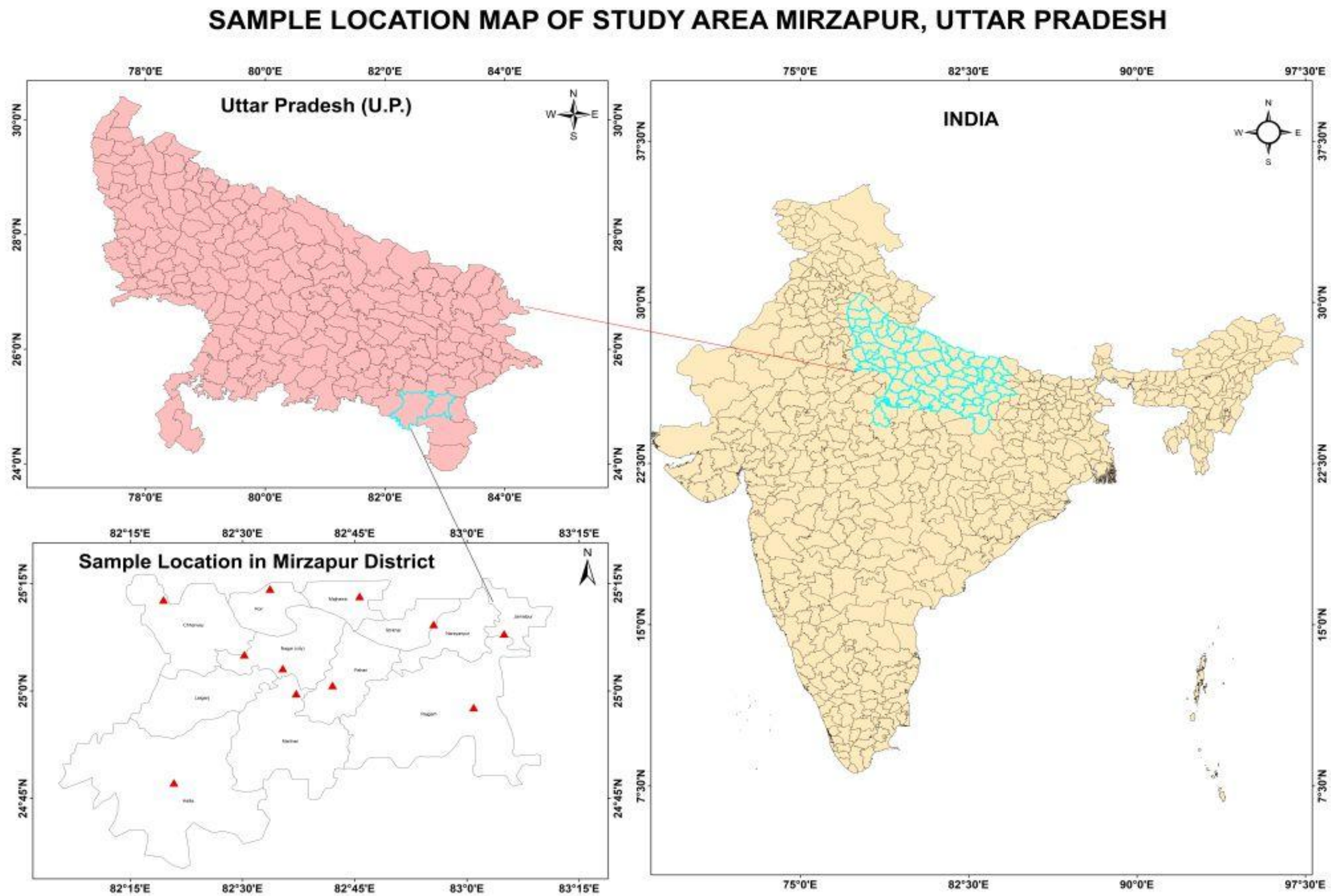


Figure 3.1 Location Map of Study area

Rainfall

The average annual precipitation of Mirzapur district is 1085.00 mm and 90% of the precipitation takes place from June to September. Numbers of rainy days are 53 and most of the rainwater in the monsoon period flows into the rivers and streams due to the hilly topography of the region.

Agriculture and Irrigation

Mirzapur district has a net cultivated area of 3,13,865 hectares of which the net irrigated area is 1,12,477 hectares. The major irrigation sources are canals and ground water.

About 35% of the area is cropped during the kharif season and the major crops grown are sesame, bajra, maize, urd, mustard, wheat etc. most of the land is kept fallow during the rabi season

Soils

Alluvial soils ranging from Sandy to Clay loams are present in the Ganga basin and Red soils (Alfisols) are mostly dominant in the Vindhayanchal region of the district.

Administrative setup

The district comes under Vindhyanchal region and the headquarters is Mirzapur town. Mirzapur district has 4 tehsils namely, Mirzapur (Sadar), Chunar, Marihan and Lalganj which are divided into 12 Blocks. District has 1 Loksabha and 5 Assembly constituencies.

3.2 Soil sampling and processing

Soil samples of both surface and subsurface soil are collected from different sites of Mirzapur district, Uttar Pradesh. The method of sample collection is described below,

- Representative sites are selected for the sampling in the field avoiding the bund regions and shallow/waterlogged parts of the field

- The surface of the sampling site is cleaned to avoid any admixture of weeds, twigs or roots of the plants.
- With the help of a spade, the soil is dug vertically up to a depth of 60cm
- Four samples are collected in the soil vertical section i.e. 0-15, 15-30, 30-45 and 45-60cm.
- Representative sample is derived from the composite sample through quartering technique.
- The representative samples are placed in the polyethylene bags and labeled.
- The samples are then shade dried in the laboratory until the moisture content is reduced.
- Samples are crushed by hand in a motor and pestle if any larger aggregates are present in the sample and then sieved through a 2mm sieve to use for the physico-chemical analysis.

3.3 Instruments and Reagents used for Soil Physico-Chemical Analysis

Table 3.3.1 Instruments or Equipment used for analysis

Parameter	**Instrument/Equipment**
Soil pH	pH meter
Electrical Conductivity	EC meter
Available nitrogen	Kjeldahl apparatus
Available phosphorus	Spectrophotometer
Available potassium	Flame photometer
Sodium content	Flame photometer
Micronutrients	Atomic absorption spectrophotometer

Table 3.3.2 Reagents used for Physico-Chemical Analysis of Soil

S.No.	Parameter	Reagents/Chemicals used
1	Soil pH	• Buffer solutions of pH 4, 7 and 9 • Soil and water suspension at ratio 1:2
2	Soil EC	• Solution of 0.01N KCl • Soil and water suspension of 1:2 ratio
3	Soil Organic Carbon	POTASSIUM DICHROMATE OXIDISABLE OC • 1N potassium dichromate • 0.5N Ferrous Ammonium Sulphate • Diphenyl amine indicator • Ortho phosphoric acid/ sodium fluoride • Concentrated Sulphuric acid TOTAL ORGANIC CARBON • 1N potassium dichromate • 0.2N Ferrous Ammonium Sulphate • Concentrated Sulphuric acid • Phenyl anthranilic indicator
4	Available Soil Nitrogen	• 0.32% potassium dichromate • 2.0% boric acid • 2.5% sodium hydroxide • Mixed indicator (bromocresol green in ethanol) • 0.02N sulphuric acid

S.No.	Parameter	Reagents/Chemicals used
5	Available Phosphorus	OLSEN METHOD • 0.5M sodium bicarbonate solution • 2.5N sulphuric acid • P-nitrophenol indicator • Activated charcoal • Ascorbic acid • Ammonium molybdate • Antimony potassium tartrate
6	Available Potassium	• Neutral normal ammonium acetate • Working standards of K from potassium chloride solution
7	Calcium and Magnesium	• 0.01N EDTA SOLUTION • 4N sodium hydroxide • Ammonium chloride- ammonium hydroxide buffer • EBT indicator • Ammonium purpurate (Murexide) indicator
8	Sodium content	• Neutral Normal Ammonium Acetate • Working standards of Na from pure dry sodium chloride
9	Carbonates and Bicarbonates	• Neutral Normal Ammonium Acetate (for extraction) • 0.05N standard Sulphuric acid • Phenolphthalein indicator • Methyl Orange indicator
10	Micronutrients	• DTPA • Calcium chloride • Tri methanol amine (TEA) • Dilute HCl(to adjust pH)

3.4 Physicochemical analysis of soil samples

The soil samples are analyzed for the physical and chemical parameters in the laboratory. The physical parameters analyzed are Bulk density, Particle density, Porosity, Water Holding Capacity (WHC) and Chemical parameters- pH, Electrical Conductivity, Organic Carbon (OC), Total organic carbon (TOC) Macronutrients (N,P&K), Secondary nutrients(Calcium and Magnesium), sodium, soil alkalinity (carbonates and bicarbonates) and Micronutrients (Fe, Cu, Zn &Mn).

3.4.1 Physical parameters

3.4.1a Bulk Density

Bulk density of the disturbed soil sample is done with Pycnometer (by Black 1965).

Weight of the empty pycnometer is recorded as $W_{1.}$ Then fill the pycnometer with the soil sample up to brim by tapping the bottom gently and record the weight of the pycnometer filled with soil as $W_{2.}$ Empty the soil from pycnometer and fill the water with the help of a burette, the burette reading represent the volume of the pycnometer(V). The bulk density is calculated by the following formula,

Bulk density $=\frac{W2-W1}{V}$ g/cc

3.4.1b Particle density

Particle density/ True density of the soil determined using pycnometer suggested by Black.

Empty weight of the dry pycnometer is recorded as $W_1$and pycnometer is filled with water up to brim and $W_2$is noted. 10 grams of soil is taken in a beaker and about 15ml of distilled water is added. The soil with water is heated on a hot plate and heated to boil. Later the soil is allowed to cool and the contents are transferred into the pycnometer and filled with distill water and the weight is recorded as W_3. The particle density is calculated by,

Particle density = $\frac{10}{(W2+10)-W3}$ g/cc

3.4.1c Water Holding Capacity

Water holding capacity of the soil is done by keen cup method (by Piper 1966).

In a keen cup filter is arranged at the bottom covering all the perforations and the weight of the cup with filter is recorded as W_1. Then soil is filled in the cup by gently tapping it and W_2 is recorded. The cup with the soil is placed in a petri plate filled with water and left for 4-5 hours so that the soil becomes saturated completely. Later the keen cup is removed from the water and kept aside for 30 minutes to allow the drainage of excess water and the weight of the keen cup with soil is recorded as $W_{3.}$ The water holding capacity is calculated with the following formula,

$$\text{Water Holding Capacity (\%)} = \frac{(W3-W1)-(W2-W1)}{W2-W1}\times 100$$

3.4.1d Porosity

Porosity of the soil can be estimated by bulk density and particle density of the soil using the following formula,

$$\text{Porosity (\%)} = [1-\frac{Bulk\ density}{Particle\ density}]\times 100$$

3.4.1e Soil Colour

Soil colour of the profile samples is estimated by Munsel Colour chart which evaluates the Hue (Dominant colour), Value (Degree of brightness or darkness) and Chroma (Purity of colour) of soil.

3.4.2 Chemical parameters

3.4.2a Soil pH

Soil pH estimated by a digital pH meter (by Jackson) which measures the active acidity of the soil.

To measure the soil pH, 10 grams of soil is taken in a beaker and water is added in a ratio of 1:2 or 1:2.5 i.e., either 20 or 25ml of distilled water is added to the soil and stirred vigorously and kept aside for 30 minutes. After half an hour the contents are stirred well and the reading is noted.

Before taking the reading of the soil sample, the pH meter is calibrated using the buffer solutions of pH- 4 and pH-7.

3.4.2b Electrical conductivity

Electrical conductivity of the soil is the indicator of soluble salts present in the soil which is measured by using EC meter as described by Jackson.

To measure the EC of the soil, 10 grams of soil sample is taken in a beaker and distill water is added at a ratio of 1:2 or 1:2.5 and stirred well. The contents are allowed to settle for 30 minutes and the reading is taken using EC meter without disturbing the soil.

Before taking the readings of soil samples the EC meter should be calibrated using 0.01N KCl which gives a EC of 1.41dS/m.

3.4.2c Organic Carbon

- **Potassium dichromate oxidizable OC- Walkley and Black method**

One gram of soil sample is taken in a 500ml conical flask, 10 ml of potassium dichromate and 20ml of concentrated sulphuric acid is added into the flask and kept in dark for 30 minutes. Later 200ml of distilled water is added to the contents followed by addition of 2-3 drops of diphenyl amine indicator and half spatula of sodium fluoride.

The contents are titrated against 0.5N ferrous ammonium sulphate solution until the brown color of the contents turns to ink blue and then green. The appearance of green color is the end point of the titration. A blank titration should also be carried out. The organic carbon through this process is calculated by formula,

$$OC\% = N\frac{B-S}{Weight\ of\ the\ soil}\times 0.03\times 100$$

Whereas,

N - Normality of FAS

B – Titer value/Burette reading of Blank

S – Titer value/Burette reading of Soil sample

- **Total organic carbon**

Total organic carbon is determined by rapid and precise method by Yeomas and Bremmer, 1988.

To one gram of soil sample taken in a conical flask, 5ml of 1N potassium dichromate and 7.5ml of concentrated sulphuric acid is added. Then it is placed on a block digester for 30 min and later allowed to cool for 15 minutes. The volume of the sample contents id made up to 50ml by adding distilled water and titrated against 0.2N ferrous ammonium sulphate solution using Phenyl anthranilic indicator (calculated with same formula as OC).

3.4.2dAvailable nitrogen

Estimation of available nitrogen in the soil described by Subbiah and Asija in 1956.This method uses a kjeltech semi auto analyzer. In the distillation tube 5 grams of soil sample is taken and 5ml of distill water is added to the tube to clear any soil particles attached to the sides of the tube, 25ml of potassium permanganate is added and the distillation tube is set into the analyzer. In a 250ml conical flask 20ml of boric acid of pH 4 is taken and attached to the outlet pipe of analyzer.

On pressing the button mounted on the apparatus 25ml of sodium hydroxide solution is aspired into distillation tube gradually. The distillation process is set for 9min. In the distillation process, Nitrogen released from the soil sample in the form of ammonia gets trapped by boric acid which is indicated by the green color of the contents in the conical flask at the outlet pipe.

After distillation, the contents are titrated against 0.02N sulphuric acid until the green color turns into pink color.

$$\text{Available Nitrogen (kg/ha)} = \frac{(S - V) \times 0.02 \times 14 \times 2.24 \times 10^6}{1000 \times 5}$$

Whereas,

S = Titration value of Sample

V= Titration value of Blank

3.4.2e Available phosphorus

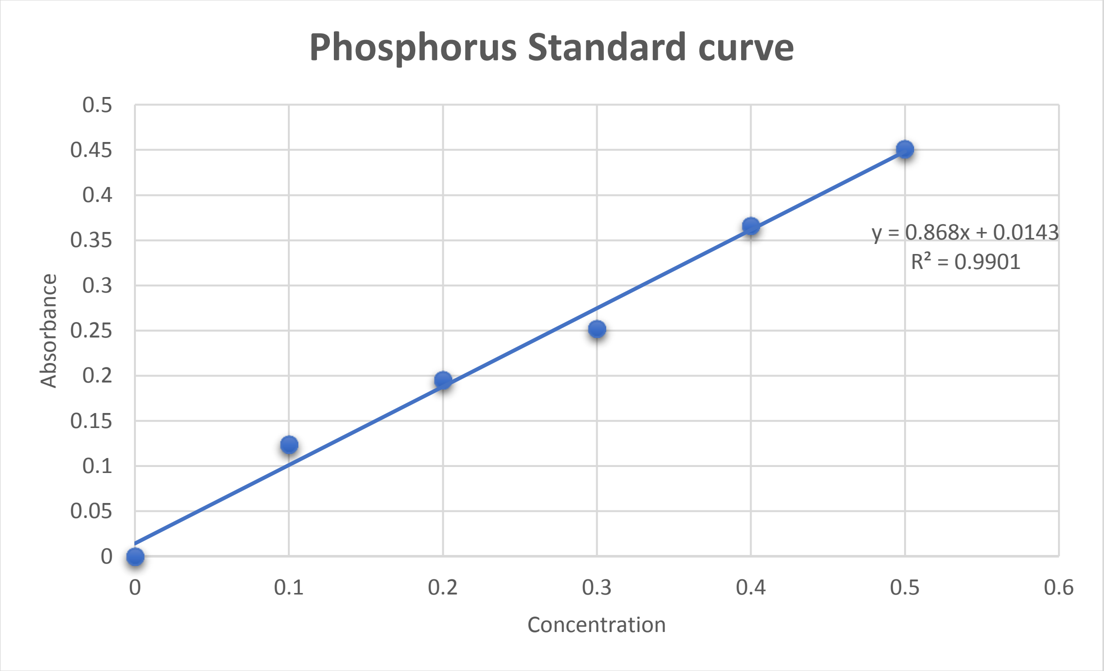
The average pH of soil samples is between slightly acidic to slightly alkaline. Olsen’s method (1954) is opted for the estimation of available phosphorus as the pH is above 5.0.

This process involves in the preparation of 2 reagents, Reagent A and Reagent B. Reagent A is a mixture of Ammonium molybdate, Antimony potassium tartrate and 2.5M Sulphuric acid. Reagent B or Murphy Riley solution is prepared by adding 200ml of Reagent A and 1.056g of Ascorbic acid.

2.5 grams of soil sample is taken in a 250ml conical flask and 50ml of 0.5N sodium bicarbonate solution is added followed by half spatula of activated charcoal. The samples are kept for shaking on a mechanical shaker for 30 minutes. The contents are filtered using Whatman No.1filterpaper.

From the filtrate 10ml of aliquot is pipette out into a 25ml volumetric flask and 2-3 drops of p-nitrophenol indicator is added then the contents turn to yellow color. 2.5M sulphuric acid is added drop by drop until the yellow color disappears and then 8ml of Reagent B is added and volume is made up using distilled water.

At 730nm, the sample readings are taken in spectrophotometer. Working standards od phosphorus are prepared to make a standard curve.



Available phosphorus(kg/ha) = concentration of sample×50(dilution factor) ×2.24

3.4.2f Available Potassium

Available potassium of the soil is estimated using Flame photometer, using Neutral Normal Ammonium Acetate as the extractant as described by Schellenberger and Simon in 1945.

Five grams of soil sample is taken in a 250ml conical flask, 25ml of neutral normal ammonium acetate is added and the contents are shaken on a mechanical shaker for 5 minutes. The contents are filtered using Whatman No.1 filterpaper and reading is recorded in the flame photometer.

Standards of potassium of different concentrations (ppm) are made using KCl for calibrating the flame photometer

Available potassium (kg/ha) = Sample reading (ppm) × 5(dilution factor)×2.24

3.4.2g Exchangeable Calcium

The exchangeable calcium in the soil is determined using neutral normal ammonium acetate (by Jackson, 1973.) as 5 g of soil is added with 25ml of NNAA and shaken for 5 minutes. The contents are filtered and 5ml of aliquot is taken for the titration.

In a 250ml Erlenmeyer flask, 5ml of aliquot is taken and added with 25ml of distilled water. 5ml of 4N sodium hydroxide buffer solution is added to the sample followed by addition of 50mg/ a pinch of Murexide (Ammonium purpurate) indicator which gives the contents pink color. The contents are titrated against 0.01N EDTA solution until the purple color appears and the titer value is noted.

$$\text{Exchangeable calcium (meq/L)} = \frac{Titration\ value \times Normality\ of\ EDTA \times 1000}{Volume\ of\ aliquot\ taken}$$

3.4.2h Exchangeable Calcium & Magnesium

In soil, the exchangeable calcium+ magnesium is done after the preprocessing of the soil sample with neutral normal ammonium acetate solution as mentioned in exchangeable calcium process.

From the filtrate obtained through pre-processing with neutral normal ammonium acetate, 5ml of aliquot is taken in a 250ml Erlenmeyer flask and 25ml distilled water is added.one ml of ammonium chloride-ammonium hydroxide buffer is added to the contents followed by 2-3 drops of Eriochrome Black T (EBT) indicator which gives a wine-red color to the contents. Sample is titrated against 0.01N EDTA until the wine-red color turn to Blue.

By subtracting the calcium content from calcium and magnesium content, the exchangeable magnesium can be determined.

Calcium+ Magnesium (Meq/L) = $\frac{Titration\ value \times Normality\ of\ EDTA \times 1000}{Volume\ of\ aliquot\ taken}$

Exchangeable Magnesium= Ca+ Mg (Meq/L) – Ca(Meq/L)

3.4.2i Sodium content

In soil, the sodium content is determined by using Flame photometer after the pre-processing of the soil sample with Neutral Normal Ammonium Acetate.

Five grams of soil sample is taken in a 250ml conical flask and 25ml of NNAA is added to it. The contents are placed on a mechanical shaker and shaken for 5 minutes and filtered through Whatman No.1 filter paper. The filtered aliquot is aspired to the flame photometer to record the readings (ppm).

Working standards of different concentrations (ppm) of sodium are made to calibrate the flame photometer before taking the sample readings.

3.4.2j Carbonates and Bicarbonates

Soil solution is extracted with 25ml of Neutral Normal Ammonium Acetate added to 5grams of soil sample and placed on a mechanical shaker for 5 min. the contents are filtered through Whatman No.1 filter paper.

In a 250ml conical flask 5ml of filtered aliquot is taken and 25ml of distilled water is added. By addition of 2-3 drops of phenolphthalein indicator, if the contents show pink colour it is titrated against standard sulphuric acid until the colour disappears to estimate the carbonates. If the contents do not show any colour after the addition of indicator it represents the absence of carbonates.

To the same contents in the conical flask, 2-3 drops of methyl orange indicator is added which gives a straw yellow colour and it is titrated against standard sulphuric acid until the contents turn to rosy red colour. The burette readings are noted for further calculations.

$$CO_3^{-2} \text{ inMeq/L} = \frac{Normality\ of\ Sulphuric\ acid \times Burette\ reading \times 1000}{volume\ of\ aliquot\ taken}$$

$$HCO_3^{-} \text{ in Meq/L} = \frac{Normality\ of\ Sulphuric\ acid \times Burette\ reading \times 1000}{Volume\ of\ aliquot\ taken}$$

3.4.2kMicronutrients

Micronutrients Iron, copper, Manganese and Zinc are estimated by Atomic Absorption Spectrometer using DTPA extraction method.

Soil sample of 10 grams is taken in a 250ml conical flask and 20ml of DTPA extractant(0.005M DTPA+0.1M TEA+0.01M $CaCl_2$ of pH 7.3) is added to it. The contents are shook for 2 hours on a mechanical shaker and filtered with Whatman No.42 filter paper. The filtered aliquot is aspirated to atomic absorption spectrometer to get the readings.

$$\text{Micronutrients (mg/kg)} = \frac{AAS\ reading \times Volume\ of\ extractant}{amount\ of\ soil\ sample\ taken(g)}$$

3.5 Spatial Variability mapping of soil properties

The observations of physico-chemical parameters analysed by the standard procedures are subjected to interpolation in Geographic Information system (GIS) technology using ArcGIS 10.5 software. The variability maps are created for the soil profile of 0-15, 15-30, 30-45 and 45-60 cm depths to demonstrate the variability of soil properties which differ with the increase in depth using Inverse Distance Weighing (IDW) interpolation which is a multivariate interpolation technique which uses the scattered set of points.

Chapter IV

RESULTS AND DISCUSSION

Soil is a dynamic natural body and the vital component for plant growth and food production. Efficient management and monitoring of soil system is the key factor for the increased productivity of the soil. Soil profile study helps understanding soil genesis as well as the inherent quality and condition of the soil. Advanced technologies in remote sensing like radar and spectroscopy are proved to be efficient in non destructive study of the soil profile. Remote sensing and Geo spatial technology can be considered as a potential technology for the precise evaluation and monitoring of soil physical properties, erosion status, nutrient content and soil quality etc. the current study on **"Soil profile mapping of Mirzapur district of vindhyan region using Geo spatial techniques"** makes use of the ground truthing (Laboratory analysis) and GIS technology to represent various physical and chemical parameters of soil profile.

4.1 Spatial Variability Mapping of Physico-Chemical properties of Soil profile samples from various regions of Mirzapur district of Vindhyan region

The spatial variability mapping of soil profile samples of Mirzapur district in Uttar Pradesh is done by recording the coordinates of the sample sites using Global Positioning System and Geo referencing the soil samples.

Soil profile samples are collected from twelve regions in the district at depths of 0-15cm, 15-30cm,30-45cm,45-60cm covering the surface and subsurface soil. The soil samples are labelled and stored in the polythene bags. Soil profile samples were analyzed in the laboratory using the standard analysis methods to determine various Physico- chemical parameters such as soil pH, Electrical Conductivity, Bulk Density, Particle Density, Porosity, Water Holding Capacity, Organic Carbon, Organic Matter, Major nutrients Nitrogen,Phosphorous&Potassium, Secondary nutrients Calcium(Ca) and Magnesium (Mg) were determined.

Soil alkalinity was estimated by analyzing Carbonates and Bicarbonates in the samples with standard laboratory method of titration. Sodium levels in the soil profile samples were estimated using Flame Photometer. Atomic Absorption Spectrophotometer (AAS) was used to quantify the levels of micronutrients, Iron(Fe), Copper (Cu), Manganese (Mn) and Zinc (Zn) in the soil profile samples.

Values of various physical and chemical parameters after the laboratory analysis were used to draw the spatial variability maps with the help of ArcGIS Map 10.5 by digitalizing the study area and creating a shape file. The data is further subjected to IDW interpolation for interpreting the levels of various soil parameters. The relation between the physico chemical parameters and micro nutrients levels was analysed with Karl Pearson Correlation Coefficient.

Sampling Location Details

Table 4.1 Location details of sampling sites.

Sample ID	Sampling point	Latitude	Longitude	Elevation (m)
1	Belahi	25.0387	83.50627	135
2	Badauhi	24.78659	82.34732	166
3	Lauriya	25.01325	82.70072	105
4	Hinauta	24.96172	83.01493	102
5	Karanpura	25.08465	82.50417	88
6	Gaura	25.21228	82.32417	73
7	Bhagaon	25.2377	82.56145	77
8	Bela	24.99424	82.6196	170
9	Charia	25.22045	82.76093	70
10	Barkaccha,RGSC(Orchard)	25.05253	82.5898	167
11	JalalpurMafi	25.15524	82.92583	60
12	Ori	25.13321	83.08279	70

4.1.1 Physical properties of soil

4.1.1.1 Soil pH

The pH values of the soil profile samples collected from various regions of Mirzapur District(Table 4.1) ranged from 5.1 to 8.8. Lower levels of pH are observed in the soil at 30-45cm depth and the higher level of pH is recorded in the surface layer of 0-15cm depth. The soil profile sample with highest pH is of Jabalpur mafi located in eastern part and the lowest soil pH is found the soil profile sample of RGSC, Barkaccha, central part of the district.

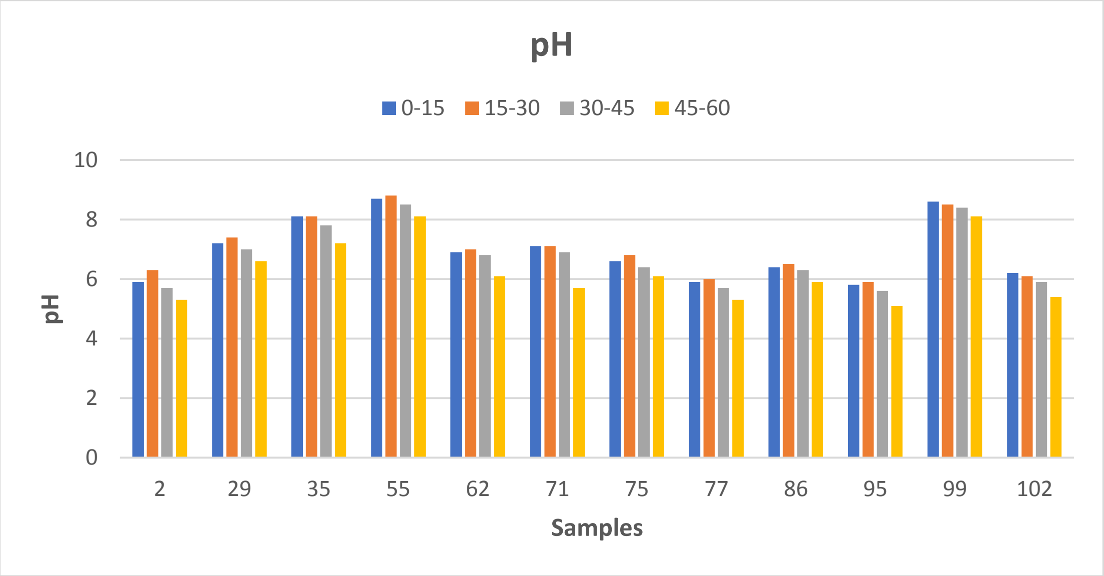


Figure 4.1 Chart of pH values in soilprofile samples at various depths

The coefficient of variance for the pH values is observed as 15.2% indicating a moderate level of dispersion. The coefficients of skewness and kurtosis are 0.517 and -0.818 representing a positively skewed data and light tail distribution. The pH values decreased with the increase in depth in all the soil profiles.

It can be inferred from the spatial variability map that about 70% of the surface profile samples exhibited a pH range of 6.6 to 8.2. Soil pH is significantly influenced by organic matter content, clay content, crop type and climatic factors.

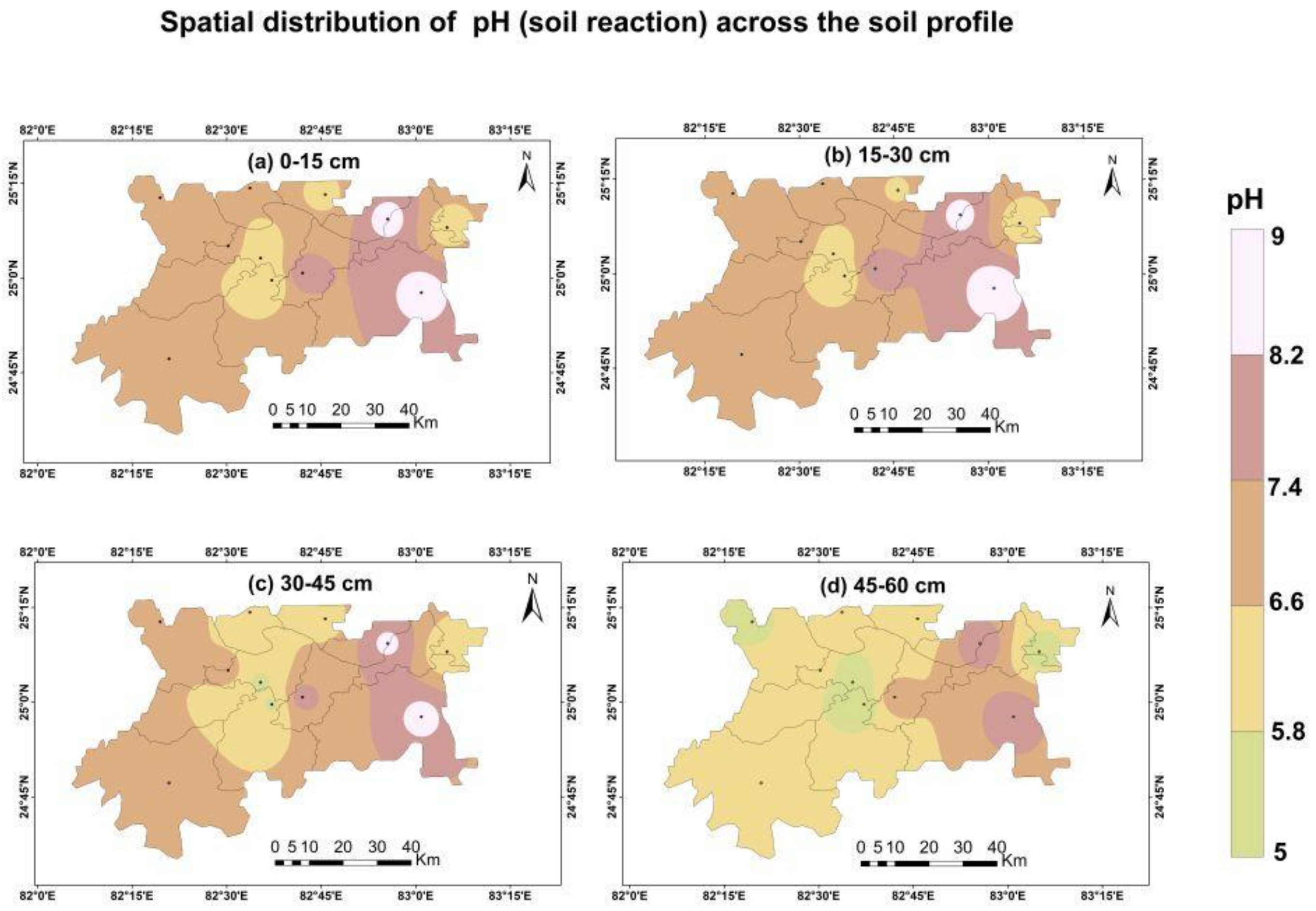


Figure 4.2 Spatial variability map of soil pH across soil profiles of various regions in Mirzapur district of Vindhyan region

4.1.1.2 Electrical conductivity

The soil profile samples of Mirzapur district (Table 4.1) showed Electrical conductivity values ranging from 0.02 to 0.206dS $m^{-1}$with a mean value of 0.084dS m^{-1}. Highest EC values are observed in the surface layer of 0-15cm depth and lowest electrical conductivity values were found at 45-60 cm depth. The soil profile with minimal values of electrical conductivity was found in Belahi the central part of the district and Ori region on Southern west part of District has shown high values of EC.

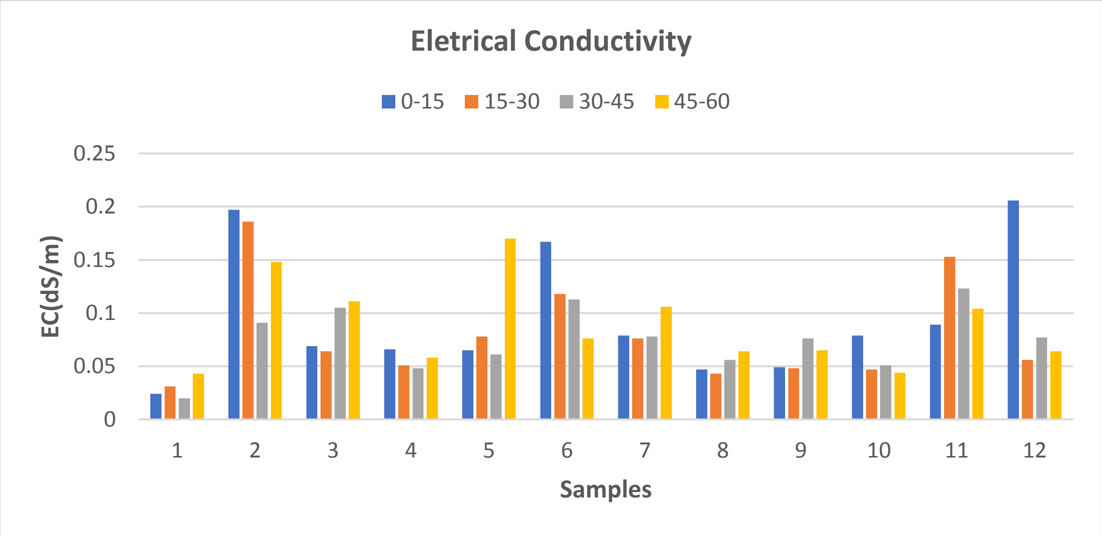


Figure 4.3 Chart of EC in soil profile samples at various depths

Electrical conductivity values showed a skewness coefficient of 1.18 which interprets a positively skewed data and kurtosis coefficient of 0.78 interprets near to normal distribution. The coefficient of variation is 53.8% which shows high dispersion.

The electrical conductivity values showed a safe range of below 2.0 dS m^{-1} which is of negligible level. The EC values were low at 45-60cm depth than the top layer in most of the soil profiles, the subsoil layer of Belahi, Badauhi, Karanpura and Bhogaon showed increase in the EC levels. Low EC values indicate lesser accumulation of salts in the soil profile. Level of salts in the soil depends on climatic factors like precipitation and temperature, rate of run-off, drainage and soil type and texture. Electrical conductivity of the sandy soil is less compared to clayey soils which represent a negative correlation between EC and Bulk density of the soil (Chaudary *et al*., 2013).

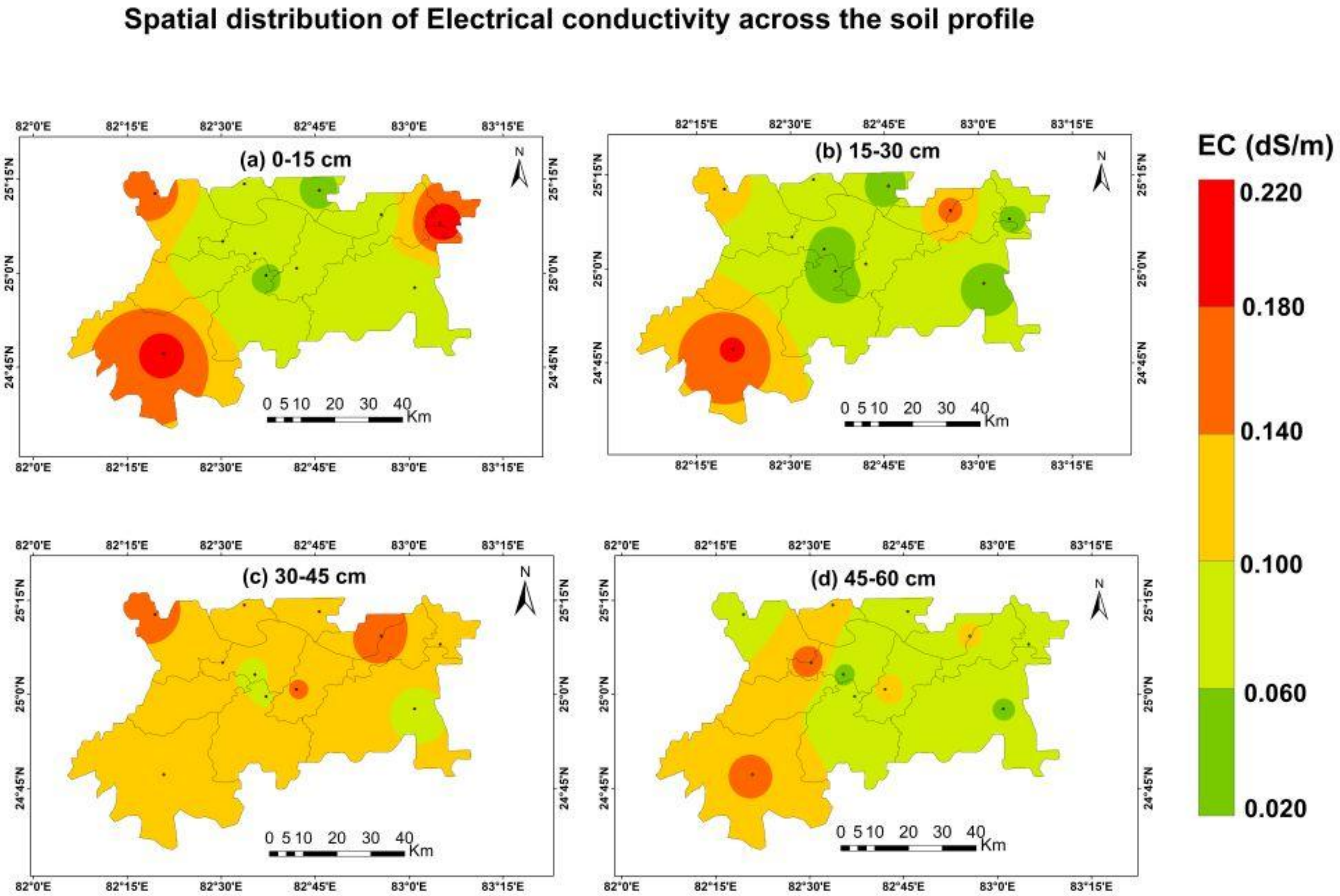


Figure 4.4 Spatial variability map of soil EC across soil profiles of various regions in Mirzapur district of Vindhyan region

4.1.1.3 Bulk Density

Bulk density values in the soil profile samples of Mirzapur district (Table 4.1) ranged from 1.251g/cc to 1.382g/cc with a average mean value of 1.324g/cc. Sub surface layer of soil at 45-60cm showed highest bulk density and the top layer of 0-15cm has lowest bulk density values. The soil profile with highest bulk density is observed in the Hinauta followed by Ori region. Lowest bulk density value in soil profile samples is observed in the Chunar region of the district.

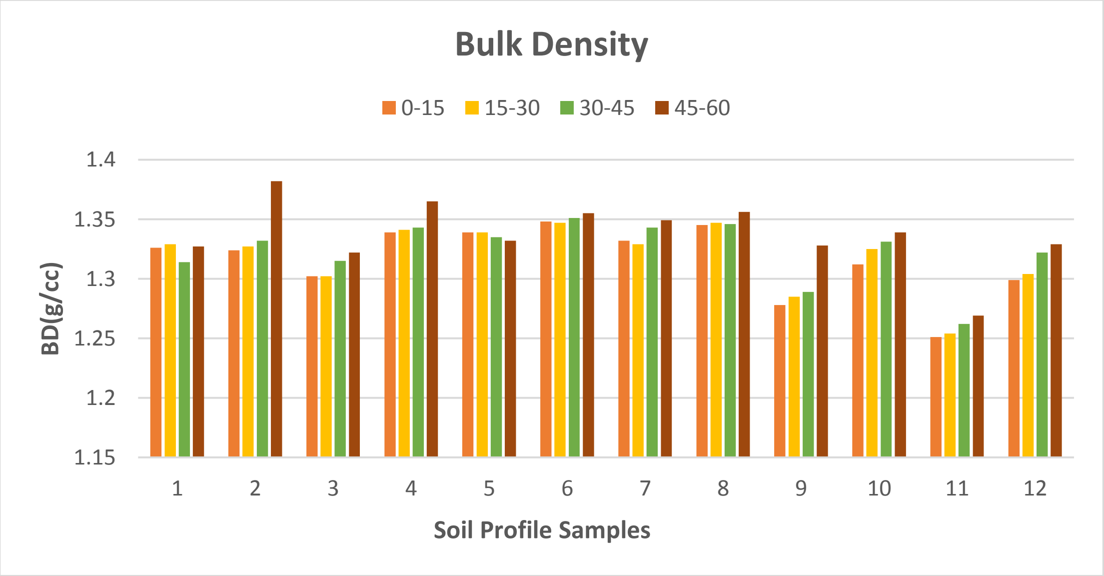


Figure 4.5 Chart of Bulk density in soil profile samples at various depths

The coefficient of skewness is -0.93 which is negative and indicates moderately skewed data. Kurtosis coefficient is 0.77 interprets a near to normal heavy tailed distribution. The coefficient of variation of bulk density is observed as 2.51 which interpret lower level of dispersion. The bulk density of the soil increased with the increase in the depth.

Bulk density of the soil is related with the soil organic matter and affects the soil porosity and water holding capacity. Bulk density shows a high degree of negative correlation with the organic matter content in the soil (Ahad *et al.*, 2015).

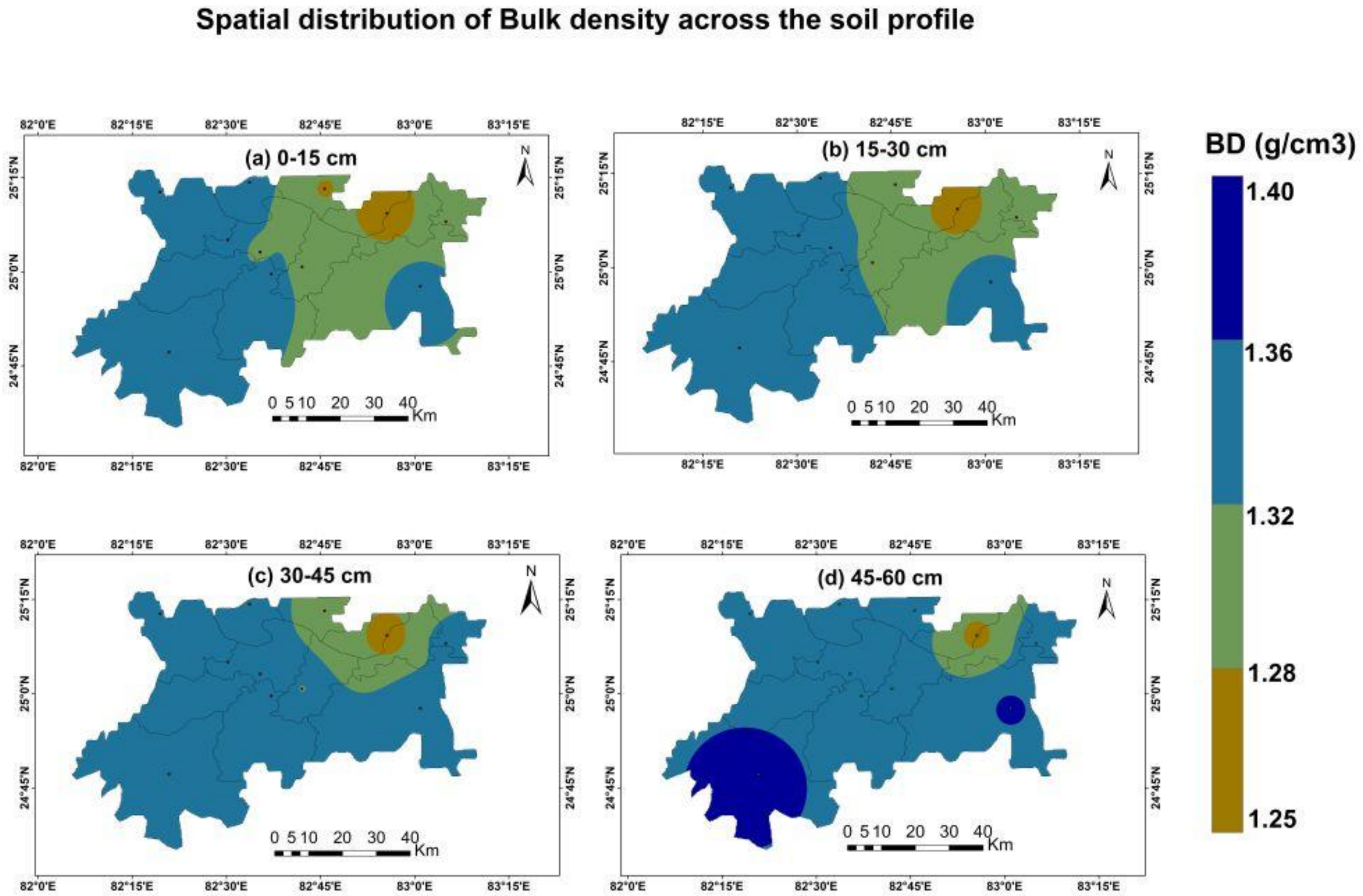


Figure 4.6 Spatial variability map of soil Bulk density across soil profiles of various regions in Mirzapur district of Vindhyan region

4.1.1.4 Particle density

Profile samples of soil in various regions of Mirzapur district (Table 4.1) showed particle density values of range of 2.399 to 2.665 g cc^{-1} with a average value of 2.5408g cc^{-1}. lower particle density values are found at 45-60cm depth of the soil profile and highest values are found in surface layer at 0-15cm and 15-30cm.Highest particle density values were observed in Hinauta, Lauriya regions and lowest particle density values are found in the Charia and Barkaccha regions of the district.

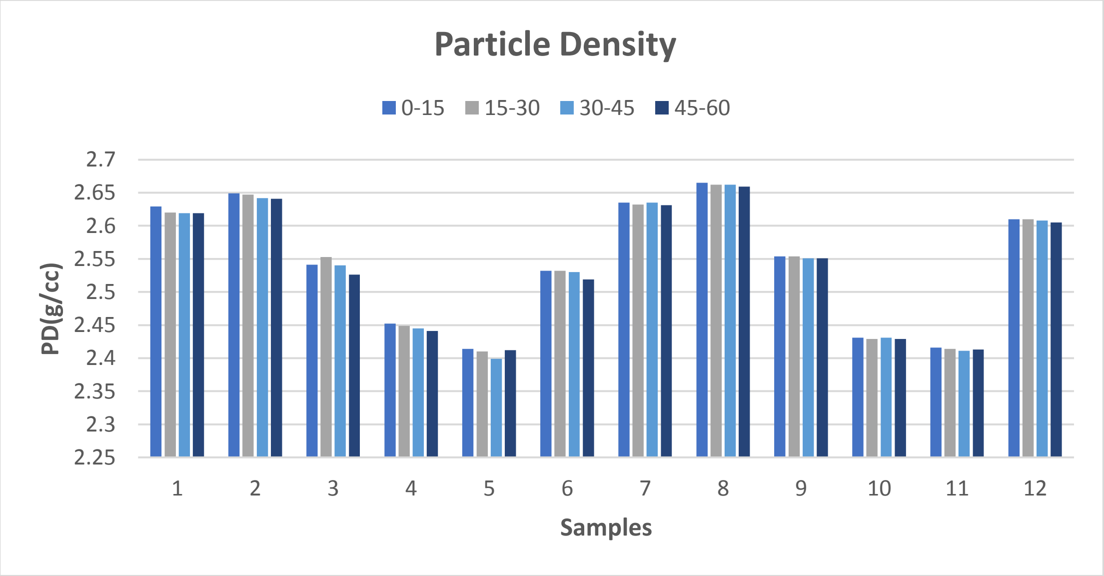


Figure 4.7 Chart of particle density in soil profile samples at various depths

Particle density values showed a skewness coefficient of -0.229 showing negatively skewed data and fair symmetry. Kurtosis coefficient of -1.517 interprets a light tailed distribution. The coefficient of variation is 3.64% which indicates a lower level of dispersion. Particle density of the soil did not show any significant change across the soil profile.

Particle density values related to soil texture, level of organic matter in the soil. Particle density is directly related with the clay and organic matter levels in the soil (Schjonning *et al.*, 2017).

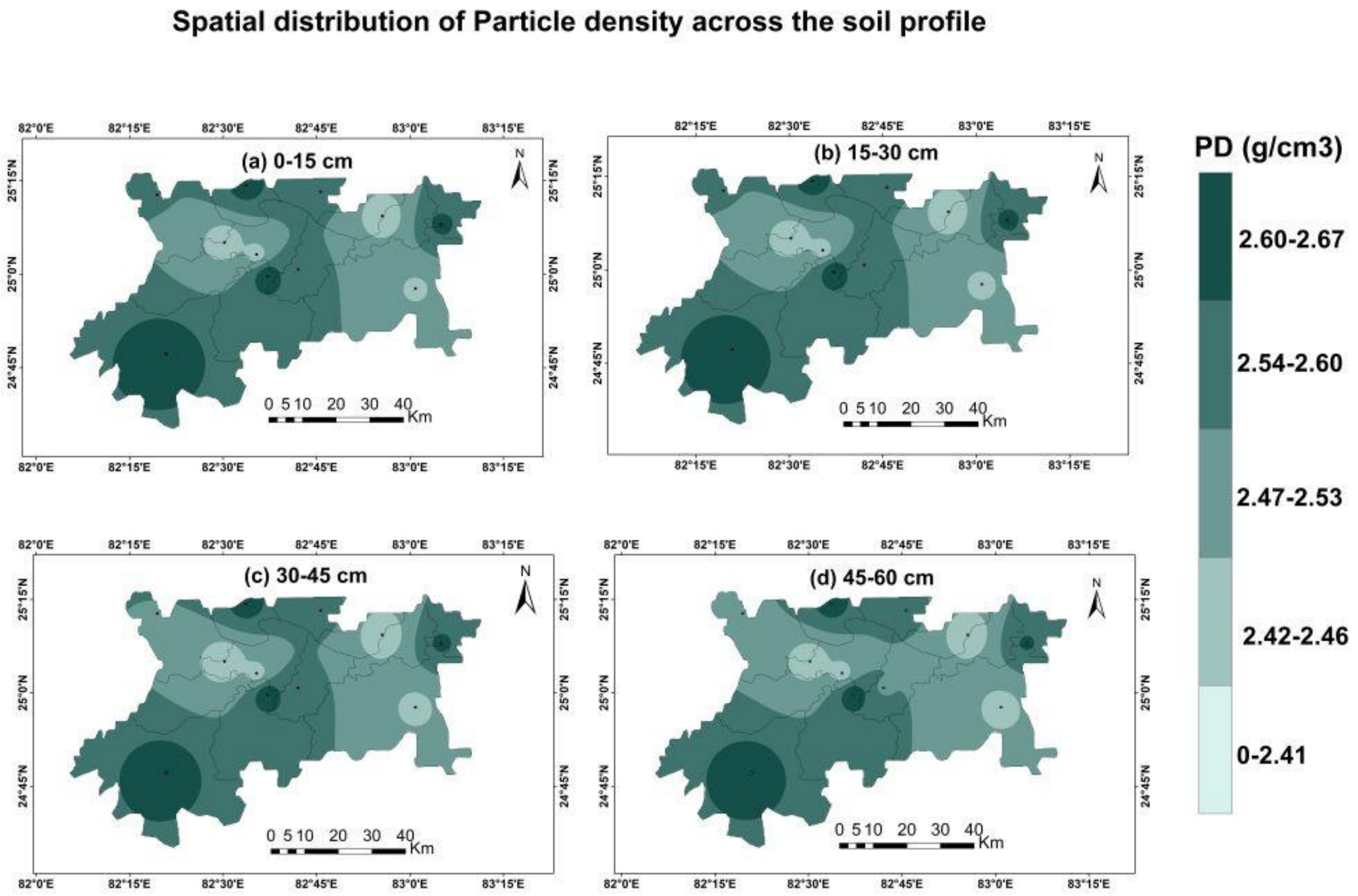


Figure 4.8 **Spatial variability map of soil particle density across soil profiles of various regions in Mirzapur district of Vindhyan region**

4.1.1.4 Porosity

The porosity values in the soil profile samples in Mirzapur district (Table 4.1) were ranged between 44% to 50.2% with a mean value of 47.7%. Porosity values are high in the furrow slice layer of 0-15cm and lowest in the sub surface layer of 45-60cm. the soil profile samples with Highest porosity value is in the Jabalpur Mafi region and lowest values were observed in the Barkaccha and Ori regions of the district.

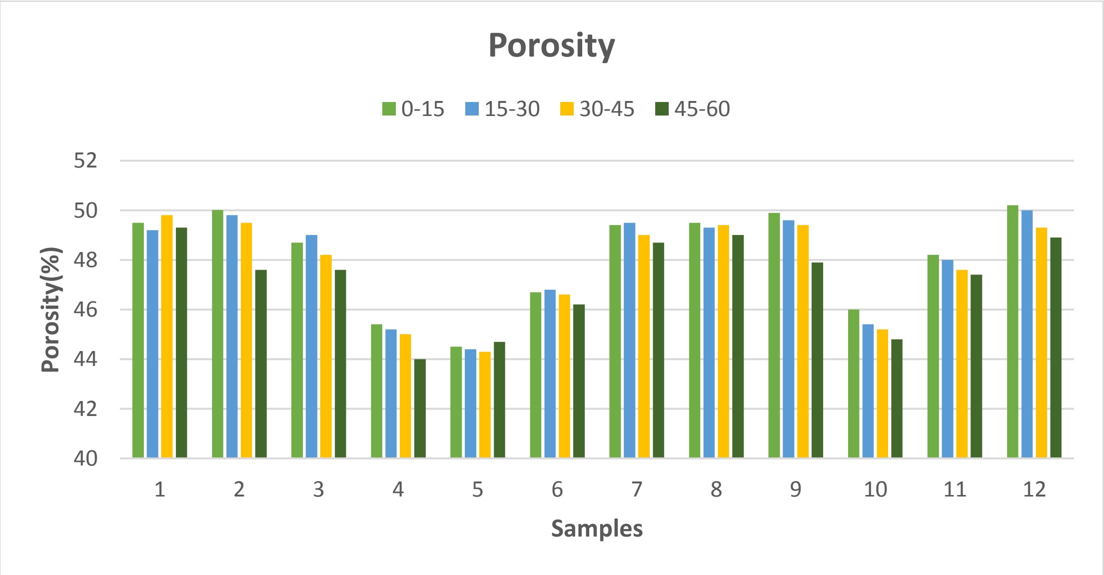


Figure 4.9 Chart of porosity in soil profile samples at various depths

The coefficient of skewness and kurtosis for the porosity of soil profile samples is observed as -0.61 and -1.09 respectively.This represents a moderately skewed data and light tailed distribution. The coefficient of variation for the porosity values of the soil profile samples is 4.06% which indicates less dispersion. Porosity of the soil decreased with the increase in the soil depth in the soil profile samples. A negative correlation is observed for porosity with particle and bulk density (r= -0.425 and -0.309). The porosity values of soil profile samples in the district mostly lied between 46-50%. Porosity values in the soil profile are mostly related with the soil texture and soil structural properties porosity is decreases with increase in the bulk density in the soil system (Ahad *et al*., 2015).

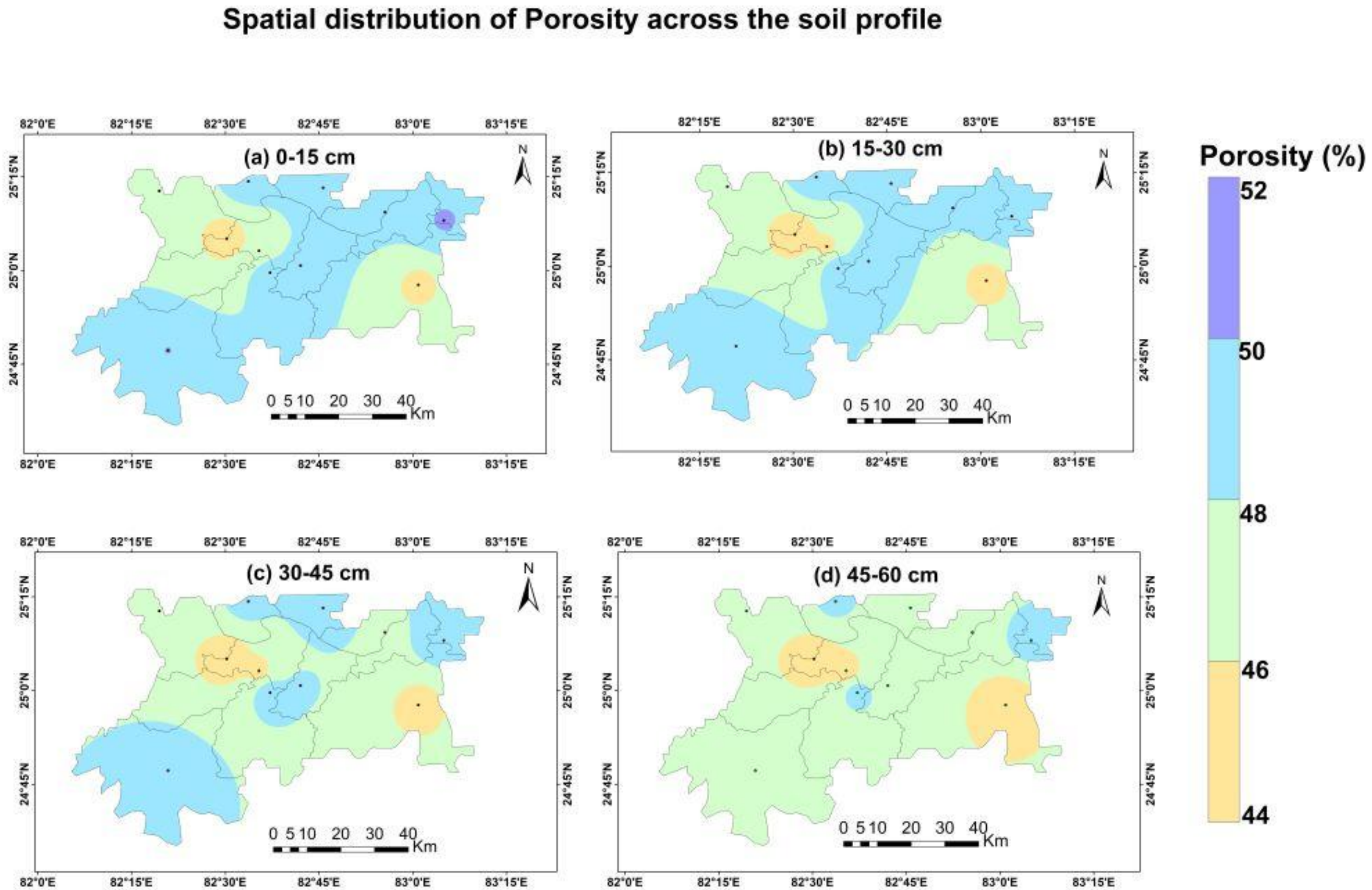


Figure 4.10 Spatial variability map of porosity across soil profiles of various regions in Mirzapur district of Vindhyan region

4.1.1.5 Water holding capacity

Water holding capacity of the soil profile samples collected from various regions of Mirzapur district (Table 4.1) ranged from 41% to 49.9% with a mean value of 45.8%. Highest values of water holding capacity is found in the surface layer at 0-15cm and 15-30cm depth and lowest values are found in the sub surface layer of 45-60cm depth in the soil profile. In the samples, the soil profile of Gaura region is with highest water holding capacity and profiles in Barkaccha and Ori are with lowest water holding capacity.

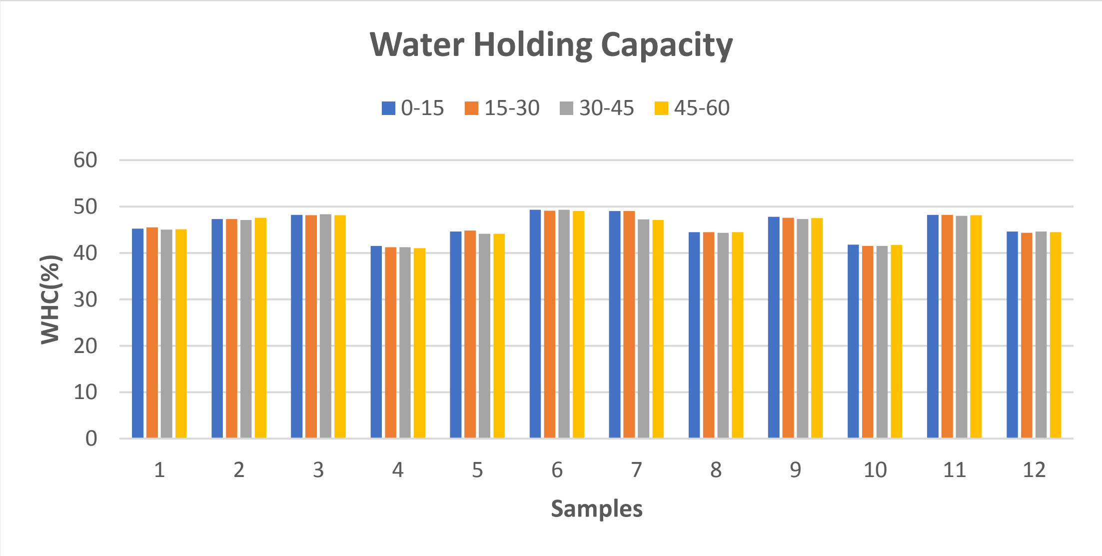


Figure 4.11 Chart of WHC in soil profile samples at various depths

The coefficient of skewness is -0.465 and coefficient of kurtosis is observed as -0.965 which represents fairly symmetrical skewness and light tailed distribution of data. The coefficient of variation for the water holding capacity of soil profile samples is observed as 5.63% indicating a less dispersion. Significant variation was not found in the water holding capacity values across the surface layers of soil profile samples, subsurface layer has lower water holding capacity.

Water holding capacity values of 44-48% is observed in the major part of the district. WHC is interrelated with the bulk density, particle density, porosity and it is significantly correlated with the organic carbon content in the soil (r=0.8010**) (Deb, 2013).

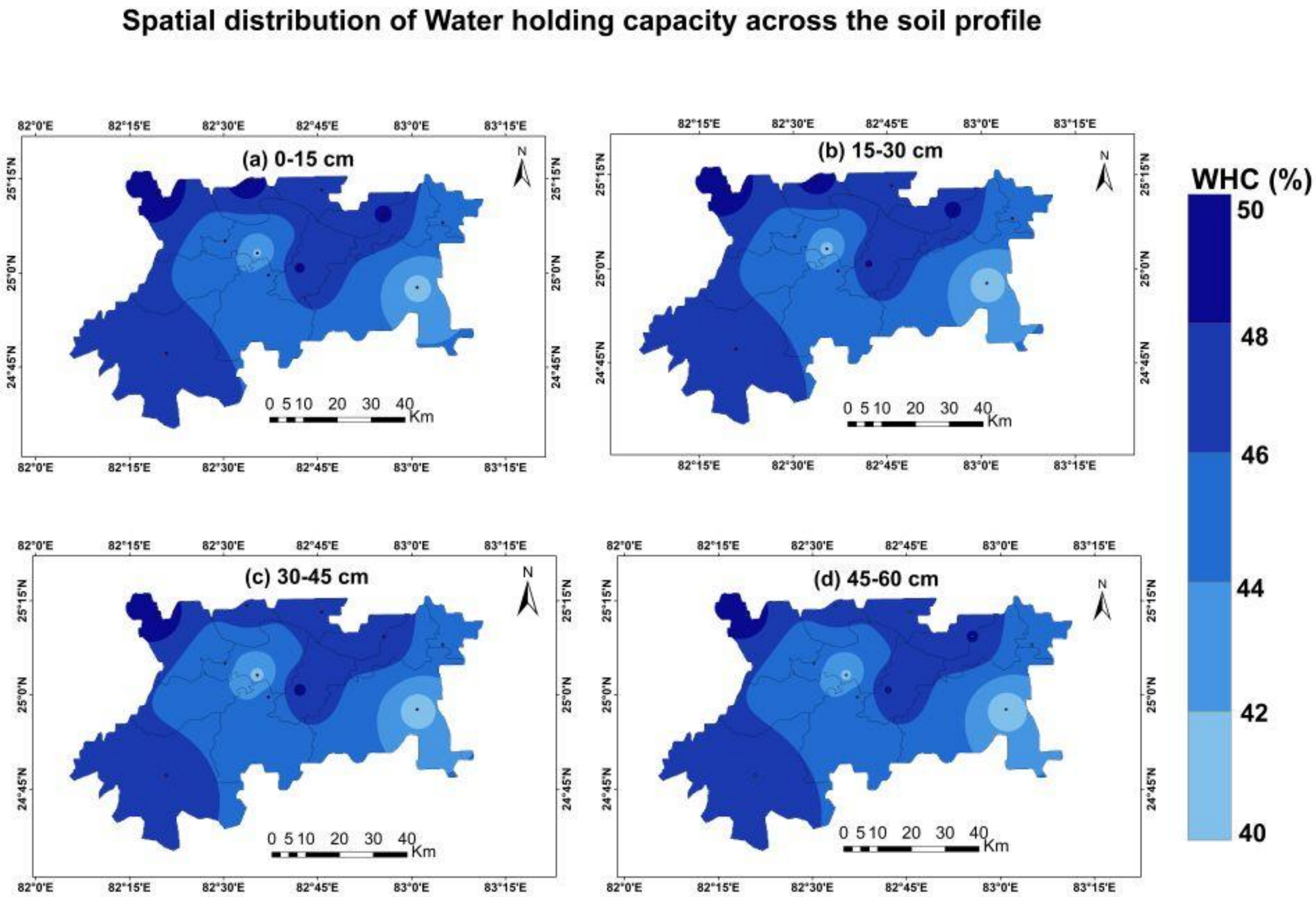


Figure 4.12 Spatial variability map of WHC across soil profiles of various regions in Mirzapur district of Vindhyan region

4.1.1.6 Soil colour

Soil colour of the soil profile samples is estimated using Munsel colour chart. The soil profile samples of Belahi, Bela and Jabalpur mafi regions have strong brownish and brown colour due to the presence of high organic matter content. No significant variability is observed in the colour of the soil across the soil profile but the relative brightness or darkness(Value) varied in foew samples with the increase in depth.(Mathew *et al*,2013) described Neural Network approach which is used to determine the relation between soil colour and soil parameters like nitrogen, organic matter, heavy minerals etc.

Table 4.2 Soil colour of profile samples

S.No.	Sample ID	Depth (cm)	Soil colour
1	1	0-15	7.5YR 5/6 - strong brown
2	2	0-15	7.5 YR 6/4 - light brown
3	3	0-15	10 YR 6/4- Light Yellowish brown
4	4	0-15	5 YR 5/6 - Yellowish red
5	5	0-15	7.5 YR 4/6 - strong brown
6	6	0-15	10 YR 5/2 - Greyish brown
7	7	0-15	10 YR 6/4 - Light Yellowish brown
8	8	0-15	7.5 YR 5/6 - strong brownish
9	9	0-15	10 YR 6/4 - Light Yellowish brown
10	10	0-15	2.5 R 5/6 - red
11	11	0-15	10 YR 5/2 Greyish brown
12	12	0-15	10 YR 5/4 Yellowish brown
13	1	15-30	7.5 YR 4/6 - strong brown
14	2	15-30	7.5 YR 5/4 - brown
15	3	15-30	10 YR 6/4 - Light Yellowish brown
16	4	15-30	5 YR 5/6 - Yellowish red
17	5	15-30	7.5 YR 4/6 - strong brown
18	6	15-30	10 YR 5/2 - Greyish brown

Table Contd…

S.No.	Sample ID	Depth (cm)	Soil colour
19	7	15-30	10 YR 6/4 - Light Yellowish brown
20	8	15-30	7.5 YR 5/6 - strong brownish
21	9	15-30	10 YR 6/4 - Light Yellowish brown
22	10	15-30	2.5 R 5/6 - red
23	11	15-30	10YR 4/3 Brown
24	12	15-30	10 YR 5/4 Yellowish brown
25	1	30-45	7.5 YR 4/6 - strong brown
26	2	30-45	7.5 YR 5/4 - brown
27	3	30-45	10 YR 6/4 - Light Yellowish brown
28	4	30-45	5 YR 5/6 - Yellowish red
29	5	30-45	7.5 YR 4/6 - strong brown
30	6	30-45	10 YR 5/2 - Grayish brown
31	7	30-45	10 YR 6/4 - Light Yellowish brown
32	8	30-45	7.5 YR 5/6 - strong brownish
33	9	30-45	10 YR 6/4 - Light Yellowish brown
34	10	30-45	2.5 R 5/6 - red
35	11	30-45	10YR 4/3 Brown
36	12	30-45	10 YR 5/4 Yellowish brown
37	1	45-60	7.5 YR 4/6 - strong brown
38	2	45-60	7.5 YR 5/4 - brown
39	3	45-60	10 YR 6/4 - Light Yellowish brown
40	4	45-60	5 YR 5/6 - Yellowish red
41	5	45-60	7.5 YR 4/6 - strong brown
42	6	45-60	10 YR 5/2 - Greyish brown
43	7	45-60	10 YR 6/4 - Light Yellowish brown
44	8	45-60	7.5 YR 5/6 - strong brownish
45	9	45-60	10 YR 6/4 - Light Yellowish brown
46	10	45-60	2.5 R 5/6 - red
47	11	45-60	10YR 4/3 Brown
48	12	45-60	10 YR 5/4 Yellowish brown

Table 4.3 Physical characteristics of soil profile samples

S.No	Sample ID	Depth (cm)	pH	EC (DSm)	PD (g cc^{-1})	BD (g cc^{-1})	Porosity (%)	WHC (%)
1	1	0-15	5.90	0.024	2.629	1.326	49.5	45.2
2	2	0-15	7.20	0.197	2.649	1.324	50.01	47.3
3	3	0-15	8.10	0.069	2.541	1.302	48.7	48.2
4	4	0-15	8.70	0.066	2.452	1.339	45.4	41.5
5	5	0-15	6.90	0.065	2.414	1.339	44.5	44.6
6	6	0-15	7.10	0.167	2.532	1.348	46.7	49.3
7	7	0-15	6.60	0.079	2.635	1.332	49.4	49
8	8	0-15	5.90	0.047	2.665	1.345	49.5	44.5
9	9	0-15	6.40	0.049	2.554	1.278	49.9	47.8
10	10	0-15	5.80	0.079	2.431	1.312	46	41.8
11	11	0-15	8.60	0.089	2.416	1.251	48.2	48.2
12	12	0-15	6.20	0.206	2.61	1.299	50.2	44.6
13	1	15-30	6.30	0.031	2.62	1.329	49.2	45.5
14	2	15-30	7.40	0.186	2.647	1.327	49.8	47.3
15	3	15-30	8.10	0.064	2.553	1.302	49	48.1
16	4	15-30	8.80	0.051	2.449	1.341	45.2	41.2
17	5	15-30	7.00	0.078	2.41	1.339	44.4	44.8
18	6	15-30	7.10	0.118	2.532	1.347	46.8	49.1
19	7	15-30	6.80	0.076	2.632	1.329	49.5	49
20	8	15-30	6.00	0.043	2.662	1.347	49.3	44.5
21	9	15-30	6.50	0.048	2.554	1.285	49.6	47.6
22	10	15-30	5.90	0.047	2.429	1.325	45.4	41.5
23	11	15-30	8.50	0.153	2.414	1.254	48	48.2
24	12	15-30	6.10	0.056	2.61	1.304	50	44.3
25	1	30-45	5.70	0.02	2.619	1.314	49.8	45
26	2	30-45	7.00	0.091	2.642	1.332	49.5	47.1
27	3	30-45	7.80	0.105	2.54	1.315	48.2	48.3
28	4	30-45	8.50	0.048	2.445	1.343	45	41.2
29	5	30-45	6.80	0.061	2.399	1.335	44.3	44.1

Table Contd…

S.No	Sample ID	Depth (cm)	pH	EC (DSm)	PD (g cc^{-1})	BD (g cc^{-1})	Porosity (%)	WHC (%)
30	6	30-45	6.90	0.113	2.53	1.351	46.6	49.3
31	7	30-45	6.40	0.078	2.635	1.343	49	47.2
32	8	30-45	5.70	0.056	2.662	1.346	49.4	44.3
33	9	30-45	6.30	0.076	2.551	1.289	49.4	47.3
34	10	30-45	5.60	0.051	2.431	1.331	45.2	41.5
35	11	30-45	8.40	0.123	2.411	1.262	47.6	48
36	12	30-45	5.90	0.077	2.608	1.322	49.3	44.6
37	1	45-60	5.30	0.043	2.619	1.327	49.3	45.1
38	2	45-60	6.60	0.148	2.641	1.382	47.6	47.6
39	3	45-60	7.20	0.111	2.526	1.322	47.6	48.1
40	4	45-60	8.10	0.058	2.441	1.365	44	41
41	5	45-60	6.10	0.17	2.412	1.332	44.7	44.1
42	6	45-60	5.70	0.076	2.519	1.355	46.2	49
43	7	45-60	6.10	0.106	2.631	1.349	48.7	47.1
44	8	45-60	5.30	0.064	2.659	1.356	49	44.5
45	9	45-60	5.90	0.065	2.551	1.328	47.9	47.5
46	10	45-60	5.10	0.044	2.429	1.339	44.8	41.7
47	11	45-60	8.10	0.104	2.413	1.269	47.4	48.1
48	12	45-60	5.40	0.064	2.605	1.329	48.9	44.5
	MEAN		6.75	0.084	2.540	1.324	47.78	45.81
	MAX		8.80	0.206	2.665	1.382	50.2	49.3
	MIN		5.10	0.02	2.399	1.251	44	41
	SD		1.03	0.045	0.092	0.028	1.94	2.58
	Skewness		0.51	1.185	-0.229	-0.929	-0.60	-0.46
	Kurtosis		-0.81	0.779	-1.517	0.770	-1.09	-0.96
	CV		15.3	53.8	3.64	2.51	4.06	5.63

4.1.2 Chemical Properties of Soil

4.1.2.1 Organic Carbon

The soil profile samples collected from various regions of Mirzapur district (Table 4.1) showed the organic carbon values ranging from 0.045% to 1.305% with a mean value of 0.49%. Highest percentage of organic carbon is recorded in surface layer and the subsurface soil layer of 45-60cm depth has shown the lowest organic carbon percentage. The soil profile of Hinauta region on southern part of the district has shown highest organic carbon value and lowest percentage is observed in profiles of Bela and Gaura regions located in western part of the district.

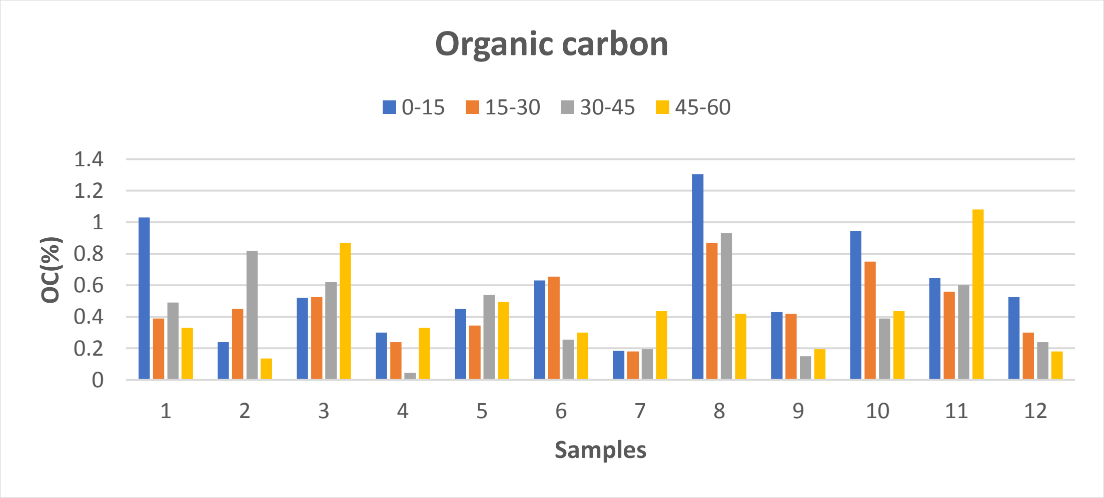


Figure 4.13 Chart of OC in soil profile samples at various depths

The coefficient of skewness for the organic carbon values is observed as 0.915 indicating a positive and moderate skewness and coefficient of kurtosis is 0.538 which represents near to normal distribution. The coefficient of variation is 57% indicating high dispersion in the values observed. The organic carbon values decreased with the increase in depth in most of the profiles, the profile samples of Lauriya and Jabalpur mafi showed a increase in OC across the profile due to the presence of clay content.

The organic carbon values of 0.34% - 0.64% is observed in the major part of the district. Soil Organic carbon is affected by soil texture 0.01-0.001mm (15%) and organic matter input (10%) and it is negatively affected by soil texture 0.25-2mm (-20%) and depth in subsoil(-11%) (Voltr *et al.*, 2021).

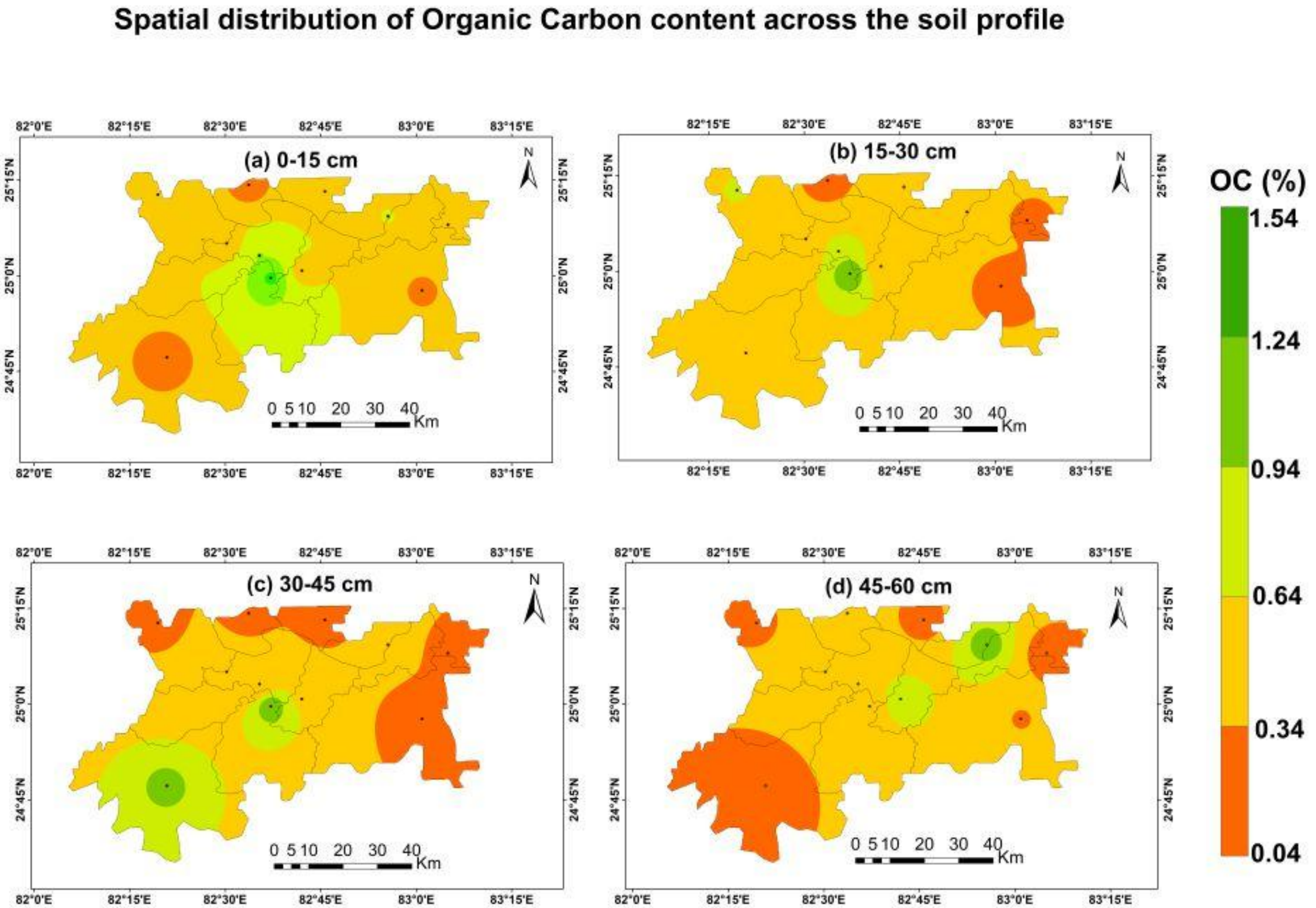


Figure 4.14 Spatial variability map of soil organic carbon across soil profiles of various regions in Mirzapur district of Vindhyan region

4.1.2.2 Total organic carbon

The organic carbon values of the soil profile samples (Table 4.1) ranged from 0.05% to 1.69% with a mean value of 0.6442%. Highest total organic carbon percentage is found at surface layer and the lowest values are observed at sub surface layer of 45-60cm depth. The profile samples with highest organic carbon content Bela regions and the lowest is recorded in the soil profile of Hinauta.

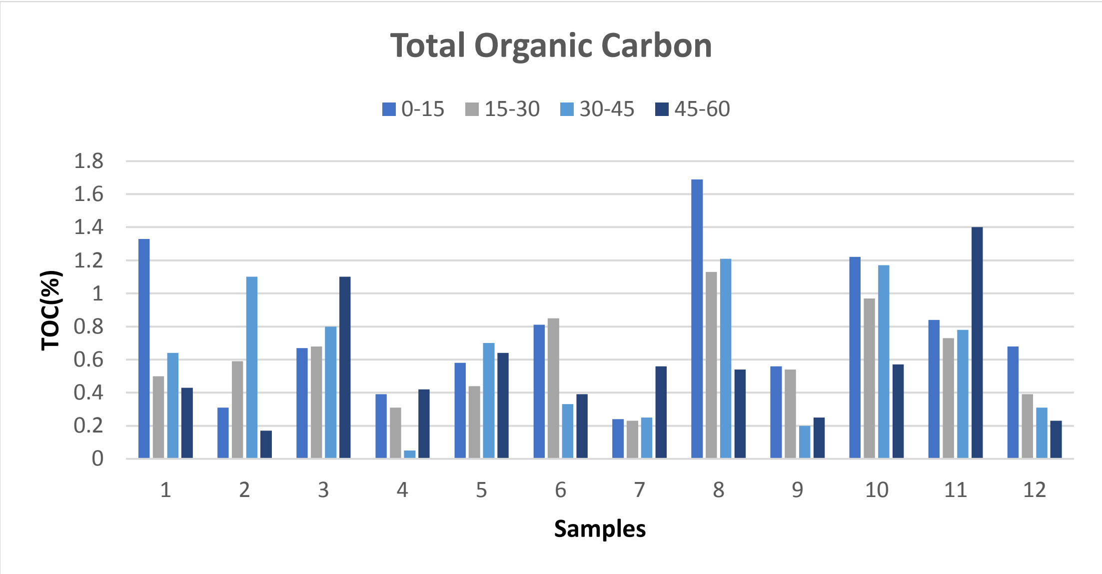


Figure 4.15 Chart of TOC in soil profile samples at various depths

The coefficient of variation is 57.3% indicating high dispersion in the data. The total organic carbon values showed a coefficient of skewness of 0.801 indicating a positive skewness and the coefficient of kurtosis is 0.183 representing a near to normal distribution. TOC values decreased with the increase in soil depth in the profile samples

In most of the areas the soil profile samples have shown a range of 0.45% to 0.65%. The total organic carbon in the soil is related to the amount of soil organic matter, vegetation and soil texture and is the key factor to represent soil productivity (Aviramidis *et al.*, 2015).

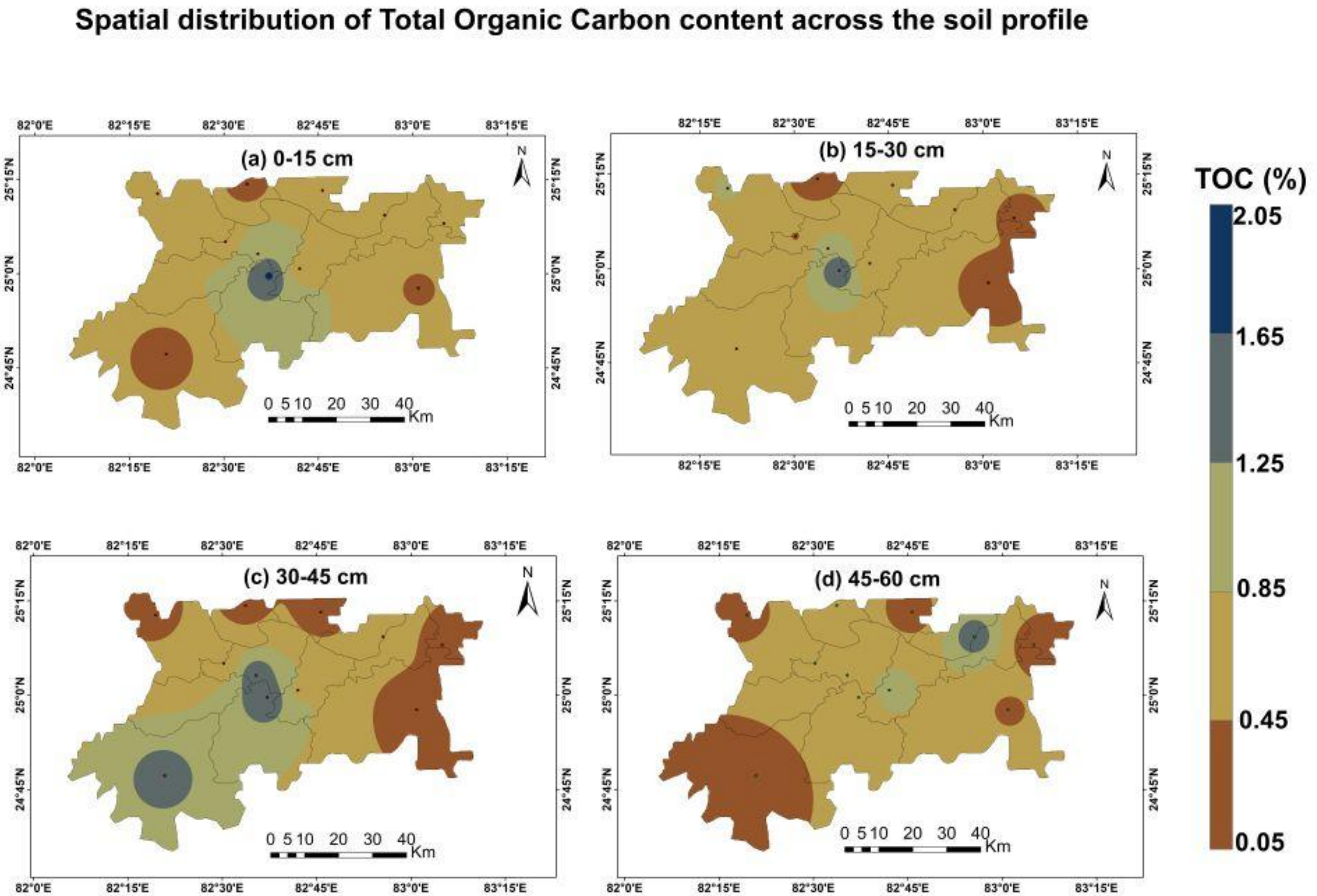


Figure 4.16 Spatial variability map of total organic carbon across soil profiles of various regions in Mirzapur district of Vindhyan region

4.1.2.3 Total Organic matter

In the soil profile samples collected from various regions of Mirzapur district (Table 4.1), the organic matter percentage is found in the range of 0.078% to 2.224% with a mean value of 0.838%. The furrow slice layer of 0-15cm has shown the highest percentage of organic matter and the lowest values are observed in subsurface soil of 30-45cm and 45-60cm depth. The profile samples of Bela region, central part of district has shown more organic matter percentage and the lowest values are observed in Hinauta region.

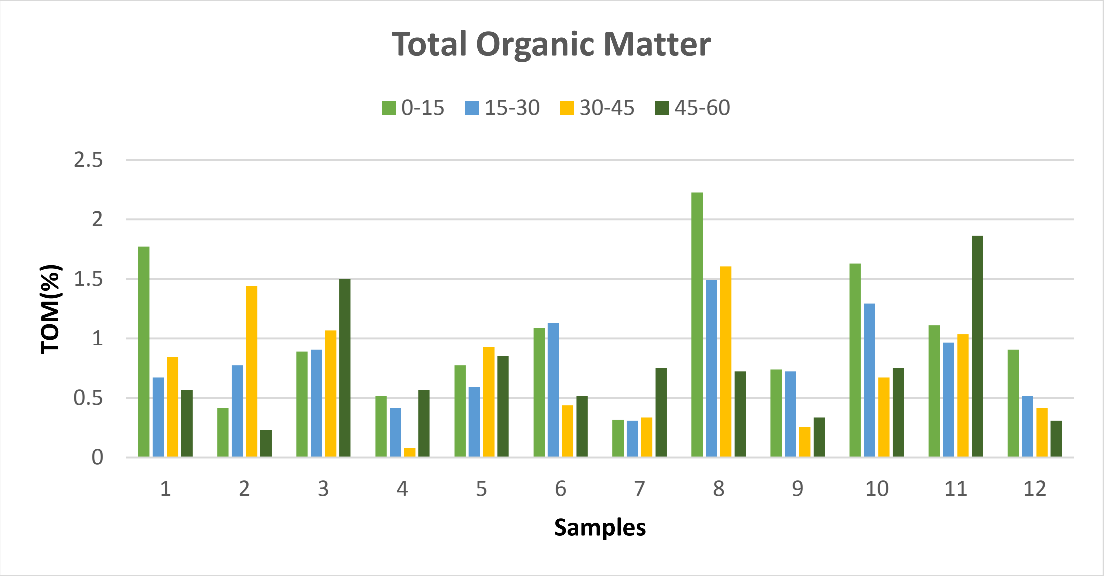


Figure 4.17 Chart of TOM in soil profile samples at various depths

The organic matter values of soil profile samples is positively skewed with a coefficient of skewness of 0.895 and the coefficient of kurtosis is 0.454 representing a near to normal distribution. high range of dispersion is observed with a coefficient of variation of 57%. Organic matter content decreased across the soil profile.

Most of the soil profile samples have shown the organic matter range of 0.5% to 1.5%. soil organic matter quantity in the soil is directly related to the temperature, type of vegetation and cultivation practices. Continuous Ploughing and tillage without any input of organic manures has shown a rapid decrease in the soil organic matter (Voltr *et al.*, 2021).

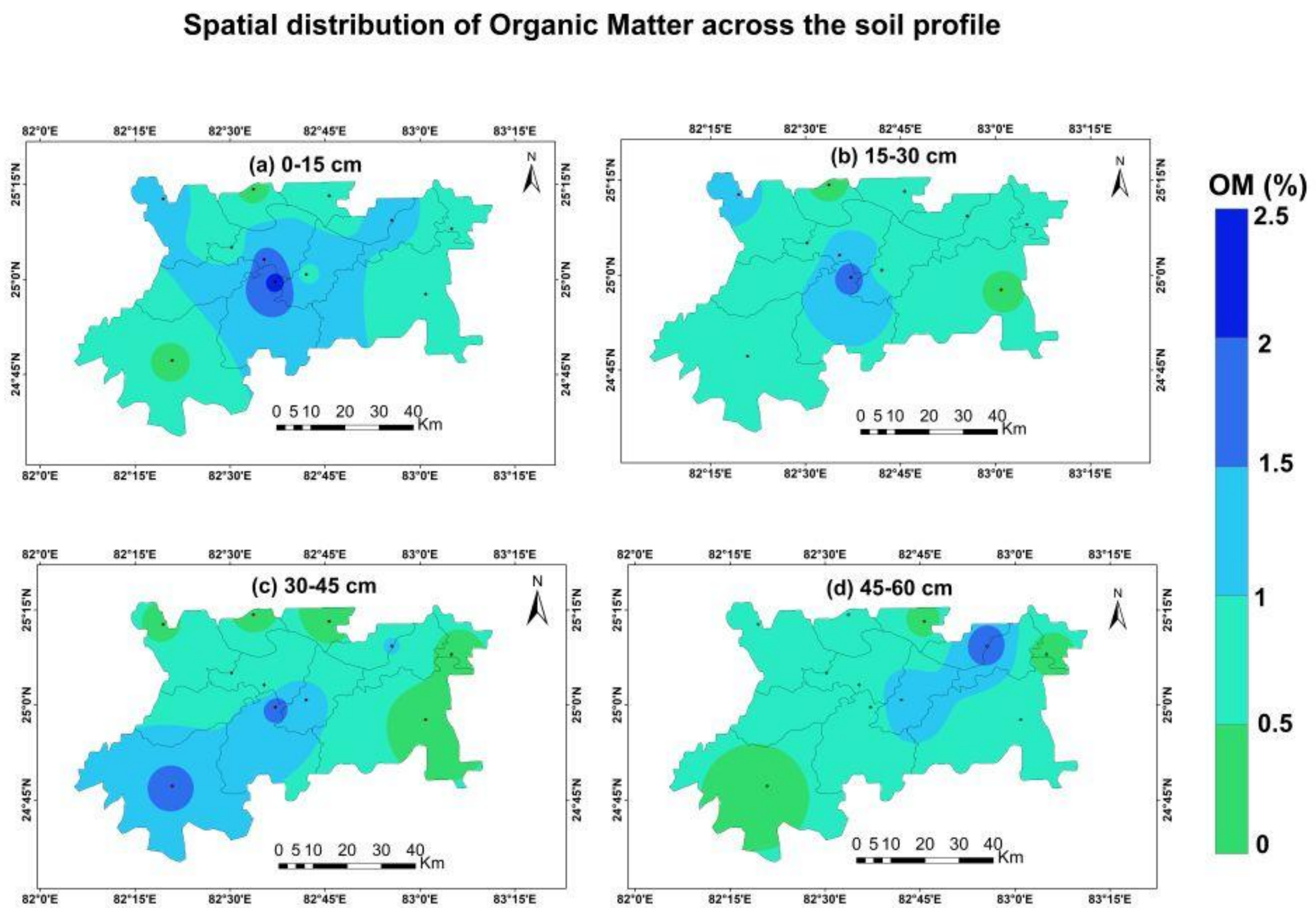


Figure 4.148 Spatial variability map of total organic matter across soil profiles of various regions in Mirzapur district of Vindhyan region

Table 4.4 Chemical parameters of soil profile samples

S.No.	Sample ID	Depth (cm)	O.C. (%)	Total OC (%)	Total OM (%)
1	1	0-15	1.03	1.33	1.77
2	2	0-15	0.24	0.31	0.41
3	3	0-15	0.52	0.67	0.89
4	4	0-15	0.30	0.39	0.51
5	5	0-15	0.45	0.58	0.77
6	6	0-15	0.63	0.81	1.08
7	7	0-15	0.18	0.24	0.31
8	8	0-15	1.30	1.69	2.22
9	9	0-15	0.43	0.56	0.74
10	10	0-15	0.94	1.22	1.62
11	11	0-15	0.64	0.84	1.11
12	12	0-15	0.52	0.68	0.90
13	1	15-30	0.39	0.50	0.67
14	2	15-30	0.45	0.59	0.77
15	3	15-30	0.52	0.68	0.90
16	4	15-30	0.24	0.31	0.41
17	5	15-30	0.34	0.44	0.59
18	6	15-30	0.65	0.85	1.12
19	7	15-30	0.18	0.23	0.31
20	8	15-30	0.87	1.13	1.49
21	9	15-30	0.42	0.54	0.72
22	10	15-30	0.75	0.97	1.29
23	11	15-30	0.56	0.73	0.96
24	12	15-30	0.30	0.39	0.51
25	1	30-45	0.49	0.64	0.84
26	2	30-45	0.82	1.10	1.44
27	3	30-45	0.62	0.80	1.06
28	4	30-45	0.04	0.05	0.07

S.No.	Sample ID	Depth (cm)	O.C. (%)	Total OC (%)	Total OM (%)
29	5	30-45	0.54	0.70	0.93
30	6	30-45	0.25	0.33	0.43
31	7	30-45	0.19	0.25	0.33
32	8	30-45	0.93	1.21	1.60
33	9	30-45	0.15	0.20	0.25
34	10	30-45	0.39	1.17	0.67
35	11	30-45	0.60	0.78	1.03
36	12	30-45	0.24	0.31	0.41
37	1	45-60	0.33	0.43	0.56
38	2	45-60	0.13	0.17	0.23
39	3	45-60	0.87	1.10	1.49
40	4	45-60	0.33	0.42	0.56
41	5	45-60	0.49	0.64	0.85
42	6	45-60	0.30	0.39	0.51
43	7	45-60	0.43	0.56	0.74
44	8	45-60	0.42	0.54	0.72
45	9	45-60	0.19	0.25	0.33
46	10	45-60	0.43	0.57	0.74
47	11	45-60	1.08	1.40	1.86
48	12	45-60	0.18	0.23	0.31
	MEAN		0.48	0.64	0.83
	MAX		1.30	1.69	2.22
	MIN		0.04	0.05	0.07
	SD		0.27	0.36	0.47
	Skewness		0.91	0.80	0.89
	Kurtosis		0.53	0.18	0.45
	CV		57	57.3	57

4.1.2.4 Available Nitrogen

The soil profile samples collected from various regions of Mirzapur district (Table 4.1)have the nitrogen levels ranging from 93.1kg/ha to 198.2kg/ha with an average value of 140.84kg/ha. The content of nitrogen was high in the surface layer of 0-15cm and lowest in the subsurface layer of 45-60cm.The soil profile with high nitrogen content is at Jabalpur Mafi and Gaura region and the lowest is observed at Hinauti region.

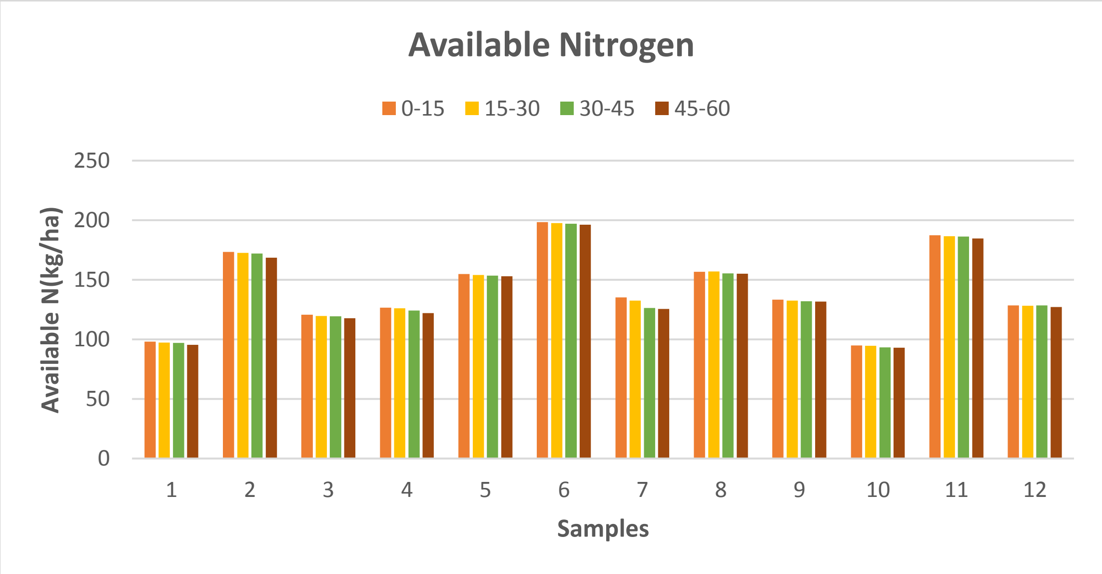


Figure 4.19 Chart of Available Nitrogen in soil profile samples at various depths

The coefficient of skewness and kurtosis of the nitrogen values is observed as 0.28 and -0.79 indicating a positive skewness and negative kurtosis indicating a light tailed distribution. The coefficient of variation is 23.4% representing a moderate dispersion level. Nitrogen values have not shown significant difference across the profile the values decreased in the sub soil layer. A positive correlation is observed with organic carbon and significant with r value of 0.549.

The available nitrogen in the soil profile samples of major part of the district ranged between 120-150kg/ha. The nitrogen levels in the soil depend on the quantity of organic matter and climatic conditions. The dry land soils have lower quantity of nitrogen compared to soils of similar composition in different regions (Farzadfar *et al.*, 2021).

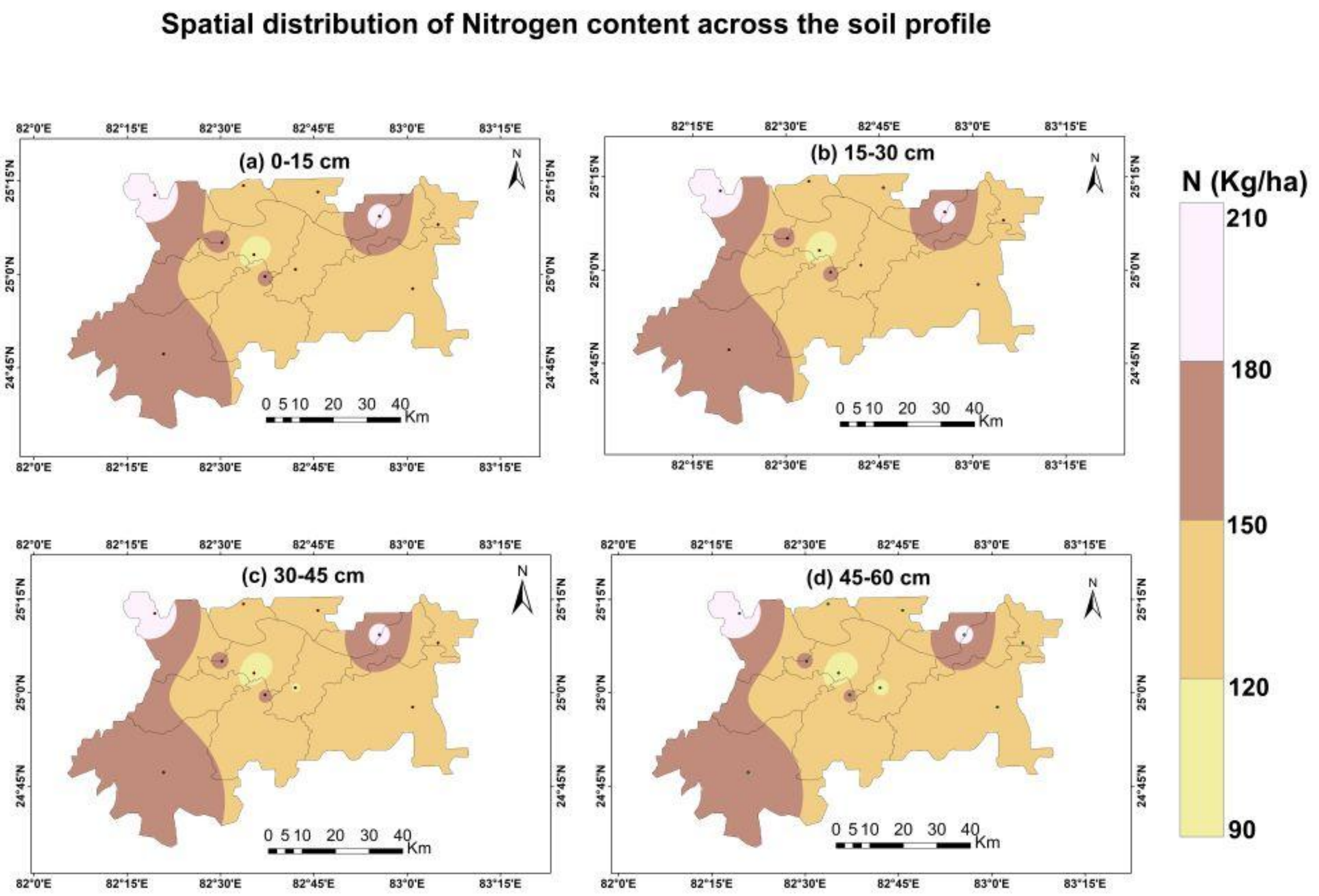


Figure 4.20 Spatial variability map of nitrogen across soil profiles of various regions in Mirzapur district of Vindhyan region

4.1.2.5 Available Phosphorous

The phosphorous levels in the Soil profile samples (Table 4.1) collected from various regions Mirzapur district ranged from16.04-40.86kg/ha with a mean value of 21.51kg/ha. Higher levels of phosphorous are observed in the surface layer soil of 0-15cm and 15-30cm depth. Low phosphorous content is observed in the subsoil of 45-60cm depth. The soil profile of Barkaccha and Charia has shown highest level of phosphorous and the lowest is observed in the soil profile samples of Hinauti, Karanpura, Bela etc.

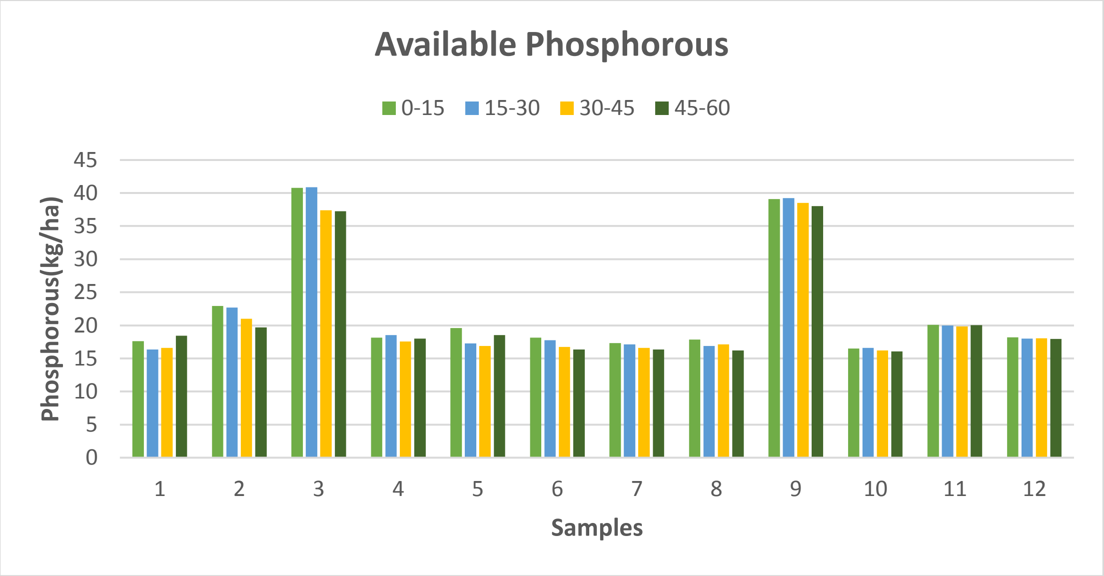


Figure 4.21 Chart of available phosphorous in soil profile samples at various depths

The coefficient of variation of the values observed is 37.2% indicating a moderate level of dispersion. The data is positively skewed with a coefficient of variation of 1.72 and a high end tailed kurtosis with 1.27 as the coefficient. The phosphorous levels decreased with the increase in the soil depth due to the decrease in organic matter and significantly negatively correlated with soil pH(r= -0.297).

Major area of the district has the soil profile samples having phosphorus level between 16-23kg/ha. The phosphorous content in the soil is highly dependent on the soil pH, Alkalinity and Acidity of the soil making the phosphorous poorly available by making it less soluble in soil solution (Balemi and Negisho, 2012).

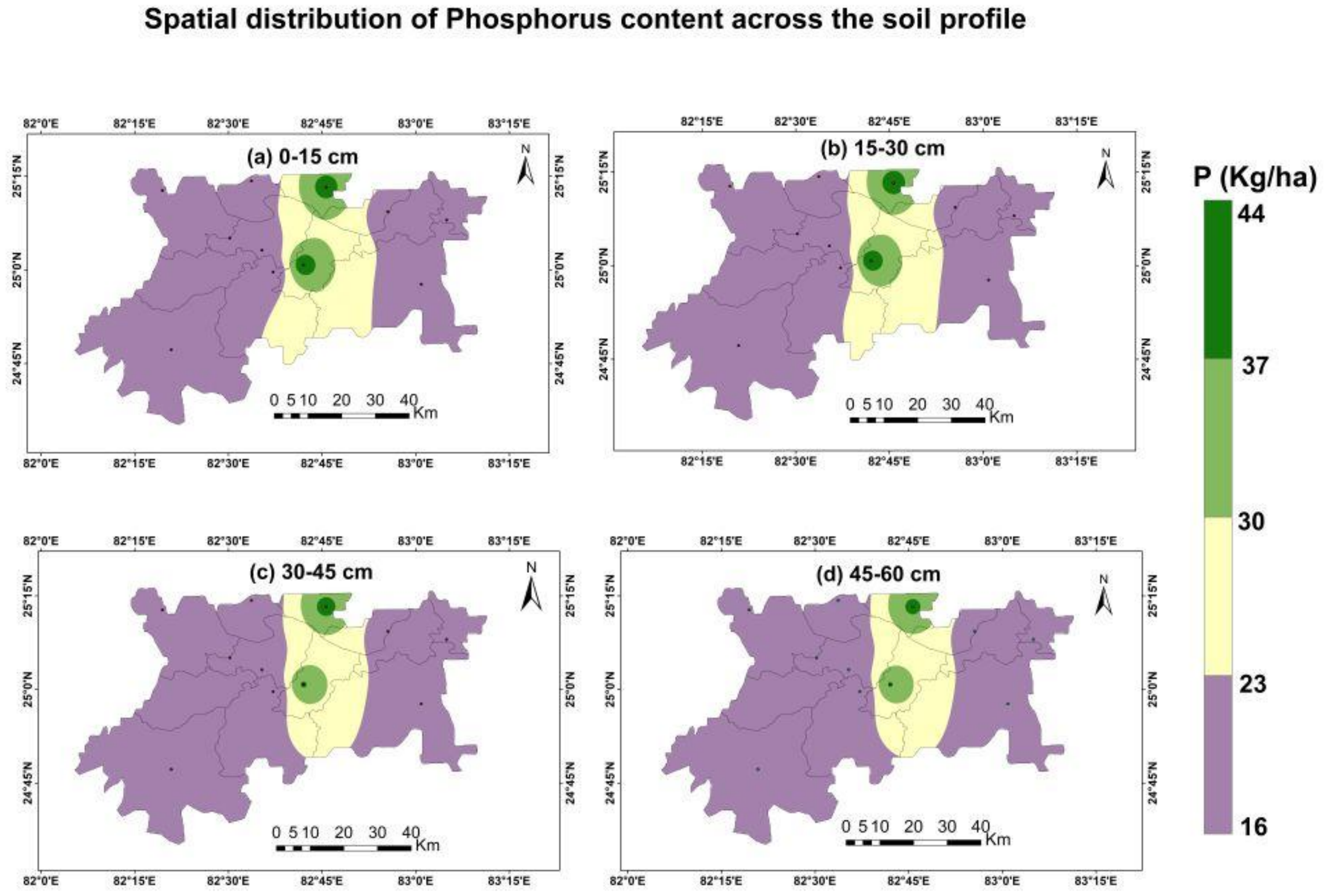


Figure 4.22 Spatial variability map of Available phosphorous across soil profiles of various regions in Mirzapur district of Vindhyan region

4.1.2.6 Available potassium

The samples of soil profile collected from various regions of Mirzapur district(Table 4.1)has shown the available potassium levels ranging from 145.6-336kg/ha with a mean value of 250.2kg/ha. The top soil of 0-15cm has shown highest level of potassium and lowest is found in the sub surface layer of 45-60cm depth. Highest available potassium is observed in the soil profiles of Charia and Barkaccha regions and the soil profile sample with the lowest potassium content is observed at Ori and Karanpura regions.

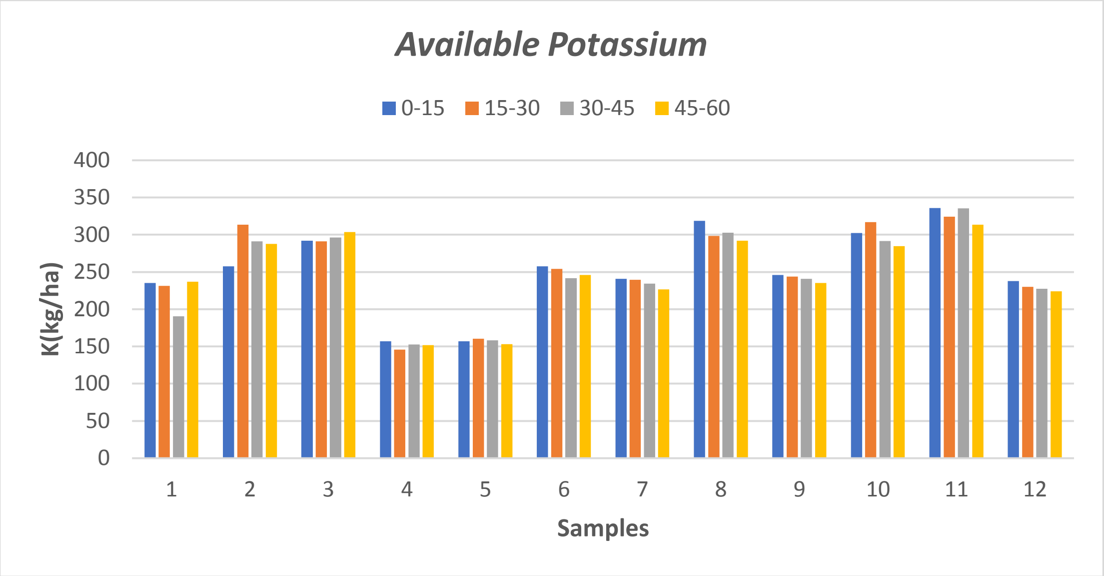


Figure 4.23 Chart of Available potassium in soil profile samples at various depths

The coefficient of skewness and kurtosis of the available potassium values in the soil profile samples is observed as -0.458 and -0.682 respectively indicating a negatively skewed and light tail distribution of the data. The coefficient of variation is 22% representing moderate dispersion. Potassium levels in the soil decreased with the increase in depth.

The available potassium content of 245-295 kg/ha is observed in major parts of the district. Available potassium in the soil is related to the clay content which reduces the mobility due to strong affinity of the exchange sites in clay (Ramamurthy *et al.*, 2017).

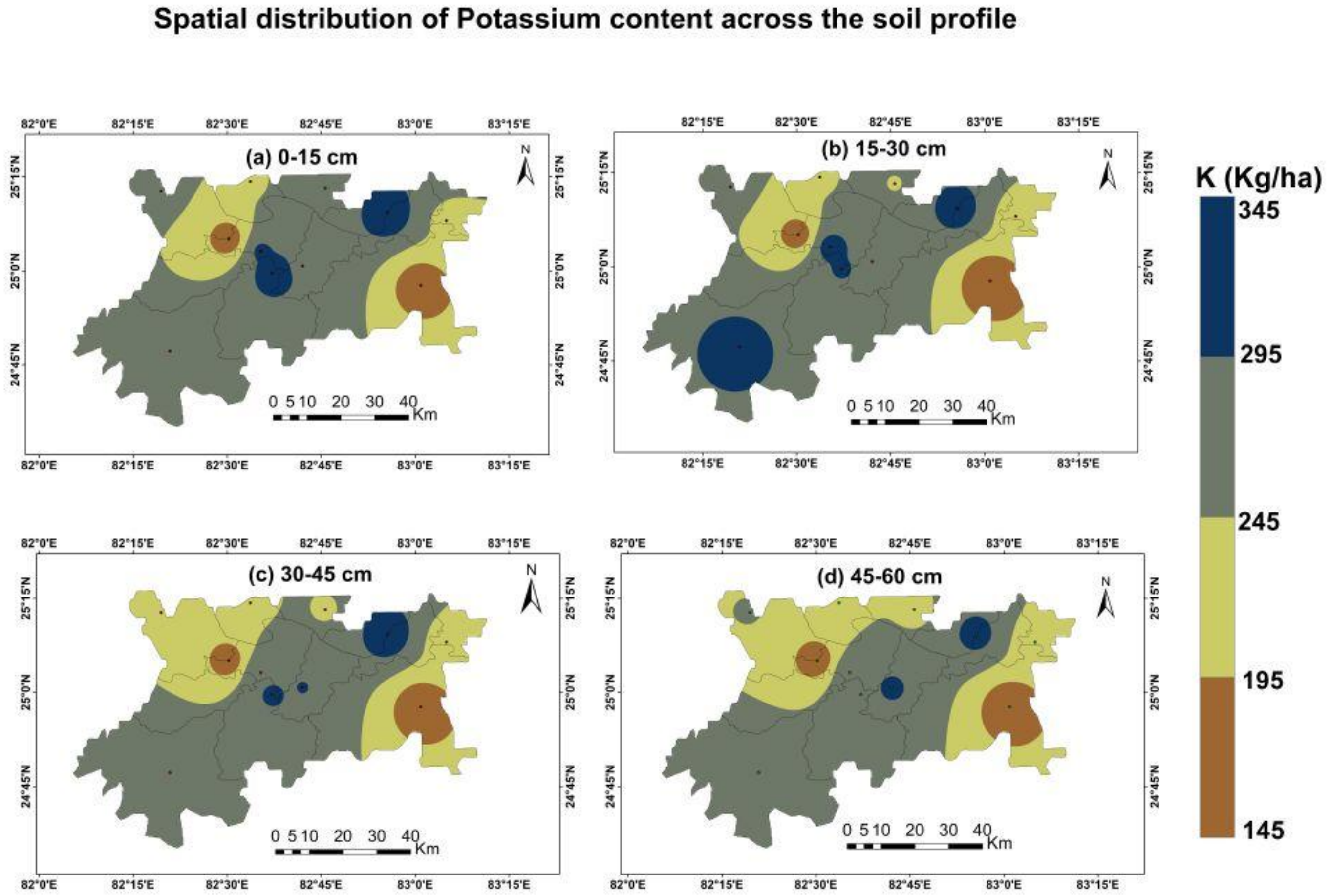


Figure 4.24 Spatial variability map of available potassium across soil profiles of various regions in Mirzapur district of Vindhyan region

Table 4.5: Primary nutrients in soil profile samples

Sample ID	Depth(cm)	Nitrogen (kg/ha)	Phosphorus (Kg/ha)	Potassium (kg/ha)
1	0-15	98.2	17.63	235.2
2	0-15	173.2	22.92	257.6
3	0-15	120.6	40.8	291.8
4	0-15	126.6	18.15	156.8
5	0-15	154.8	19.57	156.9
6	0-15	198.2	18.12	257.6
7	0-15	135.3	17.3	240.7
8	0-15	156.8	17.86	318.8
9	0-15	133.4	39.1	245.8
10	0-15	94.9	16.48	302.4
11	0-15	187.3	20.05	336
12	0-15	128.4	18.21	237.8
1	15-30	97.3	16.34	231.5
2	15-30	172.5	22.67	313.6
3	15-30	119.7	40.86	291.2
4	15-30	126	18.52	145.6
5	15-30	154.1	17.25	160.2
6	15-30	197.5	17.76	254.2
7	15-30	132.5	17.1	239.6
8	15-30	156.9	16.9	298.5
9	15-30	132.4	39.21	243.6
10	15-30	94.6	16.6	316.8
11	15-30	186.5	20	324.3
12	15-30	128.1	17.97	230.2
1	30-45	97.01	16.59	190.4
2	30-45	172.1	20.99	291.2
3	30-45	119.2	37.38	296.4
4	30-45	124.2	17.58	152.7

Table Contd…

Sample ID	Depth(cm)	Nitrogen (kg/ha)	Phosphorus (Kg/ha)	Potassium (kg/ha)
5	30-45	153.4	16.86	158.4
6	30-45	197	16.73	241.8
7	30-45	126.4	16.6	234.5
8	30-45	155.2	17.12	302.6
9	30-45	132	38.52	240.8
10	30-45	93.3	16.21	291.6
11	30-45	186.1	19.83	335.2
12	30-45	128.5	18.05	227.6
1	45-60	95.5	18.41	236.7
2	45-60	168.5	19.7	287.8
3	45-60	117.6	37.25	303.4
4	45-60	122	18.01	151.6
5	45-60	153	18.54	153.2
6	45-60	196.3	16.34	246.1
7	45-60	125.5	16.34	226.7
8	45-60	155	16.21	291.8
9	45-60	131.8	38.01	235.2
10	45-60	93.1	16.04	284.7
11	45-60	184.6	20.04	313.6
12	45-60	127.2	17.95	224
MEAN		140.8	21.51	250.09
MAX		198.2	40.86	336
MIN		93.1	16.04	145.6
SD		31.6	8.02	55.03
Skewness		0.28	1.72	-0.45
Kurtosis		-0.87	1.27	-0.68
CV		23.4	37.2	22

4.1.3 Secondary nutrients

4.1.3.1 Calcium

In the Soil profile samples collected from various regions of Mirzapur district (Table 4.1), the calcium levels are observed in the range of 13.5-68.1mg/100g with a mean value of 35.4mg/100g.top layer of the soil of 0-15cm depth is recorded with highest calcium levels and the sub surface soil layers of 30-45cm and 45-60cm has lowest calcium content. The soil profile samples with the highest calcium in Belahi of southern part and Jabalpur Mafi in eastern part of the district. The lowest calcium values are observed in the soil profile of Barkaccha and Charia regions.

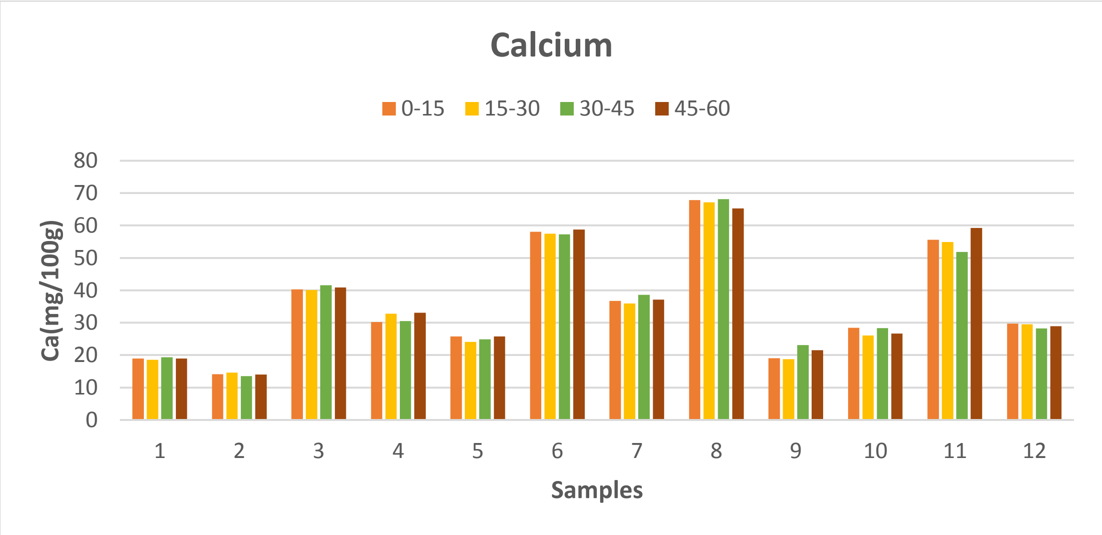


Figure 4.25 Chart of Exchangeable Calcium in soil profile samples at various depths

The coefficients of Skewness and Kurtosis of the Calcium values are observed as 0.65 and -0.74 representing positive skewness and a negative kurtosis and light tailed distribution. The coefficient of variation of the data is 46.1% indicating a moderate dispersion. Calcium values decreased from surface to subsurface layers of soil profile.

The calcium levels in the major part of the district are between 25-37 mg/100g. Calcium in the soil contributes to soil structural stability and aggregate formation. The soils in the arid region have more accumulation of calcium in the upper profile (Upadhyay *et al*., 2013).

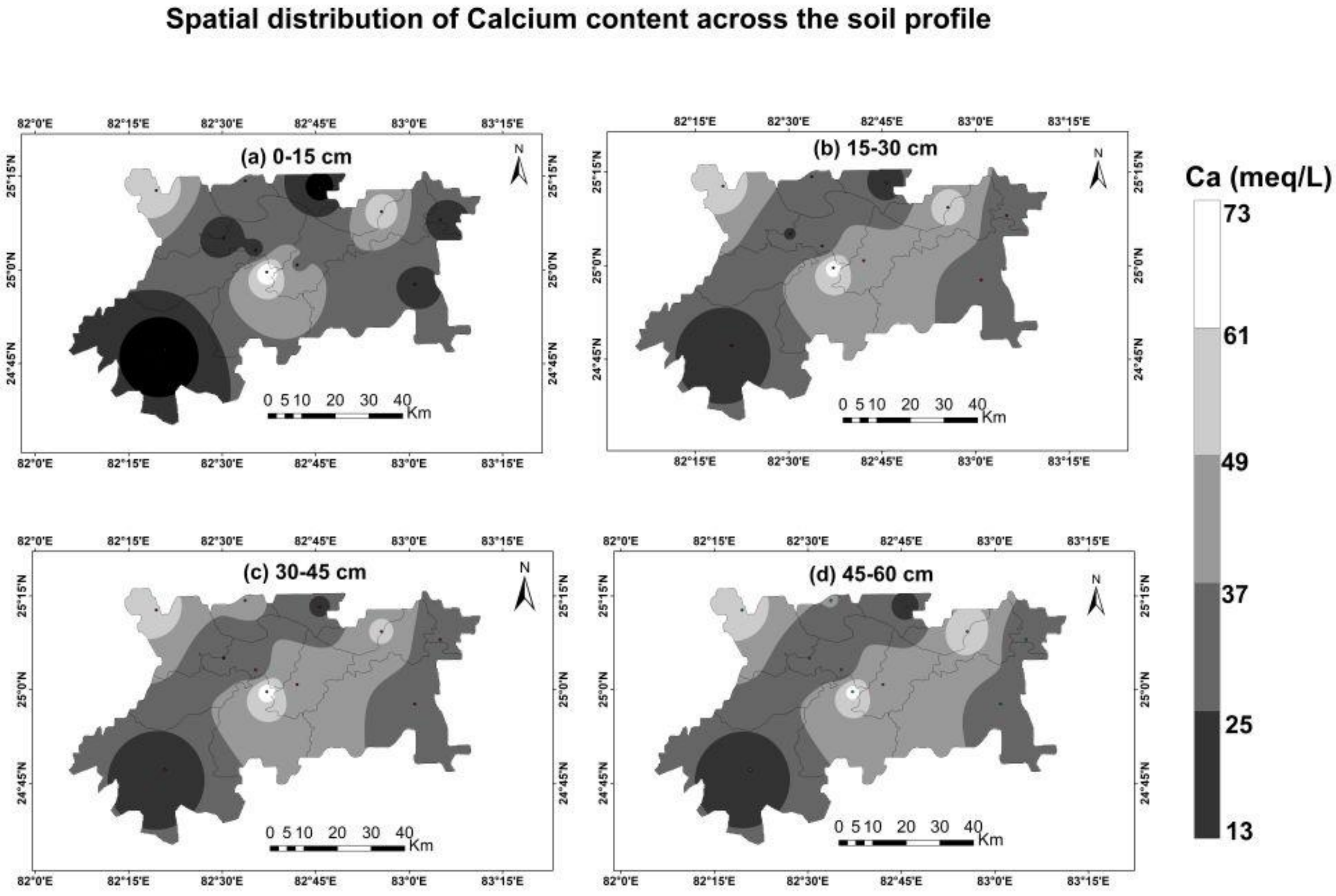


Figure 4.26 Spatial variability map of Exchangeable Calcium across soil profiles of various regions in Mirzapur district of Vindhyan region

4.1.3.2 Magnesium

In the soil profile samples collected from various regions of Mirzapur district(Table 4.1), the Magnesium (Mg) levels are observed in a range of 6.3-22.3mg/100g of soil with a mean value of 14.5mg/100g. in the soil profile, the surface layer of 0-15cm has shown highest level of Magnesium compared to soil layers of 15-30cm,30-45cm and 45-60cm. highest Magnesium levels are found in the soil profiles of Bela and Gaura regions and the lowest level is recorded in the profile of Hinauta and Bhadohi regions.

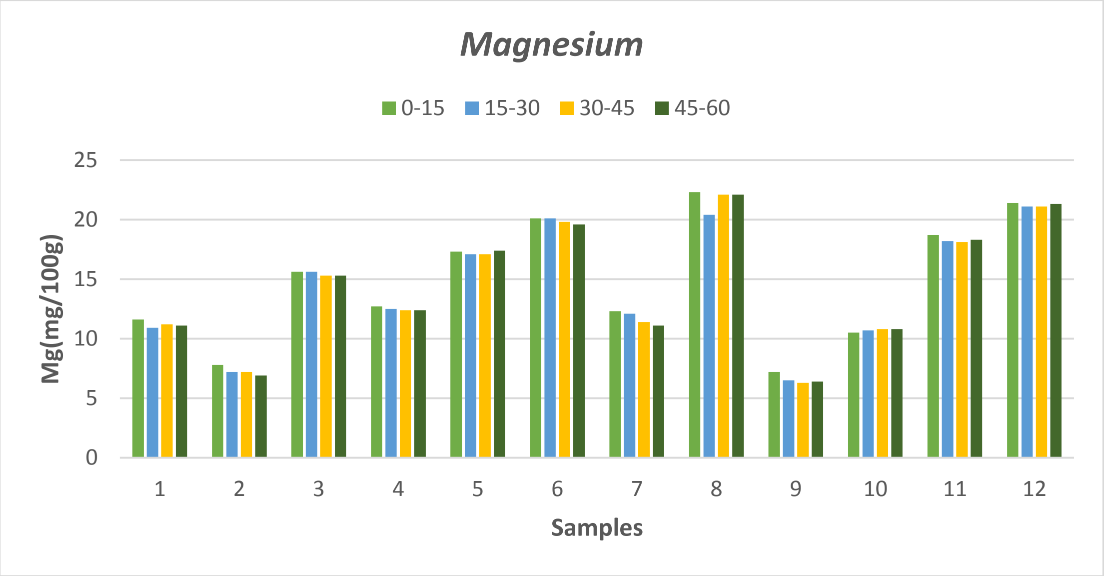


Figure 4.27 Chart of Exchangeable Magnesium in soil profile samples at various depths

The coefficient of variance is 35% representing a moderate level of dispersion. The coefficient of skewness and coefficient of Kurtosis of the Magnesium values is -0.03 and -1.27 respectively which interpret a negative skewness and light tailed dispersion. Magnesium levels decreased with the increase of depth in the soil profile in all the regions of the district.

Magnesium levels in the range of 14.3- 22.3mg/100g is observed in most of the regions of Mirzapur district. The Magnesium levels are negatively correlated with the soil pH and a linear relation can be observed between water soluble Magnesium and EC of the cultivated soils (Jayaganesh *et al.*, 2011).

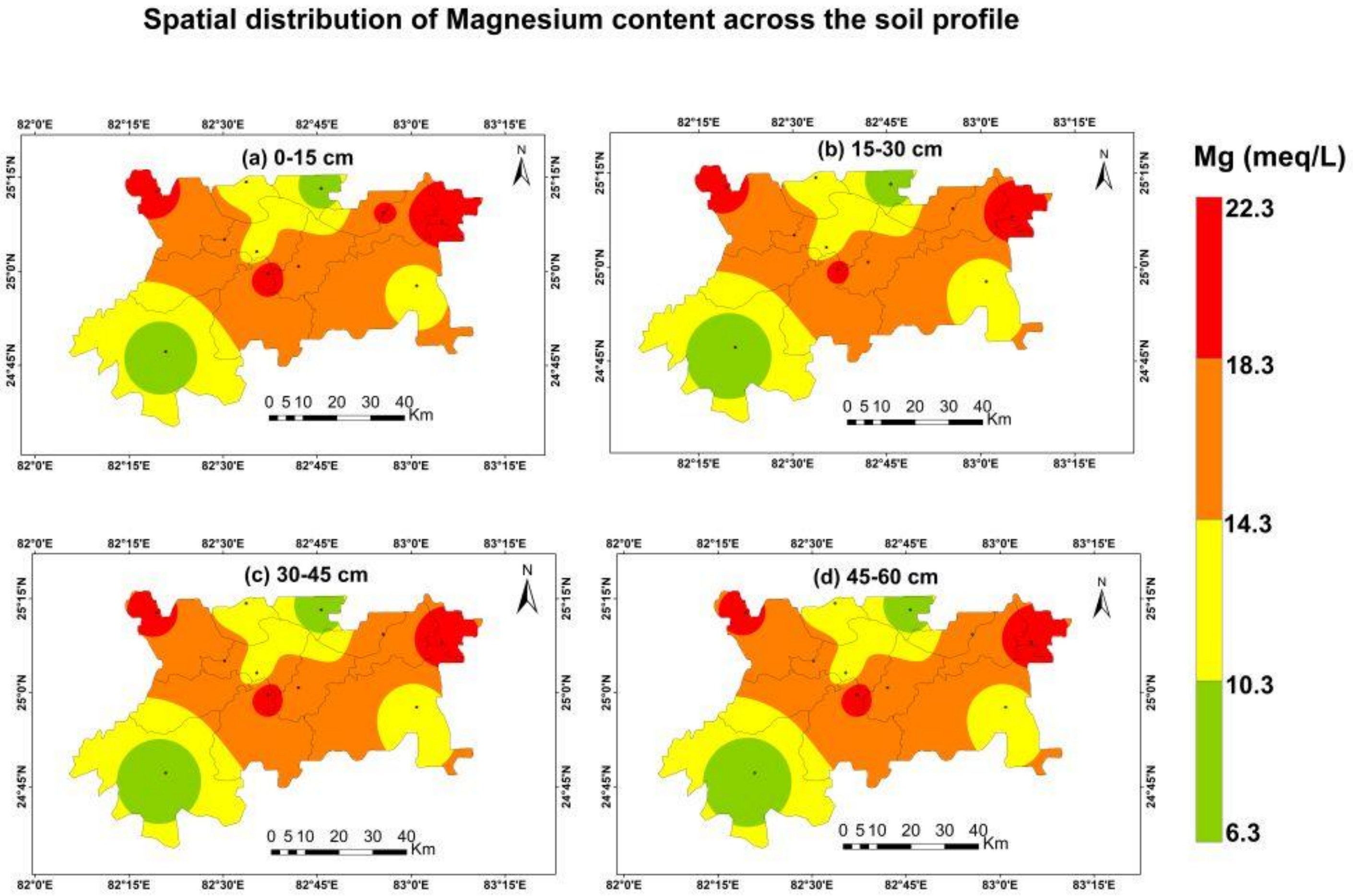


Figure 4.28 **Spatial variability map of Exchangeable Magnesium across soil profiles of various regions in Mirzapur district of Vindhyan region**

4.1.3.3 Sodium

The sodium levels in the soil profile samples collected from various regions(Table 4.1) of Mirzapur district are observed in the range of 1.5-14 mg/100g of soil with a mean value of 4.26mg/100g. Highest sodium levels are in the surface levels of 0-15cm and 15-30cm. the lowest levels of sodium is observed at a depth of 30-45cm. The soil profile samples of Karanpura region exhibited highest sodium level and the lowest is observed at Ori and Jabalpur mafi regions.

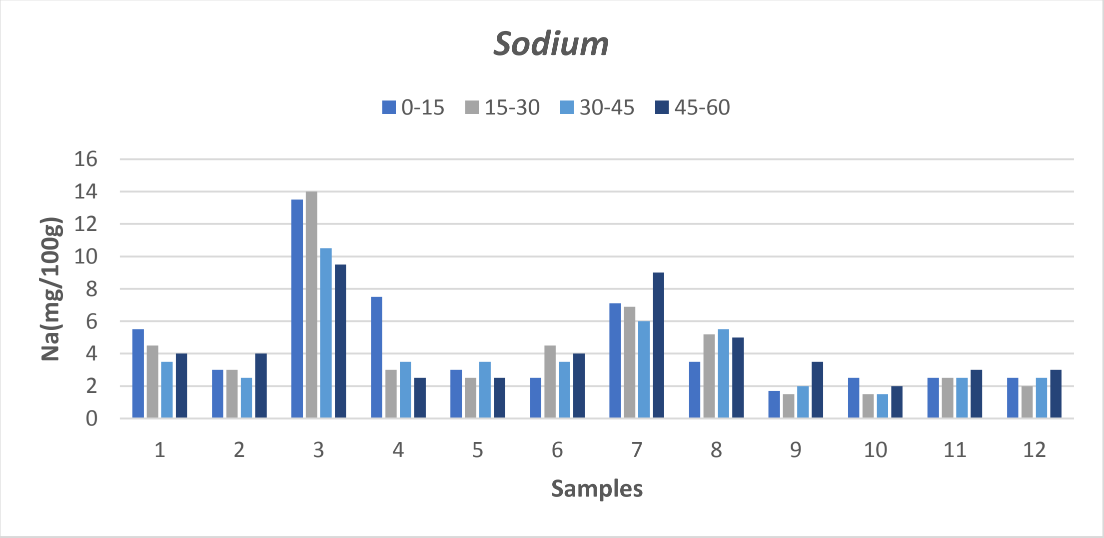


Figure 4.29 Chart of Exchangeable Sodium of soil profile samples at various depths

The sodium values of the soil profile samples showed a coefficient of skewness of 1.91 indicating a positive skewness and 3.54 as the coefficient of kurtosis interpreting a high tailed leptokurtic distribution. The coefficient of variation for the data is 67.8% indicating a high level of dispersion. Sodium levels decreased with the in the increase in the depth across the profile.

Sodium content ranging 1.5-6.5 mg/100g is observed in most parts of the district which is in the range of non-saline to slightly saline condition. Sodium levels in the soil affect the soil structure and porosity significantly. A threshold of 5% exchangeable sodium is considered to define a soil as sodic. Threshold may vary according to soil texture, organic matter etc. (Irakoze *et al.*, 2021).

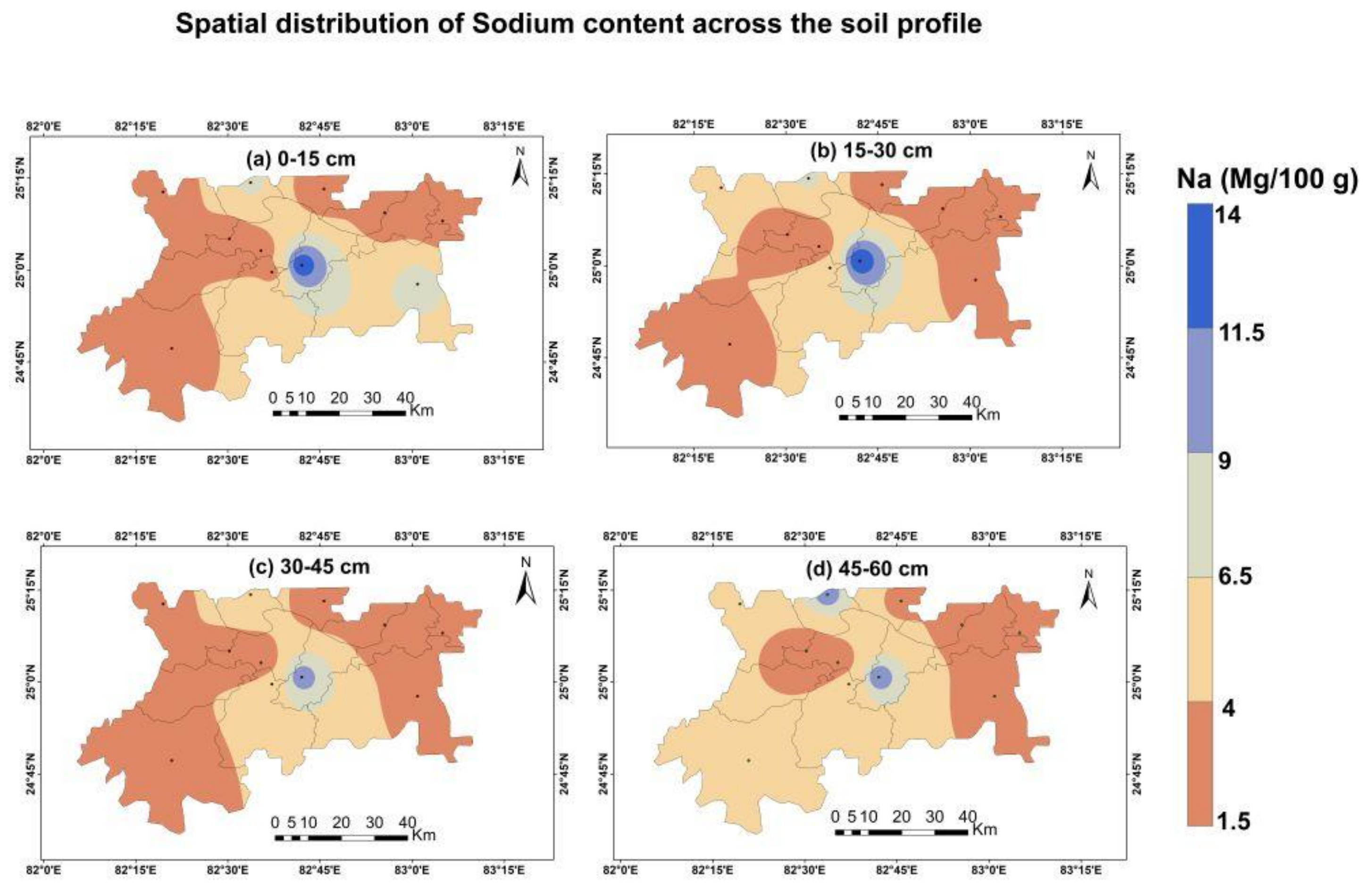


Figure 4.30 Spatial variability map of Exchangeable Sodium across soil profiles of various regions in Mirzapur district of Vindhyan region

4.1.4 Soil Alkalinity

4.1.4.1 Carbonates

The carbonate levels in the soil profile samples collected from various regions of Mirzapur district (Table 4.1) ranged between 12.3-17.1mg/100g with a mean value of 14.8mg/100g. The soil profiles of Bela has shown highest carbonates level and the lowest values are recorded in the soil profiles of Ori region. The carbonate levels are lowest in the furrow slice layer of 0-15cm depth and the subsurface soil layer of 45-60cm has shown highest carbonate levels.

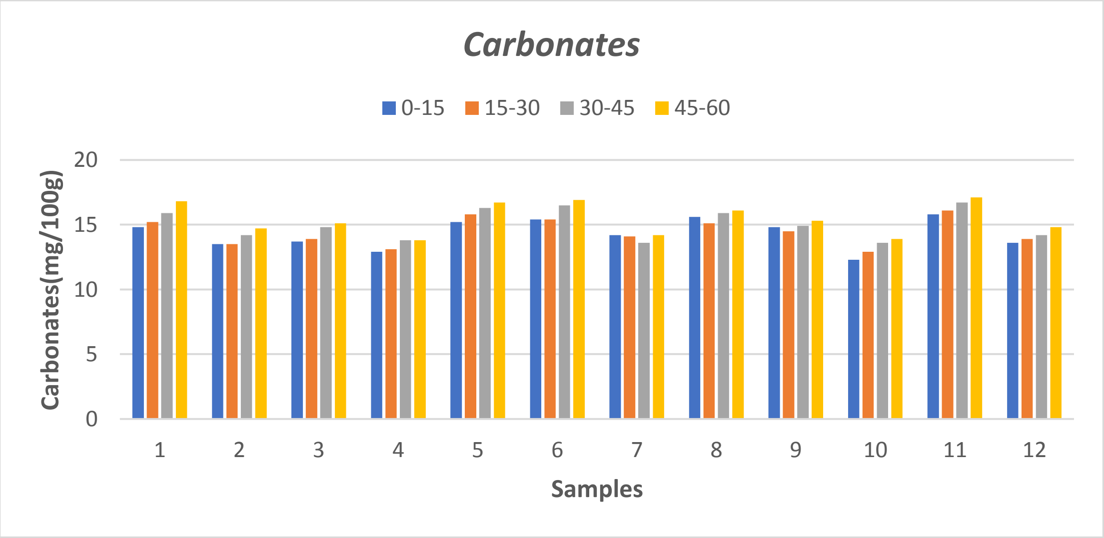


Figure 4.31 Chart of Carbonates in soil profile samples at various depths

The coefficient of skewness and coefficient of kurtosis of the carbonates values is 0.105 and -0.808 which represents a positively skewed data and a light tailed distribution. the coefficient of variance is 8.1% indicating a low level of dispersion. Carbonates content increased across the soil profile with the increase in depth in all the regions of district and showed a highly significant positive correlation with calcium and magnesium content(r= 0.425 and r=0.433)

Carbonate levels ranging between 13.5-16.5mg/100g is found in most of the soil profiles of Mirzapur district. Characterization of carbonates in the soil is essential for the prediction of soil acidification and soil pH buffering capacity (Bargrizan *et al.*, 2020).

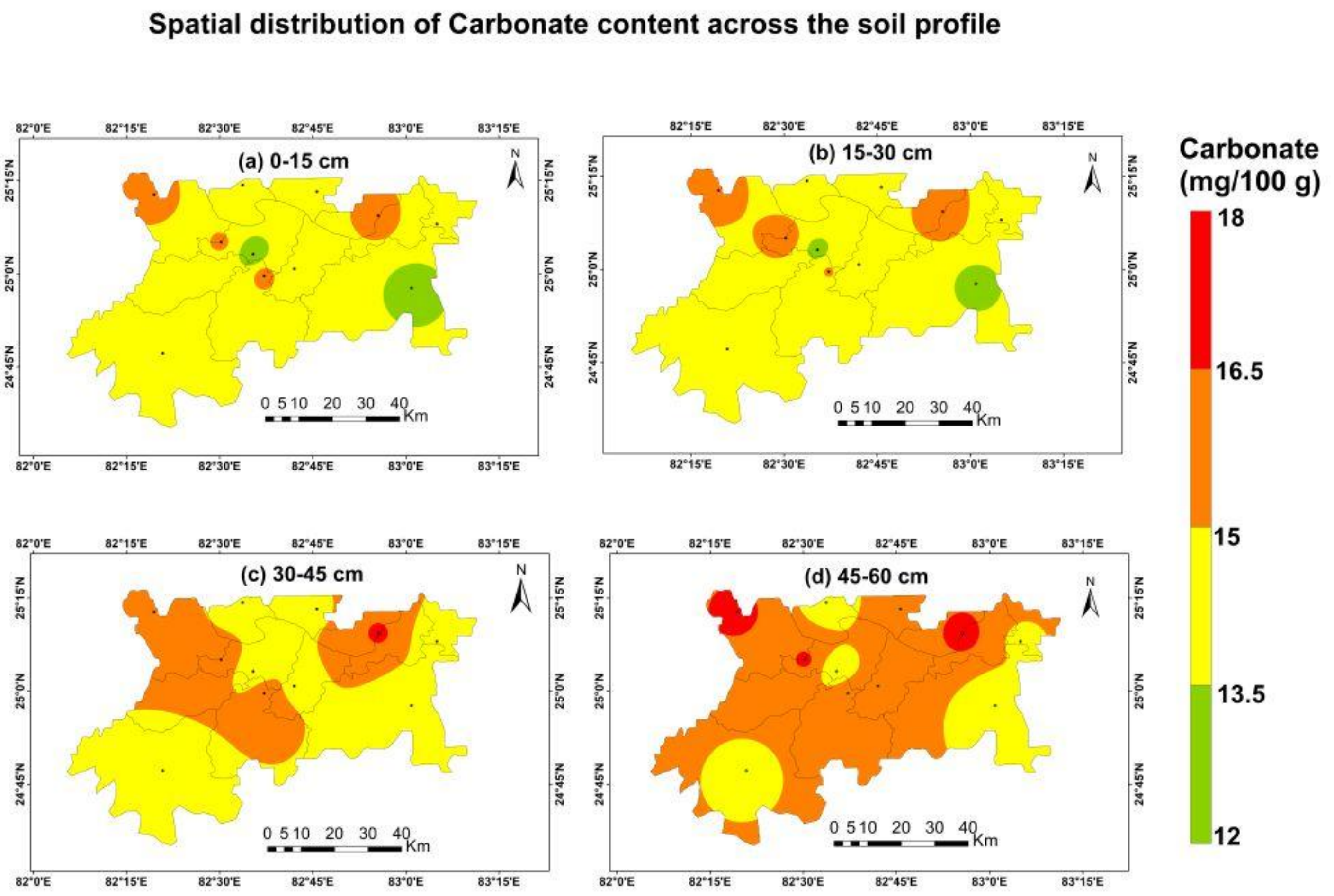


Figure 4.32 Spatial variability map of Carbonates across soil profiles of various regions in Mirzapur district of Vindhyan region

4.1.4.2 Bicarbonates

Bicarbonates levels in the soil profile samples collected from various regions of Mirzapur district (Table 4.1) ranged between 18.4-36.9mg/100g of soil with a mean value of 25.8mg/100g. In the soil profile highest level of bicarbonates are observed at a depth of 0-15cm and the lowest level of bicarbonates is observed in the subsurface layer 45-60cm. soil profile of Gaura has highest bicarbonate content and the lowest value is observed in the soil profile of Lauriya region.

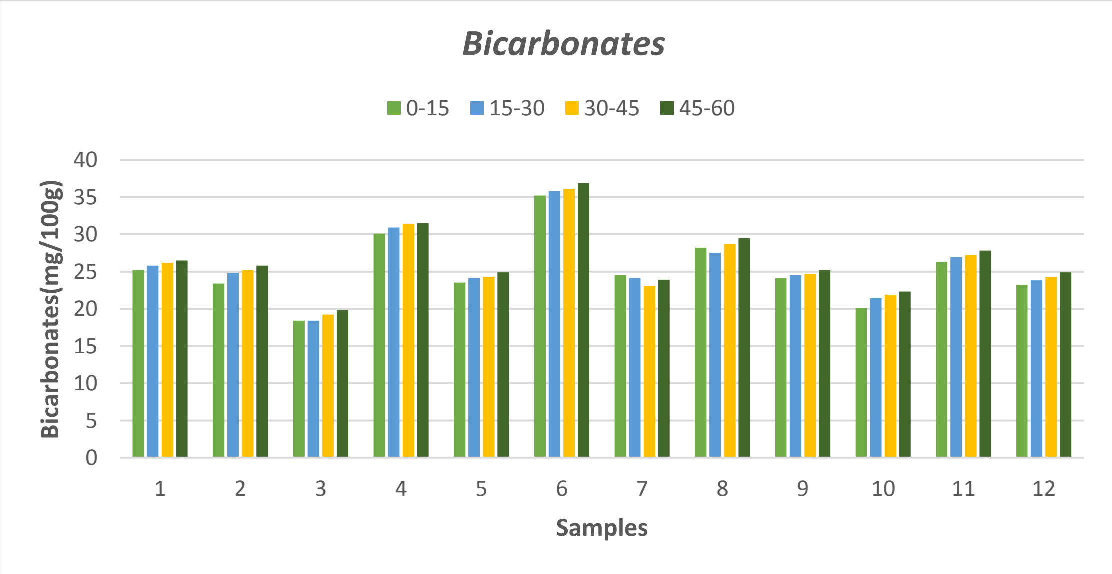


Figure 4.33 Chart of Bicarbonates in soil profile samples at various depths

The coefficient of variation of bicarbonate values is 16.7% which represents low level of dispersion. Coefficient of Skewness and Kurtosis of the data is 0.81 and 0.73 respectively indicating a positively skewed data and high tailed distribution. Bicarbonates levels increased with the increase in soil depth in all the soil profile samples.

From the map it can be inferred that 90% of the area in the district has the bicarbonates in the range of 22-30 mg/100g. The bicarbonate levels in the soil is affected by the climatic factors, soil type and increase in the bicarbonates in the soil affects the uptake of potassium, Calcium and Magnesium (Paliwal *et al.*, 1975).

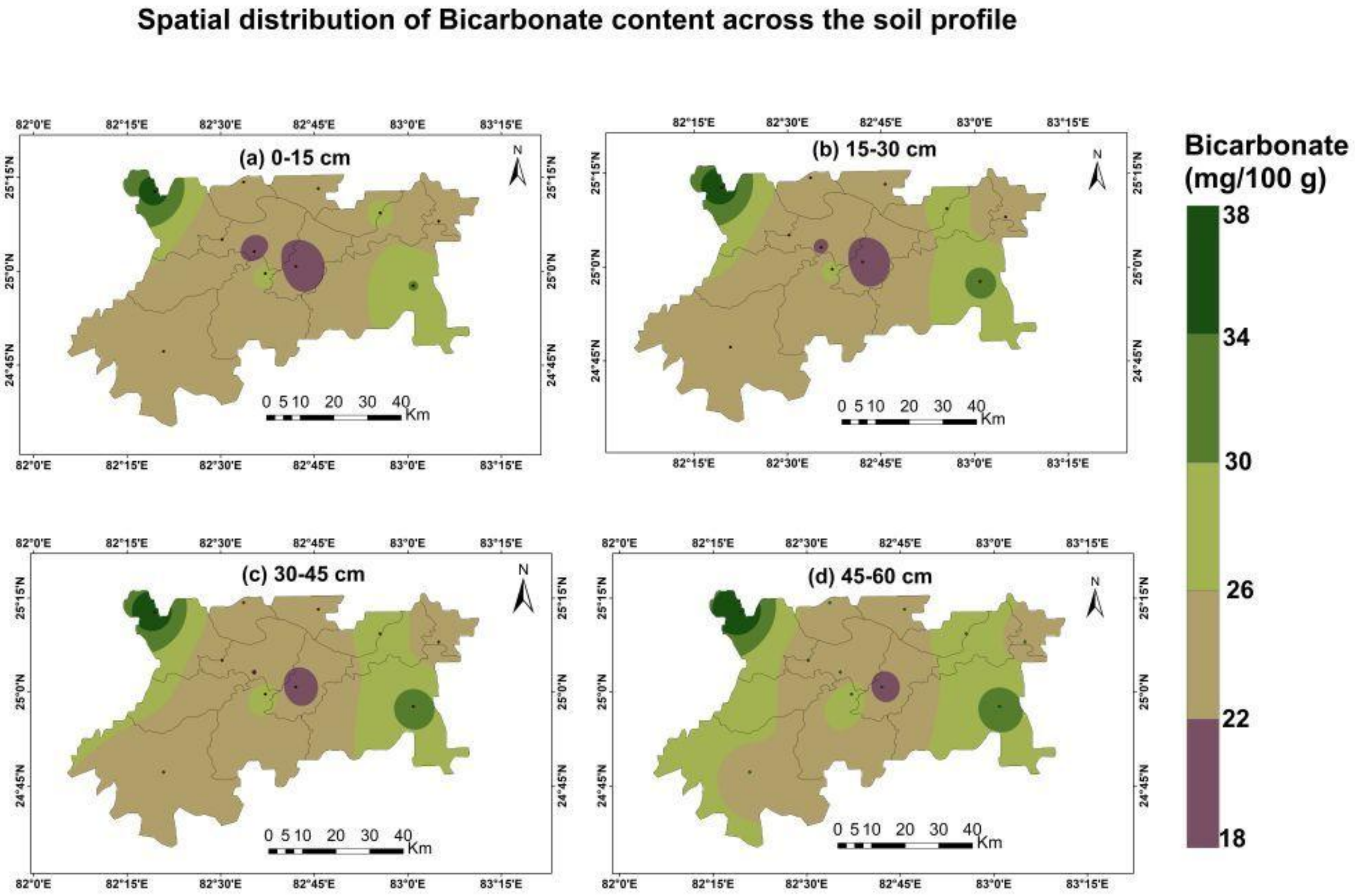


Figure 4.34 Spatial variability map of Bicarbonates across soil profiles of various regions in Mirzapur district of Vindhyan region

Table 4.6 Chemical parameters of soil profile samples

Sample ID	Depth (cm)	Ca (mg/100g)	Mg (mg/100g)	Na (Mg/100g)	Co3 (mg/100g)	HCo3 (mg/100g)
1	0-15	19	11.6	5.5	14.8	25.2
2	0-15	14.1	7.8	3.0	13.5	23.4
3	0-15	40.3	15.6	13.5	13.7	18.4
4	0-15	30.2	12.7	7.5	12.9	30.1
5	0-15	25.8	17.3	3.0	15.2	23.5
6	0-15	58.1	20.1	2.5	15.4	35.2
7	0-15	36.7	12.3	7.1	14.2	24.5
8	0-15	67.8	22.3	3.5	15.6	28.2
9	0-15	19.1	7.2	1.7	14.8	24.1
10	0-15	28.4	10.5	2.5	12.3	20.1
11	0-15	55.6	18.7	2.5	15.8	26.3
12	0-15	29.7	21.4	2.5	13.6	23.2
1	15-30	18.6	10.9	4.5	15.2	25.8
2	15-30	14.6	7.2	3.0	13.5	24.8
3	15-30	40.1	15.6	14	13.9	18.4
4	15-30	32.8	12.5	3.0	13.1	30.9
5	15-30	24.1	17.1	2.5	15.8	24.1
6	15-30	57.5	20.1	4.5	15.4	35.8
7	15-30	35.9	12.1	6.9	14.1	24.1
8	15-30	67.1	20.4	5.2	15.1	27.5
9	15-30	18.8	6.5	1.5	14.5	24.5
10	15-30	26.1	10.7	1.5	12.9	21.4
11	15-30	54.9	18.2	2.5	16.1	26.9
12	15-30	29.5	21.1	2.0	13.9	23.8
1	30-45	19.3	11.2	3.5	15.9	26.2
2	30-45	13.5	7.2	2.5	14.2	25.2
3	30-45	41.6	15.3	10.5	14.8	19.2

Table Contd…

Sample ID	Depth (cm)	Ca (mg/100g)	Mg (mg/100g)	Na (Mg/100g)	Co3 (mg/100g)	HCo3 (mg/100g)
4	30-45	30.5	12.4	3.5	13.8	31.4
5	30-45	24.9	17.1	3.5	16.3	24.3
6	30-45	57.3	19.8	3.5	16.5	36.1
7	30-45	38.6	11.4	6	13.6	23.1
8	30-45	68.1	22.1	5.5	15.9	28.7
9	30-45	23.1	6.3	2	14.9	24.7
10	30-45	28.3	10.8	1.5	13.6	21.9
11	30-45	51.8	18.1	2.5	16.7	27.2
12	30-45	28.2	21.1	2.5	14.2	24.3
1	45-60	19	11.1	4	16.8	26.5
2	45-60	14	6.9	4	14.7	25.8
3	45-60	40.9	15.3	9.5	15.1	19.8
4	45-60	33.1	12.4	2.5	13.8	31.5
5	45-60	25.8	17.4	2.5	16.7	24.9
6	45-60	58.7	19.6	4	16.9	36.9
7	45-60	37.1	11.1	9	14.2	23.9
8	45-60	65.3	22.1	5	16.1	29.5
9	45-60	21.5	6.4	3.5	15.3	25.2
10	45-60	26.7	10.8	2	13.9	22.3
11	45-60	59.2	18.3	3	17.1	27.8
12	45-60	28.9	21.3	3	14.8	24.9
MEAN		35.42	14.48	4.26	14.81	25.86
MAX		68.1	22.3	14	17.1	36.9
MIN		13.5	6.3	1.5	12.3	18.4
SD		16.30	5.07	2.89	1.20	4.34
Skewness		0.65	-0.03	1.91	0.10	0.81
Kurtosis		-0.74	-1.27	3.54	-0.80	0.73
CV		46.1	35	67.8	8.1	16.7

4.1.5 Micro nutrients

4.1.5.1 Iron

The soil profile samples collected from various regions of Mirzapur district (Table 4.1) has the Iron content ranging from 26.2- 70.8 mg/kg of soil with a mean value of 25.8 mg/kg. The soil profile of Karanpura region showed highest iron content and profile samples of Jabalpur Mafi, Charia and Gorahi recorded lowest iron levels. High Iron content is observed in the top layer of soil at 0-15cm depth and the lowest iron content is recorded in the sub soil of 45-60cm depth.

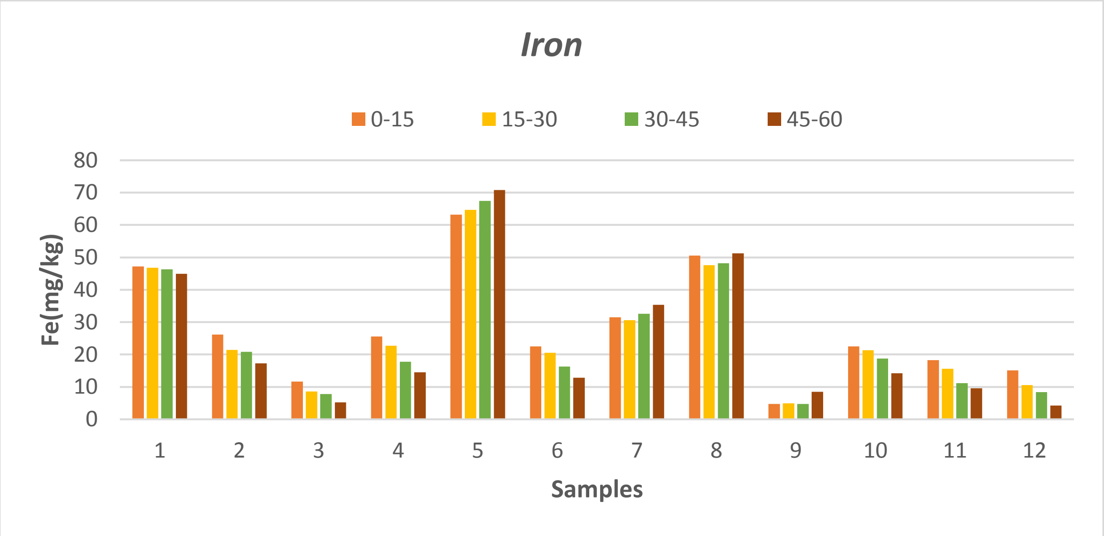


Figure 4.35 Chart of Iron in soil profile samples at various depths

The coefficient of skewness and Kurtosis for the Iron values is observed as 0.92 and -0.17 which represents positively skewed data and light tailed distribution. Coefficient of variation is 71.7% indicating a high level of dispersion. Iron content decreased with increase in depth and the content increased across the profile samples of Karanpura and Bela regions.

From the spatial variability map it can be observed that about 60% of the area has iron content ranging between 20-36 mg/kg. The iron content in the soil is significantly related to soil pH, Temperature, Aeration etc. Iron turns immobile and insoluble in alkaline condition leading to Iron deficiency (Mahendar *et al.*, 2019).

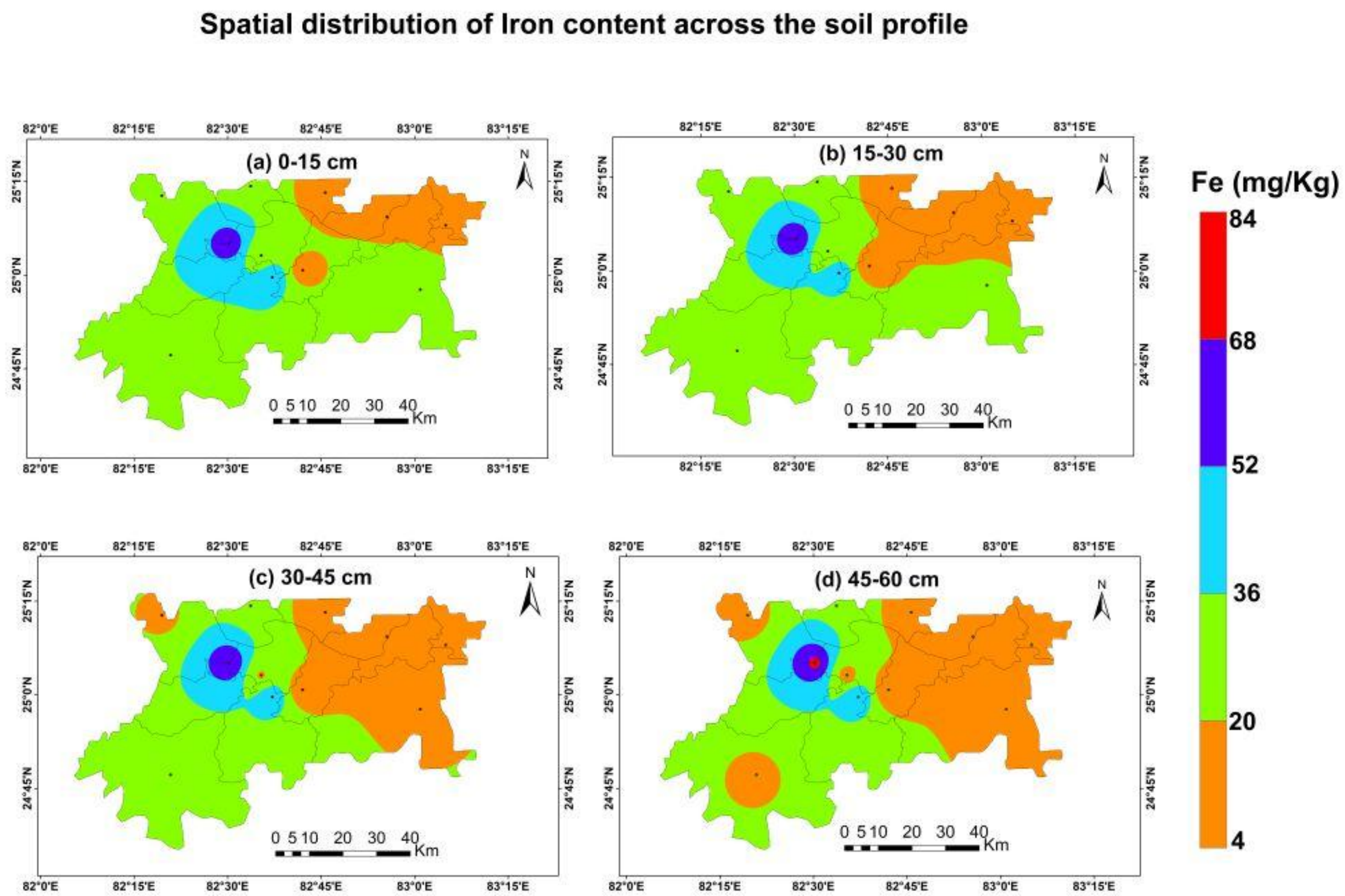


Figure 4.36 Spatial variability map of Iron across soil profiles of various regions in Mirzapur district of Vindhyan region

4.1.5.2 Copper

The copper levels in the soil profile samples collected from various regions of Mirzapur district (Table 4.1) were ranging between 0.6-3.5 mg/kg with an average value of 2.02 mg/kg. The soil profile sample of Gaura exhibited highest copper content and the lowest level is observed in Bhogaon region. Copper levels are high in the furrow slice layer of 0-15cm depth and lowest content is found in the subsoil layer of 45-60cm depth.

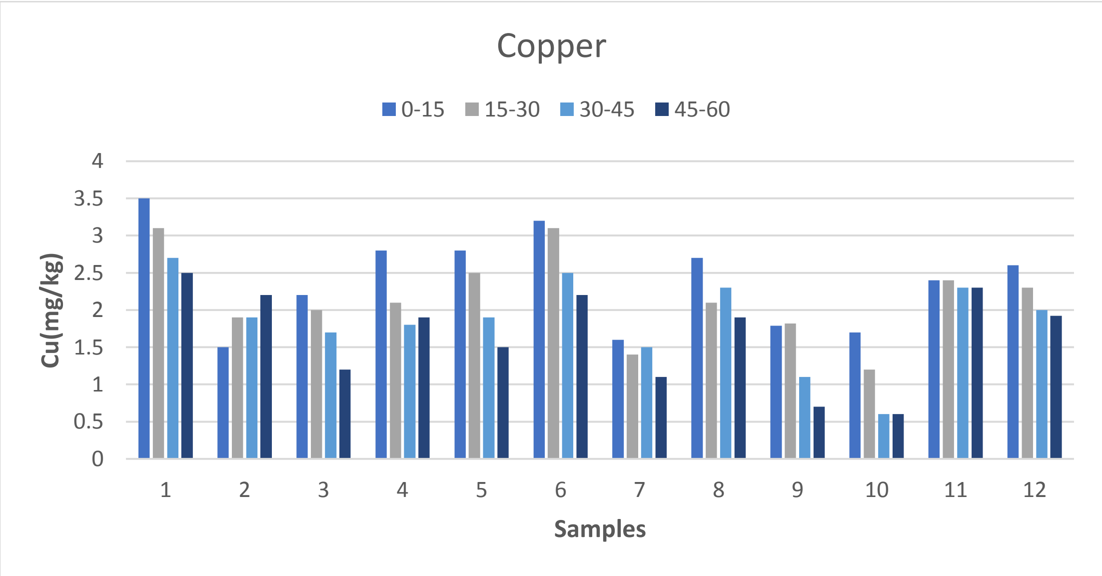


Figure 4.37 Chart of Copper in soil profile samples at various depths

The coefficient of variance for the values is observed as 32.5% which represents a moderate level of dispersion in the data. The observations has the coefficient of skewness and Kurtosis of -0.14 and -0.008 respectively indicating negative skewness and a near to normal distribution of data. Copper levels decreased with the increase in depth in the profile.

Copper levels ranging between 1.2-2.4 mg/kg are observed in most of the soil profile samples in the district which can be inferred from the spatial variability map as 70% of the area in the district showed these values. Copper content in the soil is significantly related with the soil texture and organic matter in the soil (Sharma *et al.*, 2015).

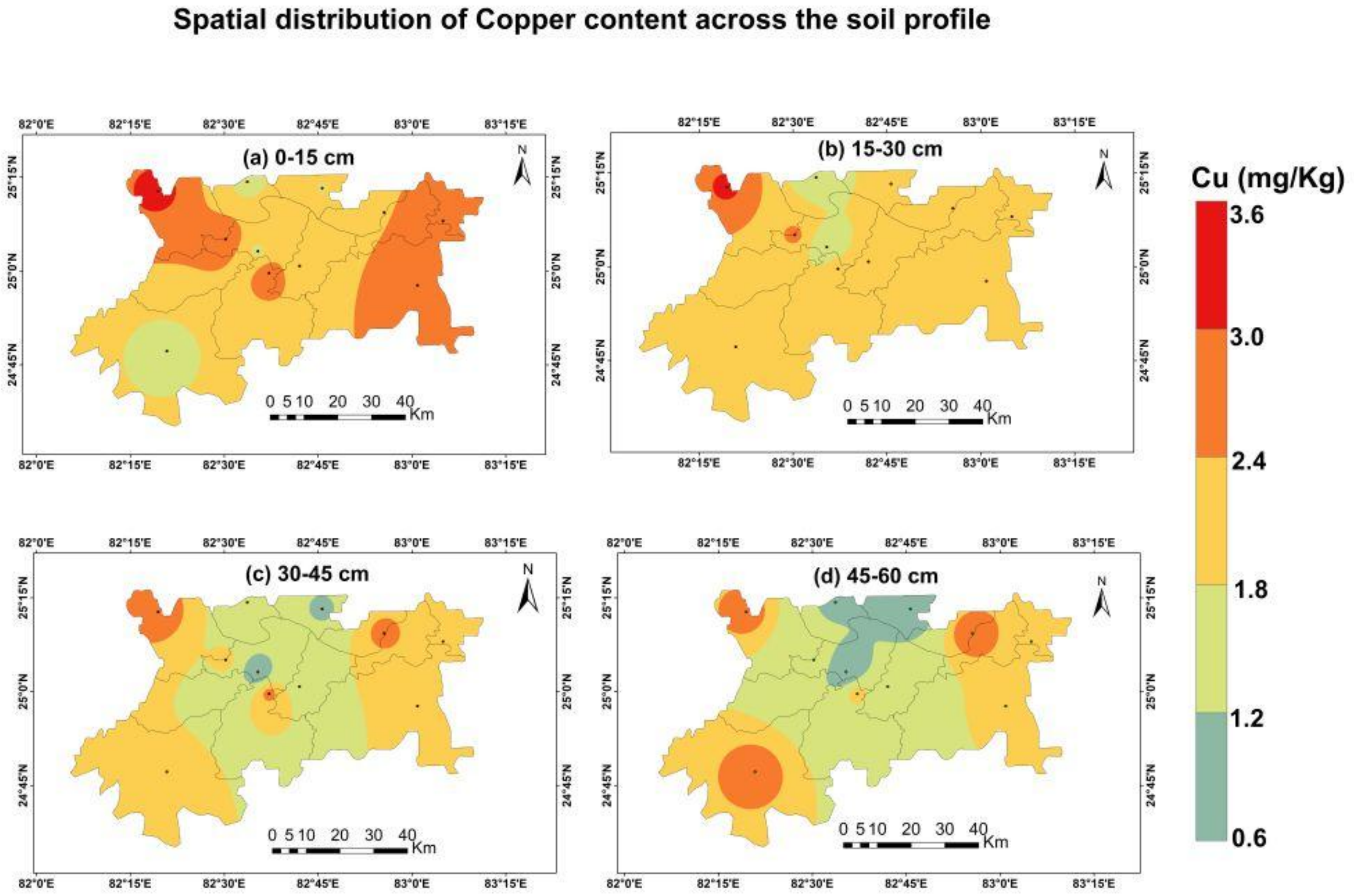


Figure 4.38 Spatial variability map of Copper across soil profiles of various regions in Mirzapur district of Vindhyan region

4.1.5.3 Manganese

The soil profile samples collected from various regions of mirzapur district(Table 4.1) have shown the manganese levels ranging from 6.4 to 36.9 mg/kg with a mean value of 11.2 mg/kg. The surface soil layer of 0-15cm depth has high levels of manganese and the lowest level of manganese is observed in the subsoil of 45-60cm depth. Highest manganese content is found in the soil profile sample of Bela region and the soil profiles of Ori, Barkaccha, Karanpura, Badohi etc. have shown the lowest levels of manganese.

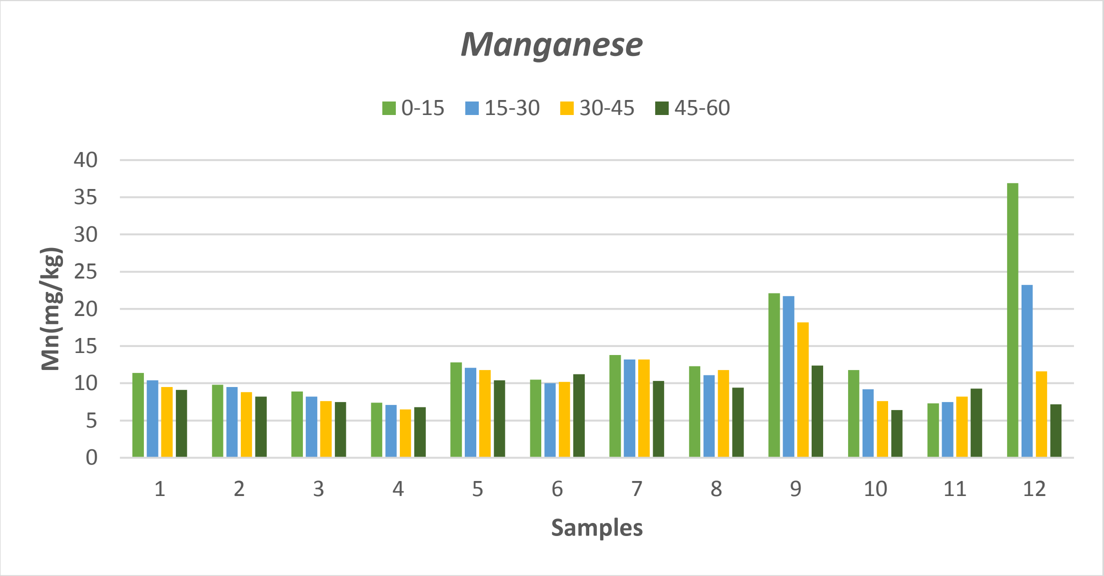


Figure 4.39 Chart of Manganese in soil profile samples at various depths

Coefficient of skewness and coefficient of kurtosis of the values of manganese is observed as 2.9 and 10.9 indicating a positively skewed data and leptokurtic distribution. The coefficient of variance is 47.5% which represents a moderate level of dispersion. Manganese levels decreased with the increase in the depth in soil profiles of all regions in the district.

It can be inferred from the spatial variability map that 80% of the area in mirzapur district has the manganese levels ranging from 6.4 to 12.6 mg/kg. The manganese levels in the soil are affected by soil pH, clay content and organic matter/ humus content in the soil (Mulder and Gerretsen).

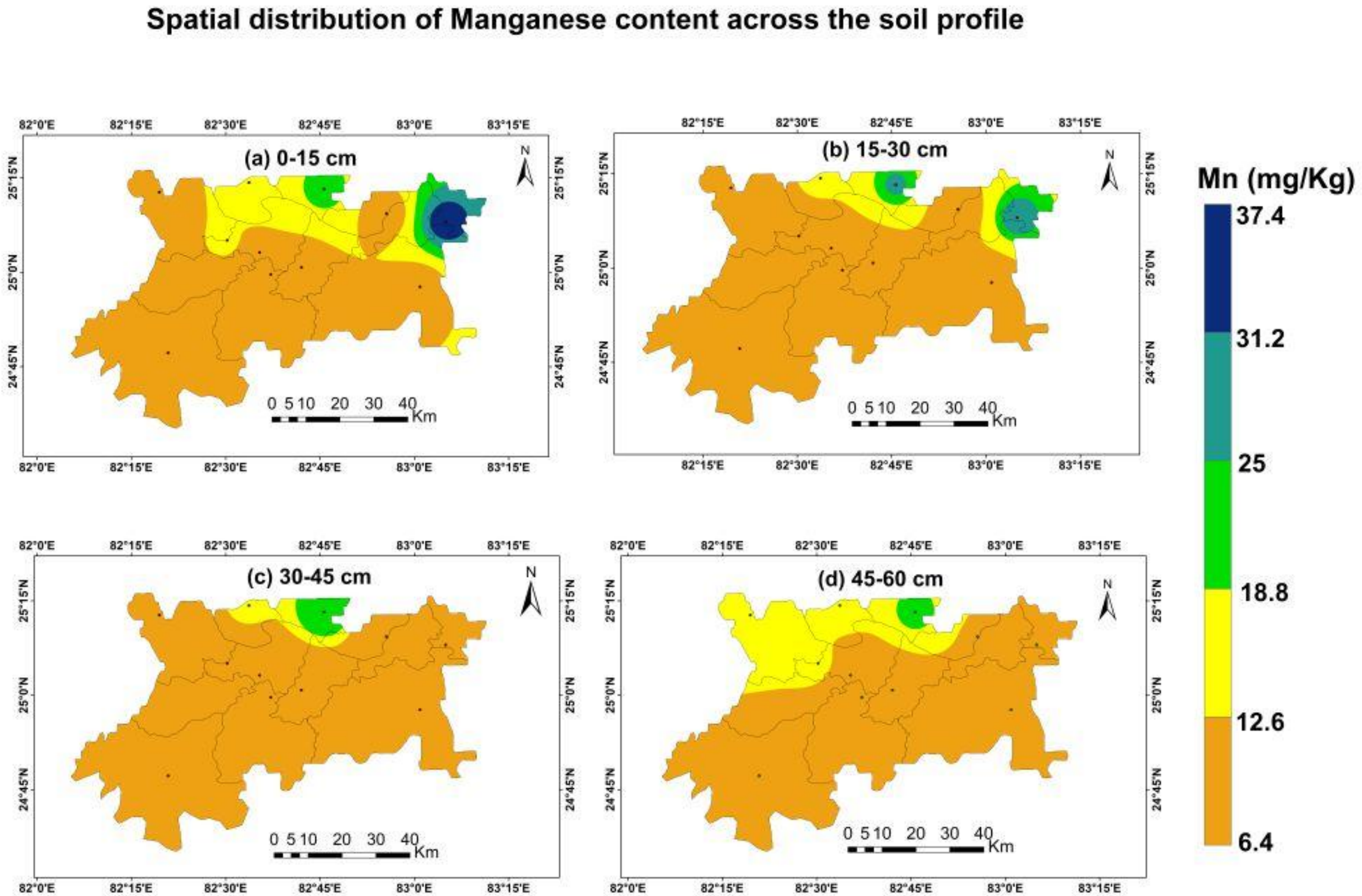


Figure 4.40 Spatial variability map of Manganese across soil profiles of various regions in Mirzapur district of Vindhyan region

4.1.5.4 Zinc

The zinc levels in the soil profile samples collected from various regions of mirzapur district(Table 4.1) ranged from 0.5 to 2.6 mg/kg with a mean value of 1.55mg/kg. The soil profile sample of Ori has recorded highest zinc content and the lowest value of zinc is observed in the profile sample of Jabalpur Mafi. The furrow slice layer soil of 0-15cm depth has exhibited high zinc content and lowest values are recorded in the subsoil layer of 45-60cm depth.

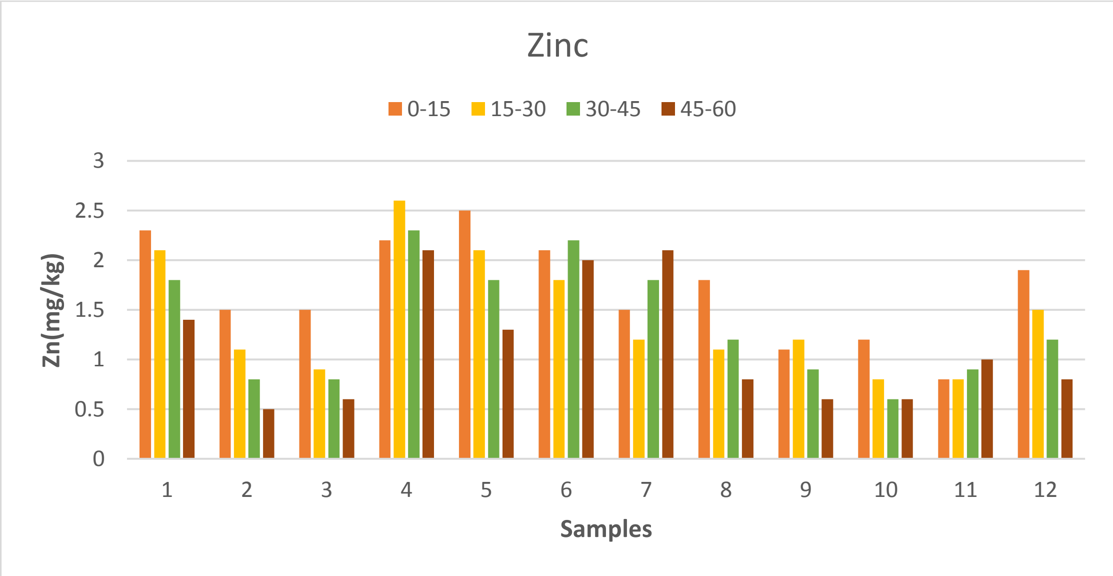


Figure 4.41 Chart of Zinc in soil profile samples at various depths

The coefficient of correlation and Kurtosis is observed as 0.26 and -1.19 which interprets a positively skewed data and a light tailed distribution. Zinc observations exhibited a coefficient of variance of 38.4% representing a moderate dispersion in the data. Zinc content decreased with the increase in soil depth in profiles of all regions

Major part of the district has soil profiles having zinc ranging between 0.9 to1.9 mg/kg. Zinc content in the soil is highly dependent on soil pH. Heavy textured soils and presence of calcium carbonate (>15%) leads to the deficiency of zinc (Arunachalam *et al.*, 2013).

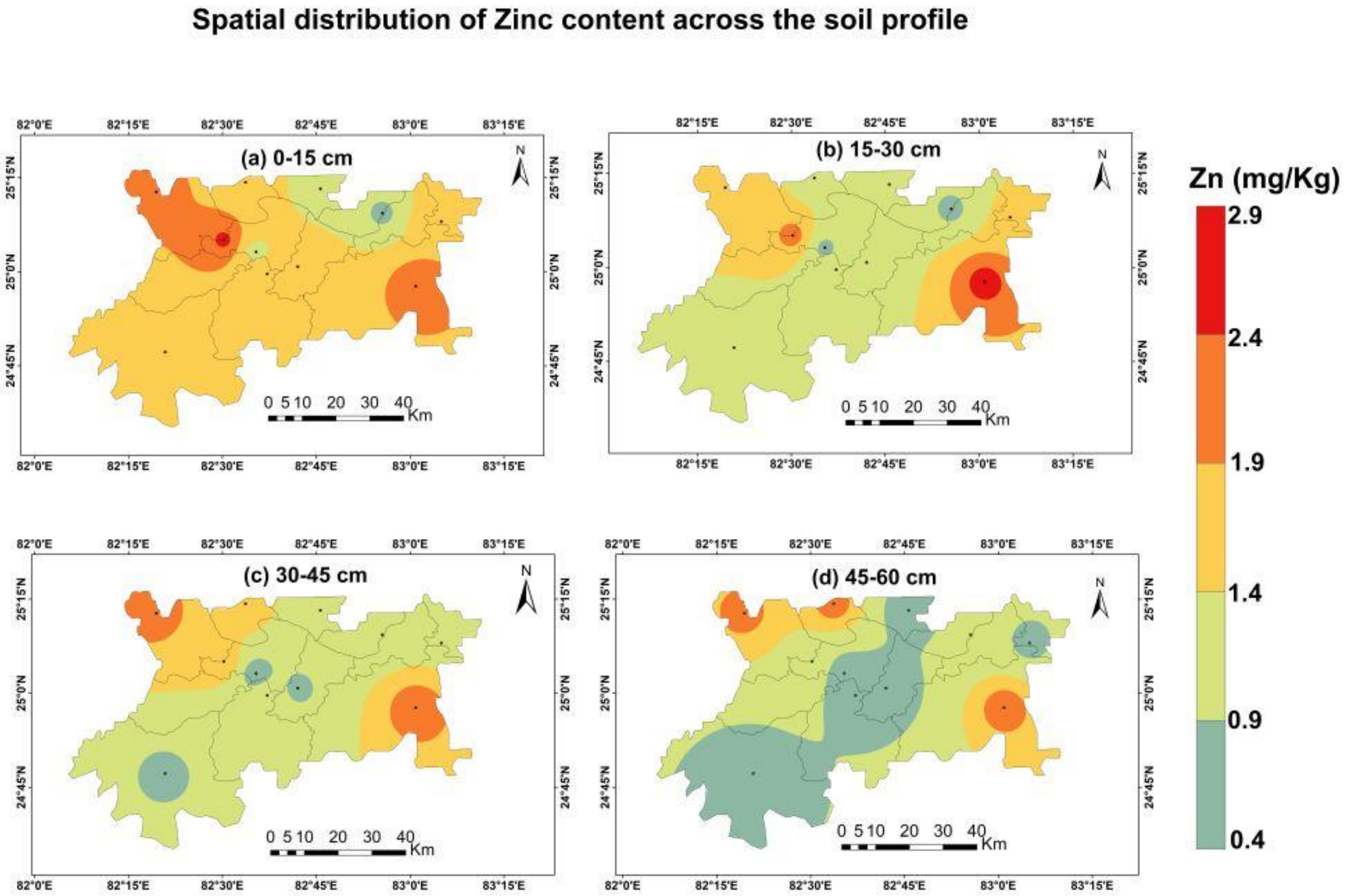


Figure 4.42 Spatial variability map of Zinc across soil profiles of various regions in Mirzapur district of Vindhyan region

Table 4.7 Micro nutrients of soil profile samples

Sample ID	Depth (cm)	Fe (mg/kg)	Cu (mg/kg)	Mn (mg/kg)	Zn (mg/kg)
1	0-15	47.2	3.5	11.4	2.3
2	0-15	26.2	1.5	9.8	1.5
3	0-15	11.6	2.2	8.9	1.5
4	0-15	25.6	2.8	7.4	2.2
5	0-15	63.2	2.8	12.8	2.5
6	0-15	22.5	3.2	10.5	2.1
7	0-15	31.5	1.6	13.8	1.5
8	0-15	50.5	2.7	12.3	1.8
9	0-15	4.7	1.79	22.1	1.1
10	0-15	22.5	1.7	11.8	1.2
11	0-15	18.3	2.4	7.3	0.8
12	0-15	15.1	2.6	36.9	1.9
1	15-30	46.8	3.1	10.4	2.1
2	15-30	21.4	1.9	9.5	1.1
3	15-30	8.6	2	8.2	0.9
4	15-30	22.7	2.1	7.1	2.6
5	15-30	64.7	2.5	12.1	2.1
6	15-30	20.5	3.1	10	1.8
7	15-30	30.6	1.4	13.2	1.2
8	15-30	47.6	2.1	11.1	1.1
9	15-30	4.9	1.82	21.7	1.2
10	15-30	21.3	1.2	9.2	0.8
11	15-30	15.6	2.4	7.5	0.8
12	15-30	10.6	2.3	23.2	1.5
1	30-45	46.3	2.7	9.5	1.8
2	30-45	20.8	1.9	8.8	0.8
3	30-45	7.8	1.7	7.6	0.8

Sample ID	**Depth (cm)**	**Fe (mg/kg)**	**Cu (mg/kg)**	**Mn (mg/kg)**	**Zn (mg/kg)**
4	30-45	17.8	1.8	6.5	2.3
5	30-45	67.4	1.9	11.8	1.8
6	30-45	16.3	2.5	10.2	2.2
7	30-45	32.6	1.5	13.2	1.8
8	30-45	48.2	2.3	11.8	1.2
9	30-45	4.7	1.1	18.2	0.9
10	30-45	18.8	0.6	7.6	0.6
11	30-45	11.2	2.3	8.2	0.9
12	30-45	8.4	2	11.6	1.2
1	45-60	44.9	2.5	9.1	1.4
2	45-60	17.3	2.2	8.2	0.5
3	45-60	5.2	1.2	7.5	0.6
4	45-60	14.5	1.9	6.8	2.1
5	45-60	70.8	1.5	10.4	1.3
6	45-60	12.8	2.2	11.2	2
7	45-60	35.3	1.1	10.3	2.1
8	45-60	51.2	1.9	9.4	0.8
9	45-60	8.5	0.7	12.4	0.6
10	45-60	14.2	0.6	6.4	0.6
11	45-60	9.6	2.3	9.3	1
12	45-60	4.22	1.92	7.2	0.8
MEAN		25.89	2.02	11.27	1.55
MAX		70.8	3.5	36.9	2.6
MIN		26.2	0.6	6.4	0.5
SD		18.58	0.65	5.36	0.59
Skewness		0.92	-0.14	2.92	0.26
Kurtosis		-0.17	-0.008	10.93	-1.19
CV		71.7	32.5	47.5	38.4

Table 4.8 Correlation table of Physico-chemical parameters

	pH	EC	PD	BD	Porosity	WHC	O.C	TOC	T OM	N	P	K	Na	Ca	Mg	Co3	HCo3	Fe	Cu	Mn	Zn
pH	1.000**																				
EC	.264	1.000**																			
PD	-.436	.005	1.000**																		
BD	-.330	-.099	.282	1.000**																	
Porosity	-.232	.067	-.425	-.309	1.000**																
WHC	.171	.204	0.296*	-.287	0.476**	1.000**															
O.C	.036	-.039	-.021	.196	.092	0.300*	1.000**														
TOC	.078	-.066	-.063	.185	.043	0.313*	0.965**	1.000**													
TOM	.035	-.037	-.022	.197	.091	0.314*	0.989**	0.966**	1.000**												
N	.238	.256	-.056	.048	-.018	.251	0.549**	0.544**	0.540**	1.000**											
P	-.227	-.010	.031	-.408	.275	.206	.028	.056	.029	.120	1.000**										
K	.046	.197	.194	-.376	.220	0.289*	0.517**	0.537**	0.517**	.207	.187	1.000**									
Na	.250	-.067	.247	.085	-.204	.214	.065	.021	.063	-.186	0.409**	.122	1.000**								
Ca	.142	.043	-.022	-.012	-.002	.242	0.414**	0.385**	0.411**	.208	-.167	0.401**	.201	1.000**							
Mg	.005	.096	-.061	.008	-.060	.022	0.301*	.263	0.298*	0.296*	-.332	.083	.064	0.740**	1.000**						
Co3	-.094	.043	-.085	-.125	-.006	0.299*	.192	.150	.191	.212	-.081	.070	-.132	0.425**	0.433**	1.000**					
HCo3	.119	.056	-.036	.241	-.226	.065	-.087	-.118	-.087	.277	-.431	-.223	-.323	0.456**	0.324*	0.406**	1.000**				
Fe	-.267	-.145	.048	.279	-.188	-.267	.190	.171	.189	-.005	-.484	-.359	-.046	.016	.190	0.312*	.059	1.000**			
Cu	.215	.021	.101	-.011	.110	.128	.284	.195	.283	.222	.269	-.117	-.005	.235	0.437**	0.318*	0.450**	0.289*	1.000**		
Mn	-.283	.154	.261	-.248	0.299*	.097	-.050	-.074	-.051	-.058	.157	-.101	-.224	-.157	.050	-.107	-.140	-.077	.079	1.000**	
Zn	.175	-.105	-.050	0.351*	-.258	-.194	-.120	-.173	-.122	.031	-.365	-.683	.003	.004	.159	-.038	.255	.203	.249	.120	1.000**

** 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

Soil is the biologically active and porous medium which acts as the store house for nutrients required for plant growth. Soil management plays a vital role in the sustainability of environment, crop production and human health directly and indirectly. The intensification of food production due to rapid increase in population made the soil quality management and monitoring as a prime requisite for sustainability (white *et al.*, 2012). The Geo spatial technology and remote sensing techniques makes use of soil spectral properties to evaluate various physical and chemical parameters, monitoring soil loss through erosion, degradation, disequilibrium in the water and carbon cycles etc which are controlled by the soil surface characteristics (Zribi *et al.*, 2011).

Soil profile is the vertical section of soil having different horizons. Profile analysis gives information soil genesis, influence of parent material on soil chemical parameters, drainage control, stability of the soil and provides a framework on the soil formative processes which influence the soil permeability (Presley *et al.*, 2008). Hence the current study on ***"Soil Profile Mapping of Mirzapur district of vindhyan region using Geo Spatial Techniques"*** is carried out to characterize and evaluate various physical and chemical parameters of soil profile samples of mirzapur district. The study reported the following findings,

- Remote sensing and GIS techniques using Inverse Distance Weighed (IDW) interpolation are found efficient for the interpretation of soil profile characteristics.
- Spatial variability mapping is an efficient technique to represent the ranges of soil physico-chemical properties.
- The pH values of the 12 soil profile samples had a mean value of 6.71 and ranged between 5.1 to 8.8.EC values ranged from0.02 to 0.206 dSm^{-1} with a

mean value of 0.084dSm^{-1}. The values decreased with the increase in depth and high dispersion is recorded in the EC values.

- The mean values of bulk density and particle density are recorded as 1.32 g cc^{-1} and 2.54 g cc^{-}1. The BD values ranged between 1.251 to 1.382 g cc^{-1} and PD ranged between 2.399 and 2.665 g cc^{-1}. Bulk density increased across the soil profile. The porosity is decreased with the increase in depth had a mean value of 47.7%.
- The water holding capacity recorded a mean value of 45.8% and the values decreased across the profile. Water holding capacity is highly significant and positively correlated to the porosity in the profile with r value of 0.476.
- Relative brightness (Value) changed in the soil colour with the increase soil depth and no significant difference is found in the Hue.
- Soil organic carbon, total organic carbon and organic matter decreased in the sub soil layers and showed a positive correlation among them(r = 0.965, r = 0.963), soil organic carbon and total organic carbon showed high significance and positive correlation with exchangeable calcium (r = 0.414 and r= 0.385). Organic carbon and organic matter values showed high level of dispersion in the profile. Spatial variability map revealed the presence of high organic carbon and organic matter levels in central part of the district.
- Primary nutrients N, P and K recorded mean values as 140.8, 21.5 and 250kg ha^{-1} respectively. The nutrient content was high in surface soil layer than subsurface and had a moderate level of dispersion. Potassium content in the soil profile is positively correlated with the organic carbon(r = 0.517).
- Carbonates and bicarbonates levels in the subsurface layer of were high compared to top soil layer. Mean values are observed as 14.8 and 25.8 mg/100g and showed a highly significant positive correlation with exchangeable calcium (r = 0.425 and r = 0.456).
- Sodium levels in the soil profile displayed a high level of dispersion with a mean value of 4.256 mg/100g. Calcium and magnesium values decreased with the increase in depth of soil recorded a mean value of 14.2 and 14.8mg/ 100g

respectively. The exchangeable Ca and Mg showed a significant positive correlation with Carbonates (r= 0.425 and r=0.433) and bicarbonates (r =0.456 and r= 0.32).

- The content of micronutrients (Fe, Cu, Mn and Zn) decreased with the increase of depth in the soil profile. The iron values showed a high level of dispersion and the rest has moderate level of dispersion. The mean values of Fe, Cu, Mn and Zn are recorded as 28.8, 2.02, 11.2 and 1.55 mg kg^{-1} respectively. Iron showed a significant positive correlation with bicarbonate content with r values of 0.31.

It can be concluded that the study of soil profile is important to evaluate the soil quality, extent of soil fertility, drainage properties and hydrological aspects in the soil system. It also helps to evaluate the soil stability and status to suit various agricultural and engineering purposes. Geo spatial technology can be considered as a potential technique for the rapid evaluation and monitoring of various soil profile characteristics. Large sets of data can be generated and analysed using the remote sensing and GIS techniques on a frequent basis and the updated information is used for the research purpose of interest. Hence the Geo spatial technology is proved to be efficient for the evaluation and characterization of soil properties across the soil profile.

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