

CHARACTERIZATION OF SOIL QUALITY PARAMETERS
OF BALAGHAT AND MALAJKHAND BLOCKS IN
BALAGHAT DISTRICT OF MADHYA PRADESH

काशी हिन्दू
विश्वविद्यालय



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in

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To,
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Dear Sir,

I have the great pleasure in forwarding the thesis entitled “**Characterization of soil quality parameters of Balaghat and Malajkhand blocks in Balaghat district of Madhya Pradesh**” submitted by **Miss. Nitu Patle, I.D. No. 20430SAC019**, in partial fulfilment of the requirements for the award of the degree of **Master of Science (Agriculture) in Soil Science - Soil and Water Conservation, Department of Soil Science & Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi.**

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

Yours faithfully,

Ramawatar Meena
Supervisor

FORWARDED

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MADHYA PRADESH**



By

Nitu Patle

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Date:

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LIST OF SYMBOLS AND ABBREVIATIONS

%	-	Percent
°C	-	Degree Celsius
Agri.	-	Agriculture
ha.	-	Hectare
Ca	-	Calcium
cm	-	Centimetre
mm	-	Millimeter
d Sm⁻¹	-	Desi simen per meter
EC	-	Electrical conductivity
WHC	-	Water holding capacity
et al.	-	<i>Et alia</i> , And others
etc	-	and so an
Fig.	-	Figure
H₂SO₄	-	Sulphuric Acid
i.e.	-	Id est. that is
i.e.	-	That is
K	-	Potassium
kg ha⁻¹	-	Kilogram per hectare
KMnO₄	-	Potassium permanganate
mg kg⁻¹	-	Milligram per kilogram
g kg⁻¹	-	gram per kilogram
M ha	-	Million hectare
N	-	Nitrogen
NH₄⁺-N	-	Ammoniacal Nitrogen
OC	-	Organic carbon
P	-	Phosphorus
pH	-	Puissance de hydrogen
RH	-	Relative humidity
NIV	-	Nutrient Index Value
S	-	Sulphur

Sq. km	-	square kilometre
viz.,	-	Vide licet, namely
No.	-	Number
Sci.	-	science
Soc.	-	Society
Univ.	-	university
S.N.	-	Serial number
J.	-	Journal
Mn	-	Manganese
Cu	-	Copper
BD	-	Bulk Density
PD	-	Particle Density
lb.	-	pound
OC	-	Organic Carbon
UP	-	Uttar Pradesh
MP	-	Madhya Pradesh

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Introduction

Madhya Pradesh is a central Indian state. Bhopal is the capital, and Indore is the largest city. Other notable cities include Jabalpur, Ujjain, Gwalior, and Satna. With nearly 72 million people, Madhya Pradesh is India's second-largest state by area and fifth-largest by population. It is bordered on the northeast by Uttar Pradesh, on the southeast by Chhattisgarh, on the south by Maharashtra, on the west by Gujarat, and on the northwest by Rajasthan.

Madhya Pradesh, which literally means "Central Province," is located in the geographic center of India, between 21.6°N and 26.30°N and 74°9'E and 82°48'E. The state is divided by the Narmada River, which runs east-west between the Vindhya and Satpura ranges; these ranges, along with the Narmada, constitute the traditional northern and southern boundaries of India. Dhupgarh, at an elevation of 1,350 meters, is Madhya Pradesh's highest peak (4,429 ft). Gujarat borders the state on the west, Rajasthan on the northwest, Uttar Pradesh on the northeast, Chhattisgarh on the east, and Maharashtra on the south.

Summer, Monsoon, and Winter are the three major seasons of Madhya Pradesh. During the summer months (March–June), the temperature in Madhya Pradesh reaches up to an average of 34.6-38 degree Celsius, which is an all-time high. Madhya Pradesh's eastern regions are often hotter than its western regions. The humidity level is quite low, and the region is prone to regular light dust storms. The southwest monsoon normally begins in mid-June and lasts until September, when the state receives the majority of its rainfall. More than 150 cm of rain falls in Mandla, Balaghat, Sidhi, Jabalpur, and other extreme eastern areas. Western Madhya Pradesh receives less than 80 cm of rainfall per year. The average annual rainfall is 1,194 mm

(47.0 in). The southern districts receive the most rain, with some locations receiving up to 2,150 mm (84.6 in), whereas the western and northern districts receive less than 1,000 mm (39.4 in).

According to 2011 estimates, the state's documented forest area is 94,689 km² (36,560 sq mi), accounting for 30.7 percent of the state's total geographical area. It accounts for 12.3% of India's total forest area. This land has been legally designated as "Reserved Forest" (65.3%), "Protected Forest" (32.8%), and "Unclassified Forest" (0.2 percent). In comparison to the national average of 700 m², per capita forest area is 2,400 m² (0.59 acres) (0.17 acres). The northern and western regions of the state, which contain the major population centers, have less substantial forest cover. The state's forest types range significantly due to variations in climatic and edaphic conditions. In January of this year, 1.5 million volunteers around the state planted 66 million trees in 12 different locations.

Balaghat is a district in Madhya Pradesh, India's central state. Its administrative headquarters are at the town of Balaghat. The tile industry, rice mills, and forests of Balaghat are well-known. Balaghat District is located in the southern part of Jabalpur Division. It occupies the south eastern portion of the Satpura Range and the upper valley of the Wainganga River. The district extends from 21°19' to 22°24' north latitude and 79°31' to 81°3' east longitude. The total area of the district is 9,245 km². The Wainganga and its tributaries are the most important rivers in the district. The town of Balaghat is situated on the Bank of River Wainganga, which flows north to south through the district and Enters in Balaghat District by Merging with Thanwar river near Nainpur of Mandla District. The Bawanthadi and Bagh rivers define the boundary with Maharashtra.

About 80% of the manganese production in India comes from Bharveli village of Balaghat District. It was originally incorporated as Manganese Ore (India) Limited in the year 1962. Subsequently, name of the Company was changed from Manganese Ore (India) Limited to MOIL Limited during the financial year 2010-11. At present, MOIL operates 11 mines, seven located in the Nagpur and Bhandara districts of

Maharashtra and four in the Balaghat district of Madhya Pradesh. All these mines are about a century old. Except 4, rest of the mines are worked through underground method. The **Balaghat Mine is the largest mine** of the Company. The mine has now reached a mining depth of about 383 meters from the surface. The recently discovered copper deposit at **Malanjkhand** is regarded as the largest in the country. Bauxite, Kyanite, Marble, Dolomite, Clay and limestone are the other main minerals of the district. About 80% of the district's area is covered with forest. It is also the District of Madhya Pradesh which has maximum forest density. Teak (*Tectona grandis*), Sal (*Shorea Robusta*), bamboo and saja are the main trees.

Balaghat is a leading district in paddy production in Madhya Pradesh, hence it is called the **Paddy bowl** of the state. Minimum temperature is between 2.5°C to 5°C with rainfall ranging from 1200 mm to 1600 mm. Soil type is sandy loam and light black.

Malanjkhand also referred to as MCP (acronym for Malanjkhand Copper Project) is an open-pit copper mine in India, located near the town of Malanjkhand, 90 Kilometres (56 mi) northeast of Balaghat in Madhya Pradesh, at an altitude of 576 MRL. It falls in the tehsil of Birsa, which is 4–5 Kilometres (2.5–3.1 mi) from the project, on the way to Raipur, Madhya Pradesh State. It is located nearby to the Kanha National Park. It is the largest **base metal mine** in India. Besides copper, quartzite, copper pyrite and manganiferous rocks are other important mineral sources found in Malanjkhand. Malanjkhand Copper Project was inaugurated by Prime Minister Smt. Indira Gandhi in 1982 and Hindustan Copper Limited started to exploit the copper ore through open pit mining. Geological Survey of India took systematic geological exploration at this deposit during 1969. Mining lease of the ore was granted to Hindustan Copper Limited in 1973. With advancement of time this project was enhanced with viable operational developments. It is the largest open cast mining in Asia.

The mining land use problems and conflicts are:

- Conflicts that emerge when two or more proponents compete for the same parcel of land, such as Mn & Cu strip mining and agricultural.
- When a particular land use on one parcel of property has an undesirable effect on the usage of neighboring parcels of land, conflicts occur. This typically highlights the issue of user compatibility or incompatibility, such as the influence of metallic mining wastes on the usage of nearby water supplies.
- Conflicts between those who want to develop a certain mineral or energy resource and those who want to preserve the environment through conservation and protection, such as the creation of gardens and parks.

The term "soil fertility" describes a soil's capacity to foster the growth of agricultural plants, i.e., to sustainably produce high-quality crops and habitat for plants. A fertile soil is one that has the ability to offer essential plant nutrients and water in the quantities and proportions needed for plant growth and reproduction, as well as the absence of potentially toxic substances that could limit plant growth. The macro and micro-nutrient reserve of a soil is the most essential factor in determining its fertility state. As a result, fertilizer recommendations based on soil testing are an excellent tool for improving soil fertility and productivity. The importance of soil analysis for determining soil fertility is enormous, as it allows us to calculate how much nutrients we need to feed externally before the start of a growing season so that plants do not suffer from nutrient insufficiency. However, various limitations in India are preventing widespread use of soil analysis, such as the prevalence of small-scale farming and a lack of institutional resources for significant soil testing (Sen *et al.*, 2008).

Plants require at least 17 elements for a healthy growth and life cycle. The three most common plant nutrients—carbon, hydrogen, and oxygen—come from non-mineral sources like air and water. The remaining 14 elements must either be added as fertiliser or taken up by plants in the form of minerals from the soil. Potassium,

phosphorus, and nitrogen are all necessary nutrients for plants. These are the nutrients that are typically provided to plants by fertilisers, and they are referred to as fundamental nutrients. The three secondary nutrients—calcium, magnesium, and sulfur—are needed in smaller quantities than the essential nutrients. Liming materials provide calcium and magnesium, whereas fertilizing materials provide Sulphur. Depending on local air quality, contaminants in rainfall also provide 10 to 20 lb. of nitrogen and sulfur per acre each year.

Minerals and soil organic matter (SOM) make up soil. water and air are two of the most important elements in life. The proportions and content of these components have a significant impact on soil physical qualities such as structure and porosity. These qualities affect the soil's capacity to function and the flow of both air and water. The chemical and physical characteristics of a soil are significantly influenced by its organic fraction, even though it makes up less than 10% of the soil's total weight. Carbon, oxygen, hydrogen, nitrogen, plus a small amount of Sulphur and other elements make up soil organic matter. These qualities affect the soil's capacity to function and the flow of both air and water. The chemical and physical characteristics of a soil are significantly influenced by its organic fraction, even though it makes up less than 10% of the soil's total weight. Soil is a mixture of solid, gaseous, and aqueous mineral and organic elements (Voroney *et al.* 2006).

Soil quality, according to Karlen *et al.* 1997, is the ability of soil to function within natural and managed ecosystem bounds, to maintain or improve water or air quality, and to support human health and habitation. Soil quality cannot be directly tested; it must be inferred from a wide range of soil variables (physical, chemical, and biological) that influence the soil's ability to perform efficiently. The multiplicity of physical, chemical, and biological variables that interact and affect soil function further complicates the identification of soil quality indicators and evaluation methodologies (Doran & Parkin, 1994). Time, climate, rainfall, flora, and human actions all play a role (Arshad and Martin 2002). Soil quality is determined by measuring the physico-chemical parameters of the soil via soil testing.

With the growth of science and technology, as well as the rise in population, urbanization, and industrialization, the demand for soil for various uses such as construction, industrialization, and agriculture are steadily increasing, resulting in a significant reduction in soil quality. According to (Lal and Singh 1998), the physical, chemical, and biological degradation processes in soil quality deterioration with regard to productivity or fertility are all included.

With soil test-based fertility management, which has been demonstrated to be an efficient approach, The combined effects of physical, chemical, or biological processes can increase the productivity of agricultural soils with high geographical variability (Goovaerts, 1998). The key markers of soil fertility include physical parameters i.e., pH, electrical conductivity, texture, structure, color, organic matter, primary, secondary, and micronutrients (B, Fe, Zn, Cu, and Mn), among others (Brady and Weil 2002).

Plant growth and development can be predicted using these characteristics. Understanding the state of soil fertility is critical for developing effective soil management techniques and devising crop cultivation plans in the specified area. Global Positioning Systems (GPS) and Geographic Information Systems (GIS) are also useful tools for assessing soil spatial variability. A geographic information system (GIS) is a set of tools for gathering, storing, accessing, processing, and displaying spatial data (Burrough and McDonnell, 1998).

EC, pH, organic carbon, and calcium carbonate are essential physico-chemical characteristics that influence the availability of nutrients in soils and, as a result, crop growth and output. All of the plant nutrients are stored in organic carbon. It improves aeration, boosts microbial activity, water holding capacity, and keeps the pH, CO₂, and calcium carbonate levels in the soils in check. The literature also shows that soil nitrogen and phosphorus are in insufficient supply in order to meet crop requirements. (Jatav and Mishra,2012)

Nitrogen is an essential part of proteins, enzymes, amino acids, and chlorophyll, all of which support root and vegetative growth. Plants can obtain

nitrogen in the form of NO_3^- and, to a lesser extent, NH_4^+ . Phosphorus plays an important role in energy storage and transfer. Nucleic acid, phytin, and phospholipids all contain phosphorus. Phosphorus is available to plants in the forms of HPO_4^- and H_2PO_4^- , and potassium is available in the forms of K^+ and K_2O , both of which act as enzyme activators and are involved in a variety of important plant physiological processes. They are also helpful in the translocation of protein and sugar tolerance to drought, as well as resistance to pests and diseases. A number of proteolytic enzymes, including papain, are activated by Sulphur. It encourages the production of seeds and nodules on the roots of leguminous plants.

In view of the above facts the present study was carried out to determine the “characterization of soil quality parameters of Balaghat and Malajkhand blocks in Balaghat district of Madhya Pradesh” with the following objectives:

- To characterize and classify the soils of Balaghat and Malajkhand Blocks in Balaghat district.
- To ascertain the fertility status of soils of Balaghat and Malajkhand blocks and preparation of nutrient wise map for identification of nutrient constraint.
- To assess the comparison of nutrient status of soil nearby Manganese and Copper Mines and far from the mines as normal cultivated area of Balaghat and Malajkhand blocks.
- To study the correlation between physico-chemical properties and available nutrients in the soils of Balaghat and Malajkhand blocks.



Review of Literature

Soil health has long been a source of concern for farmers and agriculturists because the soil is the only source of life. The deterioration in soil health as a result of decreased soil fertility has been shown to have severe effects on the soil's sustainability, ultimately leading to food safety being affected in the long run. The largest issue the world has now is ensuring the daily nutritional needs of all individuals on the planet, whose population is expected to reach over 10 billion by 2050. As a result, several technologies and approaches can be used to mitigate the decreasing fertility level of agricultural areas. The ability to analyse soil attributes and make accurate forecasts of soil performance at any given point on the landscape requires a thorough understanding of their variability and presence of available pools of nutrients.

A brief overview of Indian research on several aspects including soil physicochemical parameters, macronutrient status, and fertility are reviewed below:

2.1 Physico-chemical properties of soil.

- Particle density (PD)
- Bulk density (BD)
- Soil Reaction (pH)
- Electrical conductivity (EC)
- Organic carbon (OC)

2.2 Status of available macro-nutrients in soil.

- Nitrogen
- Phosphorous
- Potassium
- Sulphur

2.1 Physico-chemical Properties of soil

Particle density, Bulk density and WHC

Varadaraju *et al.* (2010) gathered soil samples from several locations around Karnataka's Dakshina Kannada district and analyzed chosen physico-chemical parameters. Water holding capacity ranged from 28.2 to 59.80 percent, and bulk density ranged from 2.03-2.27 g cm⁻¹.

Gupta *et al.* (2010) found that the bulk density of the soils in the foothills of the Siwaliks in Jammu, Jammu and Kashmir State varied greatly depending on soil depth, ranging from 1.31 to 1.60 Mg m⁻³ in surface and subsurface soils. In soils of barren, cultivated unmanaged, cultivated well managed, and forest areas, water holding capacity (percent) ranged from 21.9 to 32.2, 30.5 to 40.5, 35.4 to 47.5, and 35.3 to 47.3, respectively.

Meena *et al.* (2011) shows the data on wheat water use and water use efficiency as a function of tillage and mulch treatment. The highest water use efficiency was obtained in the case of bed planting (151.1 kg ha⁻¹ cm⁻¹) and the lowest in the case of deep tillage (128.4 kg ha⁻¹ cm⁻¹).

Shirgire (2012) reported that the soils in the Jamnagar district ranged in bulk density, particle density, porosity, and MWHC from 1.15 - 1.52, 2.19 - 2.83 Mg m⁻³, 22.89 - 56.80, and 36.47 - 73.02 %, with mean values of 1.30, 2.40 Mg m⁻³, 45.57, and 52.16 percent, respectively.

Nath (2014) For sixty soil samples collected (0-15 cm) from ten tea plantations, investigated the relationship between several physical and chemical properties of soil, such as sand content, total organic matter content, and macronutrients, and bulk density. The contents of sand, silt, and clay in soil samples ranged from 74.87-88.24 percent, 0.02-0.04 percent, and 11.74-25.11 percent, respectively; bulk density values for tea estate soil ranged from 0.98-1.29 g cm⁻¹. In the Shivanagar district of Assam, the water holding capacity ranged from 50.44 to 59.18 percent, with a mean value of 54.41 percent.

Ahad et al. (2015) analyzed the BD and porosity of soils in District Kupwara (Kashmir Valley), India, ranged from 01.24 to 1.46 Mg m⁻³ and 42.86 to 51.18 percent, respectively. The percentages of sand, silt, and clay in the collected samples ranged from 55.33 to 68.96 percent, 12-33 percent, and 10-18 percent, respectively, and these soils were classified as loamy sand and sandy loam due to the high sand and silt content.

Singh et al. (2015) evaluated that the average bulk density of mine soil (1.07 Mg m⁻³) was found to be higher than that of natural forest soil. In comparison to overburden coalmine soil, cultivated areas adjacent to the mining region had a lower bulk density. The bulk density of newly dropped dirt was 1.61 Mg m⁻³ on average. The porosity of cultivated soils near the mining region was higher, with an average porosity of 48.39 percent. Water holding capacity (WHC) was higher in cultivated soils and natural forest near the mining region than in restored overburden dumps. Under fresh dump, the WHC climbed from 36.48 percent to 44.59 percent.

Worku and Bedadi (2016) observed that the soils of Amibara irrigation project areas, central rift valley of Ethiopia, In Fluvisols, particle density was found to be higher in non-saline non-sodic soil (2.57 Mg m⁻³), but lower in saline sodic soil (2.50 Mg m⁻³). Bulk density was found to be lowest in non-saline non-sodic soil (1.34 Mg m⁻³) and greatest in saline-sodic soil (1.62 Mg m⁻³) in Fluvisols when salt impacted soil classes were considered. In Fluvisols, it was highest in non-saline non-sodic soil (47.85%) and lowest in saline-sodic soil (35.20%), in contrast to porosity.

Singh et al. (2016), investigated the soil fertility of Arajiline-Block in Varanasi, U.P. A total of, 38 surface soil samples, were collected at a depth of 0-15 cm and physico-chemical parameters were determined. The B.D of soil samples ranged from 1.35 - 1.42 Mg m⁻¹, while P.D and porosity were 2.24 - 2.39 Mg m⁻¹ and 36.1 - 54.0 %, respectively.

Sandip kumar Gupta et al. (2020) The bulk density measurements of both pedons from the Bairia block were provided, ranging from 1.26 to 1.48 Mg m⁻³. At 0-15 cm, Pedon-1 measured 1.26 Mg m⁻³, while at 135-160 cm, it measured 1.48 Mg m⁻³. Pedon -2's bulk density ranged from 1.28 to 1.44 Mg m⁻³. The rise in bulk density from upper to lower strata of both pedons could be attributed to clay and other minerals translocating as the compaction develops (Mandal and Sharma, 2011). The depth wise water holding capacity of soil was measured for both Pedon presented in and ranged from 19.34 to 36.37 percent of both Pedon. Pedon-1 had a range of 34.14 percent (0-15 cm) to 20.47 percent (135-160 cm) while pedon-2 had a range of 36.37 percent (0-15 cm) to 19.34 percent (135-160 cm) (135-160 cm). The value of water holding capacity in both Pedon reduced with increasing soil depth, which could be attributable to organic matter concentration and other physical considerations.

Rai et al. (2021) conducted the study in the years 2020-2021 with the goal of determining the physical properties of soils in the Darjeeling district of West Bengal. Soil samples were taken at depths of 0- 15cm, 15-30cm, and 30-45cm from nine different villages. Nine villages from three community development blocks had bulk density values of 1.07Mg m⁻³, 1.07Mg m⁻³, 1.03Mg m⁻³, 1.07Mg m⁻³, 1.05Mg m⁻³, 1.07Mg m⁻³, 1.03Mg m⁻³, 1.08Mg m⁻³, and 1.11Mg m⁻³, respectively. The highest value measured was 1.11g cm⁻³, indicating that the soil is mostly clay and aggregated loams. The lowest bulk density measured was 1 Mg m⁻³, indicating a significant level of organic materials. The particle density values of nine villages were 2.22Mg m⁻³, 2.27Mg m⁻³, 2.24Mg m⁻³, 2.31Mg m⁻³, 2.5Mg m⁻³, 2.6 Mg m⁻³, 2.65 and 2.63Mg m⁻³, respectively. The greatest particle density was 2.85 g cm⁻³, indicating a low organic matter content in the soil, and the minimum particle density was 2.0 Mg m⁻³. Nine villages from three community development blocks have water holding capacity

values of 69.48 %, 66.9%, 60.31 %, 67.4 %, 70.39 %, 69.85 %, 70.87 percent, 78.16 %, and 71.54 %, respectively. The capacity to hold water ranged from 61.53 % to 82 %.

Soil pH & Electrical conductivity (EC)

Gupta *et al.* (2010) observed that the soils in the foothills of the Siwaliks in Jammu, Jammu and Kashmir state were neutral to alkaline in response, with a pH ranging from 7.1 to 8.4 and electrical conductivity values that were generally greater in surface than subsurface soils.

Jatav (2010) reported that the EC of Inceptisols group of Baloda block of Janjgir-Champa district of Chhattisgarh ranged from 0.05 to 0.37, with a mean value of 0.13 dS m⁻¹.

Shrestha and Lal (2011) investigated composite and core samples from depths of 0-15, 15-30, and 30-45 cm in 2008. Soil physical and chemical parameters were evaluated, and changes in RMSS properties were quantified in comparison to adjacent, undisturbed locations. The pH of soil in RMSs (4.9 to 8.1) was 4 to 31% higher than in undisturbed sites (4.6 to 7.0). Similarly, EC was > 200 percent more in RMS (119 to 349 S cm⁻¹) than in undisturbed areas (43 to 154 S cm⁻¹).

Jayaprakash *et al.* (2012) analyzed the surface soils (0-20 cm) by taking 100 representative surface samples from Arecanut gardens in different talukas pertaining to non-traditional areas, to know the macro nutrient status of non-traditional growing areas. They reported that pH ranged from neutral to alkaline in nature, and electrical conductivity was within permissible limits. The majority of macronutrient status shows that the samples were in the middle to high range.

Deshmukh (2012) found that soils in the Sangamner area of Ahmednagar district, Maharashtra, with pH ranging from 8 to 9.7, indicating that the soils were alkaline. In the investigated area, EC values range from 0.1 to 46.8 dS/m. The higher

EC values were found in the downstream section (S.No. S2, S3, S4, S5, S7, and S16), indicating a low flushing rate and slow groundwater flow.

Kumar *et al.* (2013) evaluated the soils of Muzaffarnagar District, Uttar Pradesh, and discovered that the pH ranged from 6.02 to 8.39 and 6.35 to 8.50, respectively, for electrical conductivity of 0.069 to 0.390 and 0.073 to 1.10 dS m⁻¹, and organic matter content of 0.72 to 1.52 and 0.37 to 1.02 percent in surface and subsurface soils.

Parihar *et al.* (2013) analyzed the soil parameters of calcareous soils in the eastern Uttar Pradesh districts of Gorakhpur and Deoria. In Bhat, Bangar, and Kacchar soils, pH ranged from 8.1 to 8.9, 6.9 to 8.4, and 5.8 to 8.3, respectively. Soil texture varied according to soil type: Bhat soil (Type I) had a sandy loam to silt loam texture, Bangar soil (Type II) had silt clay & sandy loam texture, and Kacchar soil (III) had a texture that was more comparable to the Bhat soil (Type I). In soil types I, II, and III, the mean EC was 0.34, 0.49, and 0.51 dSm⁻¹, respectively. In these soils, however, EC followed a pattern that was the polar opposite of pH.

Mahla *et al.* (2014) analyzed the reproductive condition of the Navagarh block in Chhattisgarh's Janjgir-Champa district. The pH of the soils ranged from 4.5 to 7.2 (mean 5.73), according to the statistical assessment of soil properties. pH and EC were shown to have a significant positive relationship.

Khursheed *et al.* (2014) examined that all of the soil samples of different sites of Gwalior, M.P. had a pH of 9.5 to 10.2, indicating that they were mildly alkaline. All of the soil samples had electrical conductivities ranging from 0 to 0.6 /ums.

Tagore *et al.* (2014) Investigated the geographical variability of important soil nutrients in a soybean-growing region of the Malwa plateau in the state of Madhya Pradesh. A random sampling approach using GPS was used to obtain 168 surface soil samples from the study region. pH and EC content averaged 7.57 and 0.45 dSm⁻¹, with a range of 6.53-8.52, 0.08 to 1.24 dS m⁻¹.

Singh et al. (2015) During 2011-12, a GPS and GIS-based soil fertility mapping study collected 2334 surface soil samples from Chandauli, Mirzapur, Sant Ravidas Nagar, and Varanasi districts in eastern Uttar Pradesh. Their research discovered acidic soils (pH 5.5) in the Chandauli and Mirzapur districts. The acidic to alkaline nature of the soils in this location was indicated by a large pH range (4.5-10.4) and The EC is below 1 dSm⁻¹.

Agegnehu et al. (2016) on their study found that Organic amendments considerably enhanced soil characteristics by increasing soil water content, soil organic carbon (SOC), cation exchange capacity (CEC), and pH (0–20 cm depth), Due to biochar soil amendment, the pH of the soil rose from 5.0 to 5.6 at Holetta and from 4.8 to 5.4 at Robgebeya at harvest.

Mustafa et al. (2016) studied that the soils in the Kheragarah tehsil of the Agra district have a slightly to strongly alkaline pH (7.98-9.43), a slightly to very salty EC (1.81-7.23 dS m⁻¹), and a low organic carbon content (0.11–0.27%).

Shinde et al. (2016), studied that the pH of the soil at Agriculture College Farm Nandurbar ranged from 6.80 to 7.90, while the EC was 0.08 to 0.89 dS m⁻¹.

Truptimayee et al. (2016) studied the soils of KVK farm in Ranital, Bhadrak district, Odisha, India, and found that 41% of the soils were neutral and 59% were slightly alkaline in reactivity. Electrical conductivity (EC) for crops, on the other hand, remains within a safe range (0.488 dS m⁻¹).

Patel et al. (2017) studied the fertility status of the Jaunpur district in Uttar Pradesh and discovered chemical features such as soil pH ranging from 7.1 to 8.5, EC between 0.20 and 2.10 dSm⁻¹, and organic matter between 0.16 and 0.36 percent.

Yadav, Tikam Chand et al. (2018) Data on the physico-chemical parameters of Alirajpur district soils found that the district's overall soil pH ranged from 4.7 to 8.4. Variations in soil pH between blocks and within the district could be due to differences in soil parent material, management strategies, and land uses. At 25°C, the

electrical conductivity of soils in Alirajpur district ranged from 0.03 to 0.90 dS m⁻¹, with a mean value of 0.09 dS m⁻¹, which was within the normal range (less than 1 dSm⁻¹ at 25°C). Because of the significant rainfall and deep-water table in the research location, the soil has low electrical conductivity.

Yadav *et al.* (2018) analyzed that the pH of soil in the Robertsganj tehsil of Sonbhadra district, Uttar Pradesh, ranged from 7.29 to 8.07, and the EC ranged from 0.852 to 0.99 dSm⁻¹.

Meena *et al.* (2020) calculated the soil reaction, the results revealed that the soil of Hindaun city block was neutral with a mean value of 7.54, followed by Masalpur block (7.65) and Mandrayal block (7.66). As a result of the research findings, the soils of Hindaun city, Masalpur, and Mandrayal block of Karauli district were found to be neutral in soil response and suitable for the most of field and horticultural crops. The soil of Masalpur block had a mean value of 0.45 dSm⁻¹, followed by Hindaun city block with a mean value of 0.47 dSm⁻¹, and Mandrayal block with a mean value of 0.49 dSm⁻¹ in the research study.

S.Rajendiran *et al.* (2020) researched in the Jhabua district of M.P., the pH of the soil ranged from 5.92 to 8.59. The majority of the soil samples (55.0%) had a neutral pH. (6.5-7.5). There were additional soils that were moderately to slightly acidic (19.7%) and alkaline (25.3%).

Raja *et al.* (2021) assessed the Physico-chemical parameters of 27 soil samples from three different blocks in Malda district (West Bengal) at different depths (0–15, 15–30, and 30–45 cm) in the years 2020–2021. With a mean value range of 6.29–8.15, the pH of the soil is slightly acidic to slightly alkaline, and the Electrical Conductivity is suitable for all crops and free of salinity, with a mean value of 0.12–0.37 dS m⁻¹.

Soil organic carbon

Sidhu & Sharma (2010) reported that the soils of Middle gangetic plains are very deep, well drained to imperfectly and poorly drained. According to his assessment, organic carbon content ranged from 0.04 to 2.01%, whereas CaCO₃ content varied from 0 to 22.3 percent throughout diverse agro-climatic zones of the middle Gangetic plains, showing the soil's calcareous nature. The pH ranges from 5.6 to 9.4 and the soils are slightly to moderately acidic to sodic. Problems such as soil salinity and sodicity plague these soils.

Bhanwaria et al. (2011) collected Surface soil samples (0-15 cm) from 39 villages located at different locations of Mokala series. The organic carbon (OC) content of the soil ranged from 0.7 to 2.4 g kg⁻¹, according to the data. Soils with a high amount of organic matter and finer particles, such as clay fractions, can generally provide a larger reserve of these elements; however, coarse-textured soils with a high sand content and low OM have less reserves and are more easily exhausted.

Medhe et al. (2012) found a correlation between chemical characteristics, secondary nutrients, and micronutrient anions in soils from the Chakur tahsil in Maharashtra's Latur district. It was reported that a hundred soil samples were gathered and examined for chemical qualities, with the organic carbon content of these soils ranging from medium to high (0.2 to 1.3 percent).

Adejumobi et al. (2014) investigated the effects of irrigation methods on the soils of the Omi irrigation project in Kogi state, Nigeria. Soil samples were obtained from two operating lands (OL) in the research region, OL 5 and OL 18, at depths of 0-20 cm (A1), 20-80 cm (A2), and 80-120 cm (A3). Chemical parameters (pH, CEC, ESP, Mg, Ca²⁺, OM, and OC) were measured in the samples. Organic matter (OM) and organic carbon (OC) levels have also increased significantly (from 0.93 to 1.08 and from 9.52 to 9.79 in 2013).

Gajbhiye and Bhoje (2014) examined soil samples from three different orders: Vertisols, Inceptisols, and Entisols. Vertisols accounted for 37% of the total

surveyed soil samples, while Inceptisols and Entisols accounted for 40% and 23% of the total assessed soil samples, respectively. The study area had a low to medium organic carbon content, and the soils were calcareous.

Singh *et al.* (2014) collected 120 soil samples (20 cm depth) and evaluated for 29 physical, chemical, and biological soil characteristics. In India's eastern Himalayan area SOC is an acronym for "Standard (58 percent). SOC and exch. Al were shown to be the two most powerful markers of soil quality in the research area. Thus, in many exploitatively cultivated land use regimes in India's eastern Himalayan region, organic C and soil acidity management hold the key to improving soil quality.

Shinde *et al.* (2016), evaluated the organic carbon concentration in soils at Agriculture College Farm Nandurbar ranged from 0.37 to 0.99 percent.

Dash *et al.* (2018) evaluated the soils of RRTTS and KVK farm, Dhenkanal located in the mid-central table land agro climatic zones of Odisha, India and reported OC varies in between 0.51 to 1.59% with a mean value of 0.95%.

Kashiwar *et al.* (2018) estimated that soils of Agricultural Farm of Rajiv Gandhi South Campus (Banaras Hindu University), Barkachha, Mirzapur, Uttar Pradesh, had OC ranged from 0.26- 0.75%.

Kim *et al.* (2020) Soil qualities in opencast mines are a critical factor in mining reclamation (revegetation). The physical and chemical parameters of kaolinite tailings, reclaimed areas, and nearby wild red pine (*Pinus densiflora S. et Z.*) forests in kaolinite opencast mines in Sancheong-gun, Gyeongsangnam-do were determined in this study. Six sites were chosen for collecting soil samples at a depth of 10 cm in order to determine soil physical and chemical parameters. Red pine forests had considerably higher soil organic carbon and total nitrogen (C: 36.03 mgg⁻¹; N: 2.08 mgg⁻¹) than reclaimed lands (C: 5.00 mgg⁻¹; N: 0.31 mgg⁻¹) than kaolinite tailings (C: 2.12 mgg⁻¹; N: 0.07 mg g⁻¹).

Deepika Devdas et al. (2021) explained that the organic carbon content of soils is a reliable indicator of how much nitrogen is available. Organic carbon content in three Pedon's' soils (pedon-1, pedon-2, and pedon-3) ranged from 0.33 to 0.56 percent, 0.27 to 0.73 percent, and 0.31 to 0.70 percent, respectively, with mean values of 0.42, 0.51, and 0.51 percent. The organic C content of surface soil was found to be greater than that of lower layers. In all three Pedon's, decreasing trends in organic carbon content with lower soil depth/horizons could be related to less agricultural remains than the surface layer. **Raam et al., (2014)** in Inceptisols, **Baruah et al., (2014)** in Alfisols, and **Parmasivan and Jawahar (2014)** in Vertisols all showed similar results.

2.2 Available macro-nutrients in soil:

Nitrogen

Srinivas et al. (2011) collected 72 soil samples (0-15 cm) from the Krishna western delta in Andhra Pradesh and found that soil organic carbon, available N, P₂O₅, and K₂O ranged from 0.27 to 0.62 percent, 244 to 406 kg ha⁻¹, 30.6 to 69.4 kg ha⁻¹, and 233 to 590 percent, respectively, with mean values of 0.49 percent, 318, 48.2, and 398 kg ha⁻¹.

Punithraj et al. (2012) analyzed 80 soil samples (0-15 cm) from a tomato-growing area in Karnataka's Hassan district and found that available nitrogen content ranged from 205 to 376.3 kg ha⁻¹ (mean 265.7 kg ha⁻¹), with 71.3 percent of samples being low (250 N kg ha⁻¹) and 28.7% being medium (250 to 500 N kg ha⁻¹).

Athokpam et al. (2013) analyzed 200 soil samples (0-30 cm) from Senapati district in Manipur and found that available nitrogen levels ranged from 290.20 to 893.17 kg ha⁻¹, with a mean value of 382.04 kg ha⁻¹, which indicate that the soil of Senapati district was moderate to high in Available Nitrogen.

Devdas and Srivastava (2013) examined 112 surface soil samples from the Navagarh block in Chhattisgarh's Janjgir district and discovered that accessible nitrogen ranged from 88.0 to 399.0 kg ha⁻¹, with a mean value of 265.0 kg ha⁻¹.

Singh and Munth (2013) analyzed soil fertility in Nagaland's forest and cultivated land use systems. A mean of 318.9 kg ha⁻¹ of nitrogen was present in the forest, with a range of 251 to 426.4 kg ha⁻¹. With a mean of 286 kg ha⁻¹, nitrogen levels in agricultural areas ranged from 230.2 to 413.9 kg ha⁻¹.

Ravikumar and Somashekar (2013) discovered that soil fertility level of soils in the central area of Udipi district in the western portion of Karnataka state, developed on various landforms does not significantly vary. They also stated that available nitrogen levels in the soils were low (6.27 to 25.09 kg/ha).

Sudharani et al. (2013) studied 69 soil samples (0-15 cm) from rice-growing soils in Andhra Pradesh's Visakhapatnam area, finding that available nitrogen ranged from 125 to 392 kg ha⁻¹, with a mean value of 226 kg ha⁻¹.

Singh et al. (2014) analyzed the total of 300 soil samples (0–15 cm) were randomly collected from different locations in the Chambal region of Madhya Pradesh, one hundred from each soil group of alluvial, medium black soil, and ravinous land. Available nitrogen content ranged from 126 to 361 kg ha⁻¹ in alluvial soil, with an average pooled value of 221 kg ha⁻¹, 178 to 408 kg ha⁻¹ in medium black soil, with an average value of 227 kg ha⁻¹, and 125 to 301 kg ha⁻¹ in ravinous land, with an average value of 167 kg ha⁻¹. Alluvial, medium-black soils, and ravinous land had 97, 90, and 95 percent low (250 kg N ha⁻¹) available nitrogen, whereas the remaining 7, 10, and 5 percent of soil samples had medium (250 to 500 kg N ha⁻¹) available nitrogen, according to Subbiah and Asija (1956).

Arunkumar and Paramasivan (2015) examined the fertility of the soils in Orathur village, Veeranam command area, Cuddalore district, Tamil Nadu, and found that available nitrogen in soils ranged from 173.60 to 235.20 kg ha⁻¹, with a mean value of 203.30 kg ha⁻¹.

Ramana *et al.* (2015) evaluated the available macro nutrient status and their association with physicochemical qualities in the Raisingh Nagar block in the district Sri Ganganagar in Rajasthan. The Ganga canal and its tributaries irrigate the Sri Ganganagar district, which has 12 different farming systems. Twenty-seven representative villages were chosen, and four surface soil (0-15 cm) samples were obtained from each village and examined using conventional laboratory protocols for physicochemical characteristics and accessible N, P, K, S, exchangeable Ca, and Mg status. The study found that the organic carbon content of the soils in the Raisingh Nagar block was low to medium. 97 percent of the 108 soil samples collected had a medium level of accessible nitrogen.

Nagaral *et al.* (2016) collected 57 soil samples (0-15 cm) from Chilli-growing areas in Karnataka's Northern Transitional Zone and found that available nitrogen content ranged from 112 to 672 kg ha⁻¹ (mean 221 kg ha⁻¹), with 48% of samples being low (250 N kg ha⁻¹), 47% medium (250 to 500 N kg ha⁻¹), and only 4% high (>500 N kg ha⁻¹).

Singh (2017) examined the soils of the Baloda-Bazar area from 55 different villages and discovered that the accessible nitrogen in the soil ranged from 165.3 to 263.25 kg ha⁻¹ in various soil categories, with a mean value of 197.3 kg ha⁻¹, classifying it as having a low fertility index.

Kumar, *et al.* (2017) observed that available nitrogen levels in soils under cultivation in the Gharsana tehsil of Sriganganagar district ranged from 54.1 to 168.14 kg ha⁻¹, with a mean value of 116.13 kg ha⁻¹. Furthermore, the soils in the research area were deficient in available nitrogen and phosphorus by 100% and 45 percent, respectively.

Patel *et al.* (2017) acquired 240 surface soil samples in the Aravalli district of Gujarat to examine available major nutrients in soils. The available nitrogen content in the soils of Gujarat's Aravalli district was categorized as poor, according to the data.

Kashiwar et al. (2018) evaluated the soils of Rajiv Gandhi South Campus (Banaras Hindu University), Barkachha, Mirzapur, Uttar Pradesh, and discovered that accessible nitrogen ranged from 160 to 241.5 kg ha⁻¹.

Lohiya et al. (2018), Reported that the available nitrogen levels in the soils of Golpura village in Madhya Pradesh's Dhar district ranged between 145-263 kg ha⁻¹, with a mean value of 217.4 kg ha⁻¹.

Ramulu and Reddy (2018) studied soils at the Regional Agricultural Research Station (RARS) in Warangal, finding that available N, P, and K content ranged from 75 to 352 kg ha⁻¹ with a mean value of 209 kg ha⁻¹, 21 to 113 kg ha⁻¹ with a mean value of 49 kg ha⁻¹, and 165 to 992 kg ha⁻¹ with a mean value of 552 kg ha⁻¹, respectively.

Dameshwar et al. (2018) The Kasdol block in Matya village, Chhattisgarh, was evaluated for soil fertility. In this analysis, soil samples were taken at a depth of 15-20 cm over a matrix from desert, irrigated, and rainfed regions. The nitrogen content of soil samples ranged from 99.47 kg ha⁻¹ to 281.4 kg ha⁻¹.

Pandiaraj et al. (2020) examined soil fertility and nutrient index in a variety of Tasar Silkworm Host Plant Growing Ecosystems in Purulia District, West Bengal, India, and found that "available nitrogen (N) in the research area ranged from 124.3 to the distribution of available 246.0 kg ha⁻¹, with an average of 173.4 kg ha⁻¹."

Singh et al. (2021) conducted a study on the physico-chemical properties of the soil in the 'Kaimur District' and its surrounding areas in Bihar was conducted. Nine sampling sites were used for the assessment. Soil samples were taken at depths of 0-15 cm, 15-30 cm, and 30-45 cm, with the physico-chemical characteristics and nutritional status of the soil being examined. The amount of nitrogen (N) in the soil ranged from 223.2133 kg ha⁻¹ to 289.45 kg ha⁻¹.

Phosphorus

Vaisnow (2010), examined that the available phosphorus levels ranged from 0.35 to 51.96 kg ha⁻¹, with an average of 8.13 kg ha⁻¹ in Vertisols of Dhamtari block, Dhamtari district, Chhattisgarh. around 81.40 percent of soil samples are classed as low fertility class, 15.50 percent as medium fertility class, and 3.10 percent as high fertility class.

Kumar *et al.* (2011) analyzed the availability of major nutrients in desert soils of Western Rajasthan's Churu district, reporting that available phosphorus content ranged from 7 to 80 kg ha⁻¹, with a mean value of 18.6 kg ha⁻¹.

Kebede and Raju (2011) investigated land use/land cover change and its impact on soil parameters in Ethiopia's Hare River Watershed. Landsat pictures were used to examine changes in land use and cover. Cultivated land, grazing land, wood land, and forest (natural) were chosen as the four principal land use/cover types at three villages/sites, with significant differences in Bulk Density in all four cover types. Forest soils contained substantially more SOM and total nitrogen than pasture and woodland sites. The amount of accessible Phosphorus and sand differed significantly between the different land uses.

Das and Ansari (2011) investigated the effects of varying land uses on some important soil properties (organic carbon, EC, pH, available major nutrients, available Sulphur, available micronutrients, bulk density, and water stable aggregates > 0.5 mm), as well as their co-relationships with SOC as a function of land use. Oil palm plantation, Sapota plantation, Mango plantation, Sugarcane crop, Rice crop, Pulses and oilseed crops, Banana plantation, Vegetable crops, Floriculture crops, and Barren land were chosen for the study, which covered an area of 333.42 hectares on NAU's main campus. Overall, the findings suggest that land should not be left fallow and that efforts should be made to improve low-status SOC. Soils with low to quite medium nitrogen, phosphorus, and potassium availability.

Polara and Chauhan (2015) collected 180 surface soil (0-15 cm) samples from different talukas in Gir Somnath district to investigate various soil properties. Available P₂O₅ was reported to range from 3 to 78.1 kg ha⁻¹ (mean 21.2 kg ha⁻¹). They discovered that the samples were poor in accessible N and P₂O₅ in general.

Hadiyal et al. (2016) analyzed 250 soil samples (0-15 cm) from Girgadhda and Una talukas in Gujarat's Gir Somanth district and found that accessible P₂O₅ in soils ranged from 6 to 285 kg ha⁻¹ with a mean value of 56 kg ha⁻¹

Kumar et al. (2017) evaluated the insufficiency of important plant nutrients in Koriya district of Chhattisgarh, finding that around 76 percent of soil samples taken in the area were deficient in soil accessible P ranging from 2.25 to 28.9 kg/ha with mean value of 13.13 kg/ha.

Madhu et al. (2017) evaluated the soils in the Jamuna Paar regions of Allahabad District, Uttar Pradesh, and discovered that available phosphorus in the surface horizon ranged from 15.30 to 20.48 kg ha⁻¹. That is considered as moderate range of P.

Khadka et al. (2017) reported available phosphorus (39.775.27 kg ha⁻¹) and extractable potassium (134.124.911 kg ha⁻¹) in the soils of the Regional Agricultural Research Station (RARS), Tarahara, Susari, Nepal.

Priyadarshini et al. (2017) found that the accessible phosphorus (P₂O₅) level in soils of a few villages in Cuttack's Salepur block ranged from 4.0 to 146.9 kg ha⁻¹.

Kothyari et al. (2018) examined the status of available phosphorus in three blocks in Rajasthan's Sawai Madhopur district ranges from 18.76 to 32.96 kg ha⁻¹, represent mean value of 22.35 kg ha⁻¹.

Shashikala et al. (2019) collected 250 composite soil samples from the soils of Tatrakallu village in Andhra Pradesh using handheld GPS. Recoverable nitrogen on surface soils ranged from 13.00 to 326.00 kg ha⁻¹, according to the data. Phosphorus availability ranged from 2.00 to 512.00 kg ha⁻¹.

Sheeba et al. (2019) investigated the composite soil samples collected from a farmer's field. The soils of Kerala's southern laterites had available nitrogen was found to be medium to high in 85.32 percent of laterite soils, whereas available phosphorus was found to be high in 97 percent of the soils.

S. Rajendiran et al. (2020) investigated tribal dominated backward Jhabua district of Madhya Pradesh, India was selected and geo-referenced surface soil (0-15 cm depth) samples (540 numbers) from farmers' fields were collected. Jhabua soil's available P concentration ranged from 3.42 to 44.6 kg ha⁻¹, with a mean of 14.3 kg ha⁻¹. According to Muhr et al. (1963), the majority of soil samples from Jhabua district were low (less than 10 kg P ha⁻¹), 37.2 percent were medium (10-25 kg P ha⁻¹), and 13.8 percent were high (more than 25 kg P ha⁻¹) in accessible P. The available P status of the soils in the Meghnagar and Tandla blocks was medium, whereas the available P status of the soils in the remaining blocks was low. Past fertilization pH, organic matter content, texture, and various soil management and agronomic methods may have contributed to the low to medium accessible P in the soils of the study area (**Patidar et al. 2017a**).

Hussain et al. (2021) During the spring season of 2020, conducted a field experiment at the College of Agricultural Engineering Sciences' research station to investigate the effect of various phosphorus levels on chickpea nodule production, soil physical and chemical following phosphorus application. With three replications and five P₂O₅ application rates of 0,15,30,45,60 Kg. ha⁻¹, a randomised full block design was adopted. The application of 60 Kg.ha⁻¹ yielded the greatest values for all examined variables, with coefficient determination (R²) values of 0.95, 0.94, 0.91, and 0.99, respectively, for plant height, secondary branches per plant, pod height, and number of pod plant⁻¹.

Potassium

Shukla (2011) investigated that available potassium concentration ranged from medium to high, with just 7.4% of soil samples testing low in available

potassium. Inceptisols, Alfisols, and Vertisols orders of Pamgarh block in Janjgir-Champa district, it ranged from 90 to 656 kg ha⁻¹ (mean-275 kg ha⁻¹) (C.G.).

Patil *et al.* (2011) evaluated N, P, and K content in soils of a 1032 ha area in Karlawad village, Navalgund taluk, Dharwad district, Karnataka (India), and discovered that the research area's available potassium status was quite high, ranging from 672 to 1584 K₂O kg ha⁻¹.

Mohapatra *et al.* (2012) investigated the effects of coal mining on soil parameters in the IB river coalfield in Odisha. They studied the soils of five opencast coal operations in the IB river coalfield over three years, during the pre-monsoon (March), monsoon (July), and post-monsoon (November) seasons (i.e., 2006, 2007 and 2008). Soil samples were taken from the vertical surface of the overburden at depths of 0-5 feet, 5-10 feet, and 10-15 feet. The researchers looked at a variety of physical (soil texture, soil moisture, particle density, bulk density, and porosity) and chemical (pH, organic carbon, nitrogen, phosphorus, and potassium) characteristics. The amount of organic carbon, nitrogen, and phosphorus in the soil dropped as the depth of the soil increased. Potassium levels, on the other hand, gradually increased from the surface to higher depths.

Rajput and Polara (2012) investigated fertility in eleven talukas of the Bhavnagar district and discovered that available K ranged from 38.0 to 990.0 kg/ha, with an average value of 451.2 kg/ha.

Ahmad *et al.* (2012) Investigate the physicochemical parameters of soil and water (next to textile effluent) in the agricultural region of Bhairavgarh, Ujjain M.P., as well as irrigation water, to aid in the identification of environmental consequences. Soil samples were taken from adjoining agricultural area where untreated industrial effluent was being used for irrigation. From 0 to 25 cm deep, three replicates of each sample were taken from 10 distinct places. The results showed that applying industrial waste/effluent to polluted soils significantly improved soil available potassium when compared to uncontaminated soils. The lowest accessible potassium in uncontaminated soil was found to be between 30.7 and 33.8 ppm. When compared to

uncontaminated soil, the potassium amount in contaminated soil was highest, ranging from 50.7 to 58.7ppm. The waste water application greatly enhanced the available potassium content of the soil.

Singh *et al.* (2014) analyzed the total of 300 soil samples (0–15 cm) were randomly collected from different locations in the Chambal region of Madhya Pradesh. The amount of accessible K in the soils ranged from 128 to 391 kg ha⁻¹ in alluvial soil, with an average of 304 kg ha⁻¹, 122 to 386 kg ha⁻¹ in medium black soil, with an average value of 295 kg ha⁻¹, and 252 to 406 kg ha⁻¹ in ravinous land, with an average value of 319 kg ha⁻¹. There were no low-available-K soil samples in ravinous land, but 19% of medium-available-K soil samples and 81 % of high-available-K soil samples.

Tagore *et al.* (2014) The geographical variability of important soil nutrients in a soybean-growing zone of the Malwa plateau was investigated. One hundred and twenty-two topsoil samples were obtained from a soybean-wheat cropping system in 2011-12 for this investigation. The sampling technique took into account sample distributional consistency and ensured that all samples were taken from soybean-wheat farms. The amount of accessible K ranged from 104.56 to 851.6 kg ha⁻¹, with a mean of 461.35 kg ha⁻¹.

Khurhseed *et al.* (2014) Sixteen soil samples were obtained from various places across Gwalior (four agricultural, three highway, three industrial, three barren, and three market soils). Physical and chemical aspects of the samples were studied. Potassium was found in highway samples, with concentrations ranging from 20 to 90 (mg/l). At sites 1, 2, and 3, the potassium concentration (mg/l) in soil samples was 1200, 700, and 1200, respectively.

Kadam (2015) examined the soil of the Karad agriculture college farm in order to create a soil fertility map, reporting that the soil K content of the study area ranged from 217.00 to 274.21 kg/ha in Mundhe farm and 201.00 to 255.6 kg/ha in Saidapur farm, indicating a good manuring practise in the cultivated farm area.

Tale et al. (2015) reviewed on Physico-chemical properties of soil, she stated that according to Pal, higher potassium availability in Kaolinitic soil boosted the grain production of winter sorghum. Muhar et al classified 25% of samples as low (125 kg ha⁻¹), 67.5 percent as medium (125 to 300 kg ha⁻¹), and 2.5 percent as high (>300 K₂O kg ha⁻¹).

G Singh et al. (2016) In several villages of different blocks in the district, analyse the fertility quality of soil put under various agricultural sequences. Bhagwanpur, Bhetan, Boolpur, Kheeranwali, Khukrain, Meripur, and Swal were chosen from seven villages in three blocks: Dhilwan, Kapurthala, and Sultanpur. The soil samples were gathered at a depth of 0-15 cm. Khukrain village (92 percent) has the highest availability of potassium, followed by Bhagwanpur (72 percent), Kheeranwali (55 percent), Swal and Bhetan (45 percent), and Boolpur (44 percent). According to Bhatt and Sharma (2011), over 65 percent of samples from the district of Kapurthala have low potassium status (Available K137.5 kg/ha). Punjab soils, on the other hand, are thought to be potassium-rich, it is not necessary to use potassium fertilizer. Contrary to popular belief, soil testing results from seven villages found that village Kheeranwali had the lowest available potassium content of 28.2 kg/ha.

Desavathu et al. (2018) in Paderu Mandal, Visakhapatnam district, Andhra Pradesh, 82 soil samples were collected at random at multiple land use/cover areas, including farmland, forest, built up area, scrubland, and plantation, at a depth of 0–30 cm. In terms of soil potassium content, the research area shows a range of 22 kg/ha to 369 kg/ha. The Mandal's potassium concentration is quite low. Around 70% of the region has low potassium concentration (less than 130 kg/ha), 16% has medium level (130–330 kg/ha), and 14% has high potassium content (more than 330 kg/ha).

Rajendiran et al. (2018) studied accessible macronutrients in agricultural fields in Alirajpur and discovered that available potassium ranged from 122 to 483 kg ha⁻¹, with an average value of 352 kg ha⁻¹.

Salma et al. (2019) discovered that the average accessible soil Potassium in the chickpea producing region at Owkmandal, Kurnool district (AP) was 421.20 kg ha⁻¹.

Raja et al. (2021) evaluated the physico-chemical parameters of 27 soil samples from three different blocks in Malda district (West Bengal) at different depths (0–15, 15–30, and 30–45 cm). The potassium content of the soil samples taken ranged from 121 to 286.2 kg ha⁻¹, with a mean value of 211.7 kg ha⁻¹ and a standard deviation of 20.05. Due to decreased K loss from organic residues during the weathering process, potassium concentration was in the medium range compared to norms. **Karmakar et al., (2020) and Ghosh et al., (2020)** earlier reported similar findings (2020).

Sulphur

Bhaskaran et al. (2012) investigated eight sugarcane growing regions in Tamil Nadu. The sulphur level of soils (0-30 cm) varied substantially from 2.45 to 96.07 ppm, with an average of 25.37 ppm. Around 17% of the soils had a low accessible S concentration (less than 10.0 ppm), 35% had a medium available S content (10 to 20 ppm), and 48% had a high available S content (more than 20 ppm).

Patel et al. (2012) collected 240 soil samples from Banaskantha district of Gujarat. The available Sulphur in soil ranged from 5.24 to 60.17 mg kg⁻¹, with a mean value of 19.01 in mg kg⁻¹. They also discovered low, medium, and high levels of accessible sulphur in 30.0, 32.1, and 37.9% of soil samples, respectively.

Singh and Kumar (2012) analyzed 110 surface soil samples from the Varanasi district's vegetable growing area and discovered that available S ranged from 4.37 to 23.75 mg kg⁻¹, with a mean value of 14.9 mg kg⁻¹.

Som et al. (2012) used the global positioning 16 system to investigate the sulphur status of mixed red and black soils in the Balaghat and Mandla districts of Madhya Pradesh (GPS). In Balaghat and Mandla districts, available sulphur

concentration in soils ranged from 7.5 to 42.3 mg kg⁻¹ and 2.8 to 45.3 mg kg⁻¹, respectively. In the Balaghat district, there was a significant and positive association between sulphur and organic carbon ($r=0.2565^{**}$) (M.P.).

Singh and Mishra (2012) conducted a study in the Chiraigaon block of Varanasi. Ten communities were chosen as representative, and various numbers of surface soil samples (0-15 cm) were collected and analyzed for physico-chemical properties as well as accessible N, P, K, and S. The texture of the soils ranged from sandy clay loam to clay, according to the results. Organic carbon, available nitrogen, and phosphorus were found to be low in soil samples, whereas potassium was found to be medium. Approximately 62 percent of the samples were found to be Sulphur deficient.

Thakur and Patel (2017) determined the accessible Sulphur status in the soils of Gujarat's Mehsana district. For available Sulphur, 29.65, 49.87, and 20.49 percent of the 371 soil samples were identified in the low, medium, and high categories, respectively. The soils in Mehsana district had a low level of accessible S, according to the Nutrient Index Value (NIV) (1.91). According to them, the soils in Mehsana district have a low level of accessible Sulphur.

Singh (2017) examined the fertility status of the Baloda-Bazar district in Chhattisgarh, discovered that available S content in soil ranged from 2.51-43.1kg/ha, with a mean value of 14.1kg/ha in the area, and that nearly 87.6% of soil samples were classified as low fertility.

Raghupathi et al. (2018) executed a soil elemental status experiment in a Pomegranate grown region in Karnataka and discovered that soil accessible S ranged from 10-165 ppm in the study area, with a mean value of 53.1 ppm.

S.Rajendiran et al. (2020) investigated tribal dominated backward Jhabua district of Madhya Pradesh, India was selected and geo-referenced surface soil (0-15 cm depth) samples (540 numbers) from farmers' fields were collected. In Jhabua district, the available S status ranged from 3.12-25.2 mg kg⁻¹, with a mean value of

9.2 mg kg⁻¹. Plant roots take S from the soil solution in the form of sulphate. In light of this, the soil under investigation might be classed as insufficient (10 mg kg⁻¹), medium (10-20 mg kg⁻¹), or sufficient (> 20 mg kg⁻¹) according to **Hari and Dwivedi's** classification (1994). In the Jhabua district, 78.1 percent of soils had insufficient S fertility, 21.2 percent had medium S fertility, and the remaining 0.7 percent had high S fertility.

Aasim et al. (2021) conducted a study called "Assessment of Soil Health Parameters from Different Blocks of Kota District, Rajasthan" was carried out. A total of 27 soil samples were collected for the study from nine villages across three blocks in Rajasthan's Kota district, at three distinct depths (0–15, 15–30, and 30–45 cm). Amino acids, proteins, and lipids are all made up of Sulphur. It is essential for legume nodule formation and nitrogen fixation efficiency. Sulphur concentration in the three blocks of Kota district was determined to be adequate, ranging between 24.37 and 34.39 kg ha⁻¹. The district's soils are suitable for growing oilseed crops such as soybean and mustard.



Material and Methods

The present investigation entitled “Characterization of soil quality parameters of Balaghat and Malajkhand blocks in Balaghat district of Madhya Pradesh” was conducted at the Soil Science and Agriculture Chemistry laboratory, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. The detail account of the materials used and methodologies adopted in the investigation are described below:

3.1 DESCRIPTION OF SITE

3.1.1 Site Location

Balaghat is a town in Balaghat tehsil of Balaghat District and as same, Malajkhand is a town in Birsa tehsil of Balaghat District of Madhya Pradesh. The samples were collected in the range of 10-60 Kms away from the main city Balaghat. The geographical location of Balaghat is within 21.19' to 22.24' North latitude and 79.31 to 81.3' East longitude. The total area of Balaghat is 9245 sq. km. The location of study area is shown in the map of the Madhya Pradesh. (Fig. 3.1)

3.1.2 Agro climate

The Climate of Balaghat District, M.P is sub- tropical characterized by a hot summer and general dryness except during the southwest monsoon season. The year may divide into four seasons. The cold season, December to February is followed by the hot season from March to about the middle of June. The period from the middle of June to September is the southwest monsoon. October and November form the post monsoon or transition period. The area qualifies for *aridic* soil moisture regime in

summer and *cryic* soil temperature regime in winter, *Thermic* soil temperature regime in summer.

3.1.3 Rainfall

The normal annual rainfall of Balaghat district is 1294.5 mm. District received maximum rainfall during southwest monsoon period i.e., June to September and little amount from January to May. Thus, surplus water for ground water recharge is available only during the southwest monsoon period.

3.1.4 Temperature

The hottest and coolest months are May and December respectively. The normal maximum temperature recorded during the month of May is 43⁰C and minimum during the month of December is 8⁰C. The normal annual means maximum and minimum temperatures of district are 32⁰C & 8⁰C respectively.

3.1.5 Humidity and wind velocity

During the southwest monsoon season the relative humidity ranges between 70-75%. In the rest of the year, it is drier. The driest part of the year is the summer season, when relative humidity is less 34%. May is the driest month of the year.

The wind velocity is higher during the pre-monsoon period as compared to post monsoon period. The maximum wind velocity 7.7 km/hr. observed during the month of June and minimum 3.9 km/hr. during the month of December.

3.1.6 Land use

The highland forests are tropical moist and dry deciduous, and lowland forest are mixed forest with sal and teak. Traditional farming practice followed in region is rainfed agriculture. The major crops cultivated under rainfed condition are paddy, sugarcane, maize, arhar, soyabean, jowar, moong (green gram), urd (black gram) in *Kharif* season, while wheat and rice are grown under irrigated condition, lentil,

mustard, chickpea, linseed, under rainfed condition during *Rabi* season. Chinnor rice is cultivated under irrigated Midland to rainfed Lowland. The total area of the district is 9,245 km² (3570 m²).

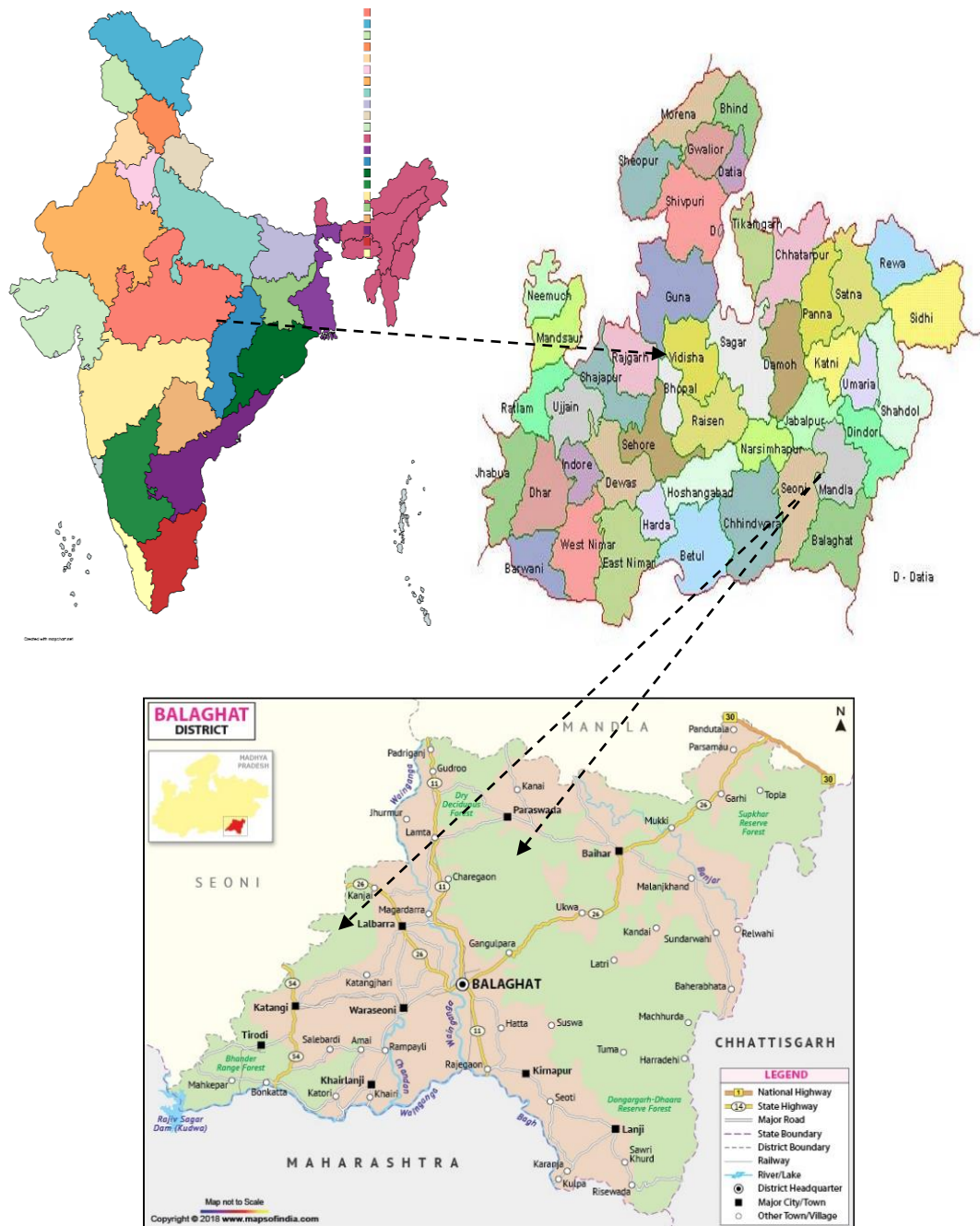


Fig 3.1: Location of Balaghat and Malanjkhanda Block in Balaghat District of Madhya Pradesh

Table 3.1 Description of Sampling Site

S.No.	Sample No.	Village	Farmer's Name	Cropping Pattern	Irrigation
1	C1S1	Bhatera	Chandan lal	Rice-Rice-Fallow	Well
2	C1S2	Bhatera	Tejram Sulakhe	Rice-Rice-gram	well
3	C1S3	Bhatera	Dheeran Sulakhe	Rice-Rice-Urd	Well
4	C1S4	Bhatera	Rajkumar	Rice-Urd-Vegetable	Tubewell
5	C1S5	Bhatera	Dhanlal	Rice-Urd-Vegetable	Well
6	C1S6	Bhatera	Hemlal	Rice-chickpea	Well
7	C1S7	Khairi	Gaurishankar	Rice-Chickpea-Rice	River
8	C1S8	Khairi	Rajkumar lilhare	Rice-Rice-Fallow	Canal
9	C1S9	Khairi	Bhurya Baghele	Rice-Wheat-Fallow	Canal
10	C1S10	Khairi	Govind lilhare	Rice-Utera-Fallow	Well
11	C1S11	Khairi	Fagulal mohare	Rice-Urd-Vegetable	Well
12	C1S12	Kumhari	Manohar Bisane	Rice-Chickpea-Rice	Tubewell
13	C1S13	Kumhari	Madhavlal Lilhare	Rice-Mung-Vegetable	Tubewell
14	C1S14	Kumhari	Purushottam Baghele	Rice-Rice-Urd	Well
15	C1S15	Kumhari	Kankarlal	Rice-Utera-vegetable	Well
16	C1S16	Kumhari	Shankar	Rice-Rice-urd	Tubewell
17	C1S17	Dhapewada	Fulchand mahule	Rice-Wheat-Fallow	Canal
18	C1S18	Dhapewada	Kapoorchand	Rice-Wheat-Fallow	Canal
19	C1S19	Dhapewada	Jhanaklal	Rice-Wheat-Fallow	Well
20	C1S20	Dhapewada	Prabhu Nagpure	Rice-Wheat-Fallow	Tubewell
21	C1S21	Dhapewada	Rekhlal	Rice-Rice-Urd	Tubewell
22	C1S22	Dhapewada	Nandlal	Rice-Wheat-Fallow	Tubewell
23	C1S23	Dhapewada	Hushiyari Sulakhe	Rice-chickpea-Rice	Well
24	C1S24	Dhapewada	Hirkan bai Rangire	Rice-Rice-Urd	Well
25	C1S25	Dhapewada	Bhuvan	Rice-Rice-Urd	Well
26	C2S1	Shitalpani	Rajiv	Rice-Rice-Arhar	Canal
27	C2S2	Shitalpani	Bairagilal	Rice-Rice-Urd	Canal
28	C2S3	Shitalpani	Dinesh	Rice-Rice-Fallow	Canal
29	C2S4	Godaritola	Taruna turkar	Rice-Rice-Fallow	Tubewell
30	C2S5	Godaritola	Dhaneshwari Bopche	Rice-Utera-Fallow	Well
31	C2S6	Godaritola	Surendra	Rice-Rice-Urd	Well

Material and Methods

S.No.	Sample No.	Village	Farmer's Name	Cropping Pattern	Irrigation
32	C2S7	Godaritola	Manoj	Rice-Rice-fallow	Canal
33	C2S8	Rupjhar	Jainth Vedhe	Rice-Rice-Arhar	Tubewell
34	C2S9	Rupjhar	Yogesh Markam	Rice-Rice-vegetable	Tubewell
35	C2S10	Rupjhar	Sonu Kawre	Rice-Chickpea-Rice	Tubewell
36	C2S11	Rupjhar	Mahendra Jaitwar	Rice-Wheat-Fallow	Well
37	C2S12	Rupjhar	Amritlal	Rice-Rice-Urd	Well
38	C2S13	Rupjhar	Raghunath singh	Rice-Rice-vegetable	Canal
39	M1S1	Awlajhari	Vishnu Prashad	Rice-Rice-Fallow	Tubewell
40	M1S2	Awlajhari	Devram	Rice-Urd-Vegetable	Well
41	M1S3	Awlajhari	Digambar	Rice-Rice-vegetable	Well
42	M1S4	Awlajhari	Kuwarlal	Rice-Chickpea-Rice	Well
43	M1S5	Awlajhari	Urmila Lilhare	Rice-Rice-Fallow	Tubewell
44	M1S6	Awlajhari	Banti Sulakhe	Rice-Chickpea-Rice	Well
45	M1S7	Awlajhari	Shyاملal	Rice-Rice-Fallow	Tubewell
46	M1S8	Tawejhari	Bhojlal	Rice-Rice-Urd	Well
47	M1S9	Tawejhari	Umendra	Rice-Rice-vegetable	Tubewell
48	M1S10	Tawejhari	Yadavrao Nagpure	Rice-Rice-Urd	Tubewell
49	M1S11	Tawejhari	Brijlal	Rice-Rice-Fallow	Tubewell
50	M1S12	Tawejhari	Indal	Rice-Chickpea-Fallow	Tubewell
51	M1S13	Tawejhari	Pratap Dahare	Rice-Rice-Fallow	Tubewell
52	M1S14	Manjhara	Rivesh Katre	Rice-Rice-vegetable	Canal
53	M1S15	Manjhara	Jitendra	Rice-Chickpea-Fallow	Canal
54	M1S16	Manjhara	Purvasa	rice-Utera-fallow	Canal
55	M1S17	Manjhara	Kailash Gajbhiye	Rice-Rice-vegetable	Well
56	M1S18	Bharveli	Rajesh Baheshwar	Rice-Wheat-Fallow	Well
57	M1S19	Bharveli	Nangarchi	Rice-Wheat-Fallow	Well
58	M1S20	Bharveli	Karulal	Rice-Wheat-Fallow	Tubewell
59	M1S21	Bharveli	Shivprakash Khare	Rice-Rice-vegetable	Tubewell
60	M1S22	Hirapur	Ganesh Mahathi	Rice-Rice-Urd	Tubewell
61	M1S23	Hirapur	Suresh	Rice-Wheat-Fallow	Tubewell
62	M1S24	Hirapur	Parasram Hinwati	Rice-Chickpea-Fallow	Well
63	M1S25	Hirapur	Sehnaz Begum	Rice-Wheat-Fallow	Well

S.No.	Sample No.	Village	Farmer's Name	Cropping Pattern	Irrigation
64	M2S1	Bhanderi	Kishar sahu	Rice-Rice-Fallow	Canal
65	M2S2	Bhanderi	Kailash dongre	Rice-Utera-Fallow	Tubewell
66	M2S3	Bhanderi	Ramkishor	Rice-Chickpea-Fallow	Tubewell
67	M2S4	Chakerwahi	Hiralal Uikey	Rice-Rice-Fallow	Tubewell
68	M2S5	Chakerwahi	Tukaram	Rice-Rice-Arhar	Well
69	M2S6	Chakerwahi	Mohanlal	Rice-Urd-Vegetable	Well
70	M2S7	Chakerwahi	Omprakash	Rice-Rice-Fallow	Well
71	M2S8	Palehara	Mulchand Rangare	Rice-Rice-Arhar	Tubewell
72	M2S9	Palehara	Jeevandas	Rice-Rice-Urd	Tubewell
73	M2S10	Palehara	Thaiyadas	Rice-Rice-Fallow	Canal
74	M2S11	Palehara	Loknath	Rice-Utera-Fallow	Canal
75	M2S12	Palehara	Pawandas	Rice-Wheat-Fallow	Canal

C1 = Sample collected from cultivated area of Balaghat block

M1 =Sample collected from mining area of Balaghat block

C2 =Samples collected from cultivated area of Malajkhand block

M2 =Samples collected from mining area of Malajkhand block

Table 3.2 : Land use pattern and other agricultural characteristics of the study area – Balaghat district (2019)

S. No.	Agricultural parameters	Area (ha)	% Share
1	Geographical area (GA)	924500	
2	Forest area	493206 (2019)	
3	Land under non- agricultural use	47461	
4	Cultivated land	302500	
5	Permanent Pasture land	31011	
6	Net cropped area	314513	
7	Double cropped area	68200	
8	Total cropped area	449381	
9	Intensity of cropping	-	125%
10	Cultural waste land	28000	
11	Barren land	9478	
12	Permanent Pasture/ grazing land	31011	
13	Fallow land	11149	

Table 3.2.1: Irrigated area

1	Net irrigated area	124700 ha
2	Gross irrigated area	141500 ha
3	Rainfed area	148500 ha

3.2 METHOD OF SOIL SAMPLING AND PROCESSING

3.2.1 Collection of soil sample

75 surface soil samples from the cultivated land of the Balaghat & Malajkhand block of Balaghat districts were randomly sampled to a depth of 0-15 cm in V shape with the help of Khurpi from 75 distinct sites of diverse geomorphological locations. The soil samples were mixed thoroughly and about a half kilogram of composite samples was drawn from each site. The sampling sites' geographic locations and agricultural patterns are listed in Table 3.1 for the districts of Balaghat.

3.2.2 Laboratory work:

Collected surface soil sample (0-15 cm depth) were brought into laboratory and dried in shade at room temperature. Air dried soil samples were crushed with the help of wooden roller and sieved through 2 mm sieve. Finally dried soil samples were kept in a well labeled polythene bag for further physico - chemical analysis by standard procedures.

Table No.-3.3: Procedure used for physico - chemical analysis of soil

Properties	Method followed	Reference
Physical properties		
Bulk density (g cm ⁻³)	Pycnometer	Black <i>et al.</i> (1965)
Particle density (g cm ⁻³)	Pycnometer	Black <i>et al.</i> (1965)
Water holding capacity	Keen box	Piper (1966)
Chemical properties		
pH	pH meter	Chopra and Kanwar, (1982)
EC (dSm ⁻¹)	Electrical conductivity meter	Sparks, (1996)
Organic carbon (%)	Wet Oxidation method	Walkey and Black (1934)
Available Nitrogen (kg ha ⁻¹)	Alkaline KMnO ₄ method	Subbiah and Asija, (1956)
Available Phosphorus (kg ha ⁻¹)	Bray's method Olsen's method	Bray and Kurtz (1945) Olsen <i>et al.</i> (1954)
Available Potassium (kg ha ⁻¹)	Ammonium Acetate method	Hanway and Heidal, (1952)
Available Sulphur (mg kg ⁻¹)	Calcium Chloride method	Chesnin and Yien (1950)

3.3 ANALYSIS OF SOIL SAMPLE

Soil samples were analyzed as per standard procedure and widely accepted methods in lab of the department. Procedure followed for physico-chemical analysis of collected soil samples are mentioned above in the Table no.3.3. The physico-chemical properties *i.e.*, mechanical analysis, soil pH, Electrical conductivity, organic carbon, available nutrients (N, P, K, S).

3.3.1 Soil pH

A pH meter was used to determine the pH of soil samples (Chopra and Kanwar, 1982). The equipment was calibrated using pH buffer solutions of 4.0, 7.0, and 9.2. A 1:2.5 soil-water suspension was made and the pH was determined. The suspension was swirled continually with a glass rod, and the electrode of a pH meter was inserted, and the pH of the suspension was recorded.

Soil samples were classified according to pH levels

Rating of the soil reaction	Range of pH
Extremely acid	< 4.6
Strongly acid	4.6 - 5.5
Moderately acid	5.6 - 6.5
Neutral	6.5 - 7.0
Moderately alkaline	7.1 - 8.5
strongly alkaline	> 8.5

3.3.2 Electrical conductivity

The EC of the soil was calculated using the soil water suspension prepared during pH determination. The electrode of the electrical conductivity meter was inserted in supernatant solution of the soil: water suspension and the EC of the soil was measured and noted in dSm^{-1} (Sparks, 1996).

3.3.3 Bulk density

The clean dry pycnometer was taken and weighed on electric balance post that soil was filled in pycnometer with the help of spatula up to brim. After that weight of the pycnometer with soil was taken, then the soil was removed from pycnometer. A burette was filled with water and it was dropped in the same pycnometer from burette until the pycnometer was completely filled with water. The reading will give the actual volume of pycnometer (Black *et al.* 1965).

Calculation: -

$$\begin{aligned} \text{weight of pycnometer} &= a \text{ g} \\ \text{weight of pycnometer + soil} &= b \text{ g} \\ \text{Volume of pycnometer} &= c \text{ mL} \\ \text{Bulk density (Mg m}^{-3}\text{)} &= \frac{\text{weight of soil (b - a)}}{\text{Total Volume (c)}} \end{aligned}$$

3.3.4 Particle density

The clean and dry pycnometer was taken and weighed water was filled in the pycnometer and weighed 10g oven dried soil was placed in a beaker and 10ml of water was added to it, heat it to expel the air. When bottle was half filled the soil particles sticking to inner side of the neck were washed by using a jet of water inserted the stopper and wiped the surface of the pycnometer, dried and weighted it (Black *et al.* 1965).

Calculation: -

$$PD = 10 / (W1 + 10) - W2$$

Where, PD = partial density (Mg m⁻³)

W1 = Weight of pycnometer + water

W2 = Weight of pycnometer + water + soil

3.3.5 Soil porosity

Porosity was calculated by using bulk density and particle density values of the soil by using the formula given below:

$$\text{Porosity (\%)} = \left[1 - \frac{\text{bulk density}}{\text{particle density}} \right] \times 100$$

3.3.6 Water holding capacity of soil

The water retention capacity of the soil samples was measured using a keen box. After a round filter paper was placed within the keen box, the weight was measured. To fill the box with soil, the soil was tapped around 20-30 times. After filling a Petri dish with water, a box and filter paper were placed inside for around an hour. The soil in the box absorbed the largest amount of water. The weight of the wet soil was estimated after draining excess water from the soil by placing the keen box on filter paper. After moist soil in the keen box was oven-dried for 24 hours at 105 degrees Celsius, the weight of oven-dried soil was measured.

$$\text{Water holding capacity (\%)} = [(B-C-D)/(C-A)] * 100$$

Where, A= weight of Keen box +weight of filter paper

B= weight of Keen box along with soil before drying

C= constant weight of Keen box along with soil after drying

D=Average amount of water held by filter paper

3.3.7 Organic carbon

The organic carbon content of the soils was determined using the Walkley and Black (1934) wet digestion method. Organic matter was oxidised with chromic acid ($K_2Cr_2O_7 + H_2SO_4$) in this process. Back titration of unconsumed $K_2Cr_2O_7$ against ferrous ammonium sulphate in a 500 mL conical flask, 1g of soil was taken. 10 mL of 1 N $K_2Cr_2O_7$ and 20 mL concentrated H_2SO_4 were added to it. Allow 30 minutes to complete the reaction. Then added a pinch of NaF salt and 2-3 drops of diphenylamine indicator to the mixture, which was diluted with 200 ml of water. To achieve a vivid green colour, titrate the solution with ferrous ammonium sulphate. At the same time, a blank was run.

$$\% \text{ Organic 'C' in soil} = \frac{(B-S) \times 0.003 \times 10 \times 1 \times 100}{B \times \text{wt. of soil}}$$

Where,

B = Volume of 0.5 N FAS consumed for blank titration

S = Volume of 0.5 N FAS consumed for sample titration

3.3.8 Available Nitrogen

Available Nitrogen content in soil was determined using Kjeltec Semi - Auto Nitrogen Analyzer (Pelican) by alkaline Potassium permanganate method as proposed by Subbiah and Asija (1956). The method has been widely adopted to get a reliable index of Nitrogen availability in soil due to its rapidity and reproducibility.

Procedure: 5 g of soil sample was weighed and transferred in a distillation tube. The sample was moistened with 5 mL distilled water, washing down the soil adhering to the neck of flask. 25 ml 0.32% KMnO₄, was added to it and the distillation tube was set to the instrument. In a 250 mL conical flask, 20 mL of 2 % boric acid solution and mixed indicator was taken and placed under the receiver tube. Tap water was run continuously in the condenser. Twenty-five mL of 2.5 % NaOH solution was sucked and added to the distillation tube. Then it was put on distillation for 9 min during this process the N released in the form of ammonia is trapped in the boric acid, which develops green colour. The flask containing the distillate was removed. The distillate was then titrated against 0.02N H₂SO₄ until the colour of solution turns to reddish purple (the original colour of boric acid solution).

$$\text{Available N (kg ha}^{-1}\text{)} = \frac{(S - V) \times 0.02 \times 14 \times 10^6 \times 2.24}{1000 \times 5}$$

where,

S = Sample titration reading

V = Blank titration reading

3.3.9 Available phosphorus

Olsen's method (Olsen, 1954) was used to calculate the amount of phosphorus in the soil. The first reagent, reagent 'A,' was made with ammonium molybdate, antimony potassium tetrates, and H₂SO₄. Then, with the assistance of reagent A, reagent 'B' was made. In a 250 mL conical flask, 2.5 g of soil was mixed with a pinch of Darco G-60 and 50 mL of Olsen's reagent (0.5 M NaHCO₃) for extraction. The contents were mechanically shaken for 30 minutes before being filtered through Whatman No. 1 filter paper. Ten milliliter of filtrate was transferred to a 50-milliliter volumetric flask and acidified to pH 5.0 with 2.5 milliliters of H₂SO₄, 10 milliliters of distilled water, and 8 milliliters of reagent B. After waiting 10 minutes, the intensity of blue color was measured with a spectrophotometer at 730 nm. At the same time, a blank was run. After calibrating the spectrophotometer with a standard solution, sample readings were taken.

Calculation –

$$\text{Available phosphorus (kg ha}^{-1}\text{)} = \frac{\text{Absorbance} \times \text{dilution factor} \times 2.24}{\text{Slope of the standard curve}}$$

3.3.10 Available potassium

The accessible potassium content of soil was calculated using the Flame Photometer (1 N ammonium acetate extract) method (Hanway and Heidal, 1952). Five grammes of soil was mixed with 25 mL of 1 N ammonium acetate solution in a 100 mL conical flask and shaken for five minutes. After passing the suspension through Whatman No. 1 filter paper, the potassium concentration in the filtrate was measured using a flame photometer. Flame photometer was calibrated with standard solution, followed by sample readings.

Calculation

Concentration of K in the sample from standard curve against the reading = C

$$\text{Available K (kg ha}^{-1}\text{)} = C \times 5 \times 2.24$$

3.3.11 Available Sulphur

The accessible sulphur content in soil was determined using a turbidimetric measuring technique (Chesin and Yein, 1952). 10 grams of soil and 50 mL of 0.15 percent CaCl₂ solution was made in a 250 mL conical flask. On a mechanical shaker, the contents were shaken for 30 minutes before being filtered through Whatman No. 42 filter paper. After that, 10 mL of the aliquot was transferred to a 25 mL volumetric flask containing 1 g sieved BaCl₂ crystals. Then, 1 mL of 0.25 percent gum acacia solution was added and mixed. The volume was made up with distilled water and after 5-10 minutes, the turbidity was measured using a spectrophotometer with a blue filter at 340 nm. At the same time, a blank was carried out using the same technique. Following the standard reading, a sample reading was taken.

Calculation

$$\text{SO}_4 \text{ S- mg kg}^{-1} = \frac{\text{S in aliquot (ml)} \times \text{volume of extract (ml)}}{\text{Volume of aliquot (ml)} \times \text{oven dry weight (g)}}$$

3.4 Methodology for soil nutrients status evaluation

The categorization of the soils of the individual blocks as a whole in to the three fertility classes was done according to the nutrient index values calculated from the soil test summaries giving their percentage distribution into low, medium and high categories . The nutrient index (**Parker *et al.*, 1951.**) was given by-

$$\text{Nutrient Index} = \frac{(A \times 1) + (B \times 2) + (C \times 3)}{\text{NT}}$$

where,

A = Number of samples falling in low category.

B = Number of samples falling in medium category.

C = Number of samples falling in high category.

NT = total number of samples analyzed for a given area

In this percent assessment a nutrient index less than 1.5 denotes low category and that falls between 1.5 and 2.5 represents the medium fertility class . Value of 2.5 and above (maxi 3.00) signifies a high fertility class in respect of the particular nutrient (Ghosh and Hasan , 1976) . The rating of the individual soil test values into the three classes was performed according to the above mentioned limits . (Ramamoorthy and Bajaj , 1969) which have been adopted by most of the soil testing laboratories in the country.

Table No. 3.4 : Characterization of soil test values for different nutrients

	Low	Medium	High
Organic carbon (%)	<0.5	0.5-0.75	>0.75
Available N (kg ha⁻¹)	<280	280-560	>560
Available P (kg ha⁻¹)	<12.5	12.5-25	>25
Available K (kg ha⁻¹)	<135	135-335	>335
Available S (mg kg⁻¹)	<10	10-20	>20
	Deficient	Sufficient	

3.5 Statistical Analysis

Data obtained after chemical analysis of soil were analysed statistically. The correlation coefficient was obtained between relevant physicochemical properties and Range, Mean, Standard deviation and coefficient of variation of soil available nutrients were calculated by following the standard methods.



Result and Discussion

75 surface soil samples from the Balaghat and Malajkhanda blocks in the Balaghat district of Madhya Pradesh were collected, and their physical characteristics (bulk density, particle density, porosity, and water holding capacity), Chemical characteristics (pH, EC, and organic carbon), and the macronutrients (N, P, K, and S) were examined. In the current chapter, appropriate tables were used to represent the results of various soil parameter estimates for range, average, and standard deviation values. We were briefly examined many soil fertility maps and prepared for various soil parameters of the present study.

Since a long time, the Balaghat district has been subjected to intensive agricultural programmes with a variety of crops that have diverse nutrient uptake characteristics, which causes a nutritional imbalance, especially in N, P, K, and S. The concept of nutrient index provides the fundamental information regarding the nutrients that are present in the soil and their relationships to other soil properties. This can be extensively used to determine each area's individual fertilizer needs under particular circumstances. Regarding soil features and nutritional condition, very little collaborative investigation has been done on these widely dispersed soils.

The findings of the present investigation are recorded in the following sub-headings;

- 4.1 Physico-chemical properties of soil of Balaghat district.**
- 4.2 Status of available macronutrients viz. N, P, K and S in soil.**

4.3 Soil Nutrient index value.

4.4 Comparison between soils near mining area and area away from mines.

4.5 Correlation of physico-chemical properties with nutrient availability.

4.6 Fertility mapping of area.

4.1 Physico-chemical properties of soil.

4.1.1 Bulk Density

The bulk density of the soil sample in the Balaghat and Malajkhand block of Balaghat district ranged from 1.27-1.48 g cm⁻³ for Mining area and 1.20-1.35 g cm⁻³ for normal cultivated area away from mines, with a mean of 1.38 g cm⁻³ for mining area and 1.27 g cm⁻³ for away from mining area and a standard deviation of soils of mining area and cultivated area were 0.10 and 0.08, respectively. The village Hirapur had the lowest bulk density, 1.27 g cm⁻³ (sample number.M1S24) in mining area and 1.20 g cm⁻³ (sample C1S5) for village bhatara for area away from mines, while chakarwahi had the highest 1.48 g cm⁻³ (sample no. M2S6) for mining area and Dhapewada (sample no. C1S20) for area away from mines. The coefficient of variation was 4.60 percent for mining area and 3.19 % for area away from mines. Similar results were noted by Patil and Chaturvedi (2012) in soil of Jabalpur district of M.P.

4.1.2 Particle Density

The particle density of soil sample was determined by using pycnometer. Overall, it was varied from 1.53-2.58 g cm⁻³ for mining area and 1.73-2.81 g cm⁻³ for area away from mines, with the mean value of 2.09 g cm⁻³ for mining area and 1.98g cm⁻³ for area away from the mines. The lowest particle density value of mining area is 1.53 g cm⁻³ was recorded in a sample collected from Awlajhari (sample M1S2) and 1.733 g cm⁻³ for area away from mining in bhatara (sample C1S5). The highest value for mining area was 2.58 g cm⁻³ recorded in the samples collected from bhanderi (sample M2S2) and for area away from mines was 2.81 g cm⁻³ in godaritola (sample C2S6). The standard deviation was 0.25 for mining area and 0.29 for area away from

mines respectively. The coefficient of variation for both the area was 12.06% and 14.66% respectively. Similar findings were reported by Saxena *et.al.* (2010) in soil of Sarni, Betul M.P.

4.1.3 Porosity

The porosity was calculated using the particle density and bulk density of the soil. The porosity of the sample in Balaghat and Malajkhand block of the Balaghat district ranged from 40.61-63.28 % with the mean value of 54.98% for mining area and for the normal cultivated area it ranged from 45.31-70.22% with the mean value 61.15%. The standard deviation for both the area near mines and area away from mines are 5.22 and 5.72 respectively, and coefficient variation was 9.49% for area near mines and 9.36% for area away from mines. The highest porosity in mining area was observed in village Bharveli (sample no.M1S21) and in godaritola (sample no. C2S6) for the area away from mines, whereas, the lowest porosity in mining area was observed in village Palehara (sample no.M2S11) and in Shitalpani (sample no. C2S2) for area away from mines. Similar findings were reported by Saxena *et.al.* (2010) in soil of Sarni, Betul M.P.

4.1.4 Water holding capacity

The water holding capacity of the cultivated soils and soil near mines in the Balaghat and Malajkhand block of the Balaghat district ranged from 57.74-89.61% and 46.52-82.98%, respectively. The mean value for mining area and normal cultivated area were 67.52% and 69.23%, a standard deviation of 7.94 and 6.91, and a coefficient variation were 11.75% and 9.98%, respectively. Village Tawejhari (sample no. M1S10) from mining area and village Bhatara (sample C1S3) from area away from mines had the highest water holding capacity, whereas village Awlajhari (sample no. M1S7) from mining area and Kumhari (sample no. C1S16) from area away from the mines had the lowest water holding capacity. Soil texture plays an important role and directly influenced the water holding capacity of the soil. As the proportion of clay increases in the soil, the water holding capacity increases due to clay can bind or hold the water molecules more effectively. So, soils possessing

higher quantity of clay will have enhanced water holding capacity. Soil with minute water holding capacity soon dried out and decreases the plant growth. Similar results were recorded by Ahmad *et.al.* (2012) Bhairavgarh area Ujjain city of M.P.

4.1.5 Soil Reaction (pH)

The measurement of soil reaction or pH has a significant impact on the number of nutrients that are available to crops from the soil. The soil pH of the sampling sites as mining area and normal cultivated area ranged from 6.9-8.3 and 7.1-8.2, respectively. With a mean value of 7.59 and 7.58 for both mining and normal cultivated area, respectively according to a study on soil reaction using samples collected from the study areas. It means that the pH of the soil is neutral to slightly alkaline for both the sites. Yet again, it was found that a majority of soil samples (48 percent) were in the neutral reaction range and the remaining 52 percent samples (Table: 4.1.5) were in the slightly alkaline reaction range, concluding that soil has no significant limitations on crop production diversity from the standpoint of soil reaction. Standard deviation was 0.36 and 0.29 for both the mining area and area away from mines. Coefficient variation 4.76% for mining area and 3.79% for area away from mines. The highest pH value was recorded in village Tawejhari (sample no. M1S11) from mining area and in Khairi & dhapewada (sample no. C1S7 & C1S21) for cultivated area away from mines. Whereas the lowest pH value was recorded in village Palehara (sample no. M2S11) from mining area and in Khairi & kumhari (sample no. C1S10 & C1S16) from cultivated area away from mines. Similar findings were recorded by Ahirwar *et al.* in 2021.

Table 4.1.5 : Distribution of soil samples under different pH rating

Class	Limit	No. of samples	% of samples
Strongly acidic	<4.5	0	0
Moderate acidity	4.5 - 5.5	0	0
Slightly Acid	5.5 - 6.5	0	0
Neutral	6.5-7.5	36	48
Slightly alkaline	7.5-8.5	39	52
Moderate alkaline	8.5-9.5	0	0
Strongly Alkaline	> 9.5	0	0

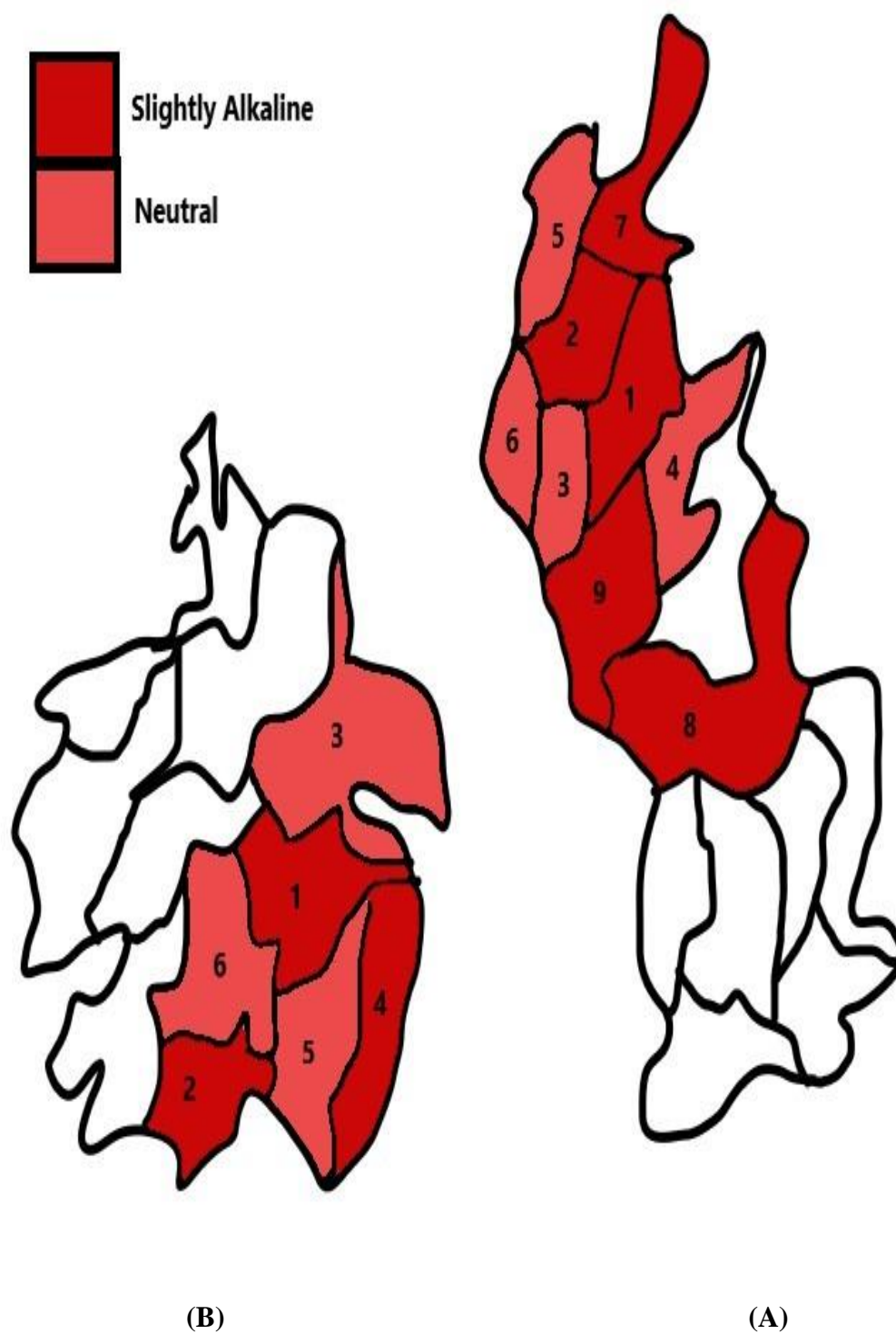


Fig 4.1 : Soil pH of Balaghat (A) & Malajkhand (B) Block of Balaghat District

4.1.6 Electrical Conductivity (EC)

Through analysis of soil EC (Electrical Conductivity) in the soil water suspension, all soil samples collected from the study region were assessed for total soluble salt content. Using appropriate rating values, they were divided into several groups depending on their impact on crop growth following the evaluation of the soil EC value (Table: 4.1.6). As a result, the EC level of the soil indicates that how many nutrients are available for crops to absorb in order to increase yield. The soil EC of the study regions as area near mines and cultivated area away from the mines was found to vary from 0.12-0.68 dSm⁻¹ and 0.13-0.69 dSm⁻¹ with a mean value of 0.34 dSm⁻¹ and 0.42 dSm⁻¹, respectively. Table no.4.12 indicating relatively low EC within a very narrow range and the standard deviation for both the area near the mines and cultivated area away from the mines were 0.15 and 0.15, respectively. With the coefficient of variation being 42.31% for mining area and 35.53% for area away from mines. Additionally, it was discovered that all 75 samples were low in EC, indicating that soil salinity was not a factor in any crop productivity limitations. Village palehara (sample no.M2S12) from area near the mines and Dhapewada (sample no.C1S18) from normal cultivated area away from the mines recorded the highest electrical conductivity value, whereas village Tawejhari (sample no. M1S8) from area near mines and Shitalpani (sample no.C2S1) from area away from mines recorded the lowest electrical conductivity value. Similar results for different soils were also reported by Tomar (1968), Singh (2012), Dilliwar *et al.* (2014) and Singh *et al.* (2014).

Table: 4.1.6 : Distribution of Soil Samples under different E.C. rating

Classes	Ranges (dSm ⁻¹)	No. of samples	% of samples
Low	<1.0	75	100
Medium	1.0-2.0	0	0
High	2.0-3.0	0	0
Very High	>3.0	0	0

4.1.7 Organic carbon

For the objectives of fertility, physical, chemical, and biological properties, the organic carbon content of soils is a major factor. Thus, the organic carbon content of soil samples was examined (Table 4.1.7).

The surface soil in the Balaghat and Malajkhanda block of the Balaghat district was found to have an organic carbon content that ranged from 0.10-1.68% in area near mines and 0.18-2.33% in cultivated areas away from mines, with a mean value of 0.83 % and 0.98 % respectively, a standard deviation of both the areas near mines and away from mines were 0.40 and 0.56 respectively, and a coefficient of variation of 48.18% and 57.59%, respectively. The village Palehara from area near mines and Rupjhar from area away from mines, recorded the maximum organic carbon value (sample no. M2S10 & C2S11), while the village Bhanderi from cultivated area near mines and village Bhatara from area away from the mines recorded the lowest (sample no. M2S3 & C1S4). Soil organic carbon is intrinsically connected to soil fertility and the potential for agricultural productivity. High levels of organic matter in soil produce outstanding physical and chemical characteristics (Garcia-Gil *et al.*, 2004, Veeresh *et al.*, 2003). Mandal *et al.* (2011) also found that crop species and cropping systems may play an important role for variations in soil organic carbon. Findings of Singh *et al.* (2014) and Y.li. *et al.* (2018) also support the findings of present study.

Table 4.1.7 : Distribution of Soil Samples under different Organic Carbon Rating

Class	Range (%)	No. of samples	% of samples
Low	<0.5	17	22.6
Medium	0.5-0.75	12	16.0
High	>0.75	46	61.33

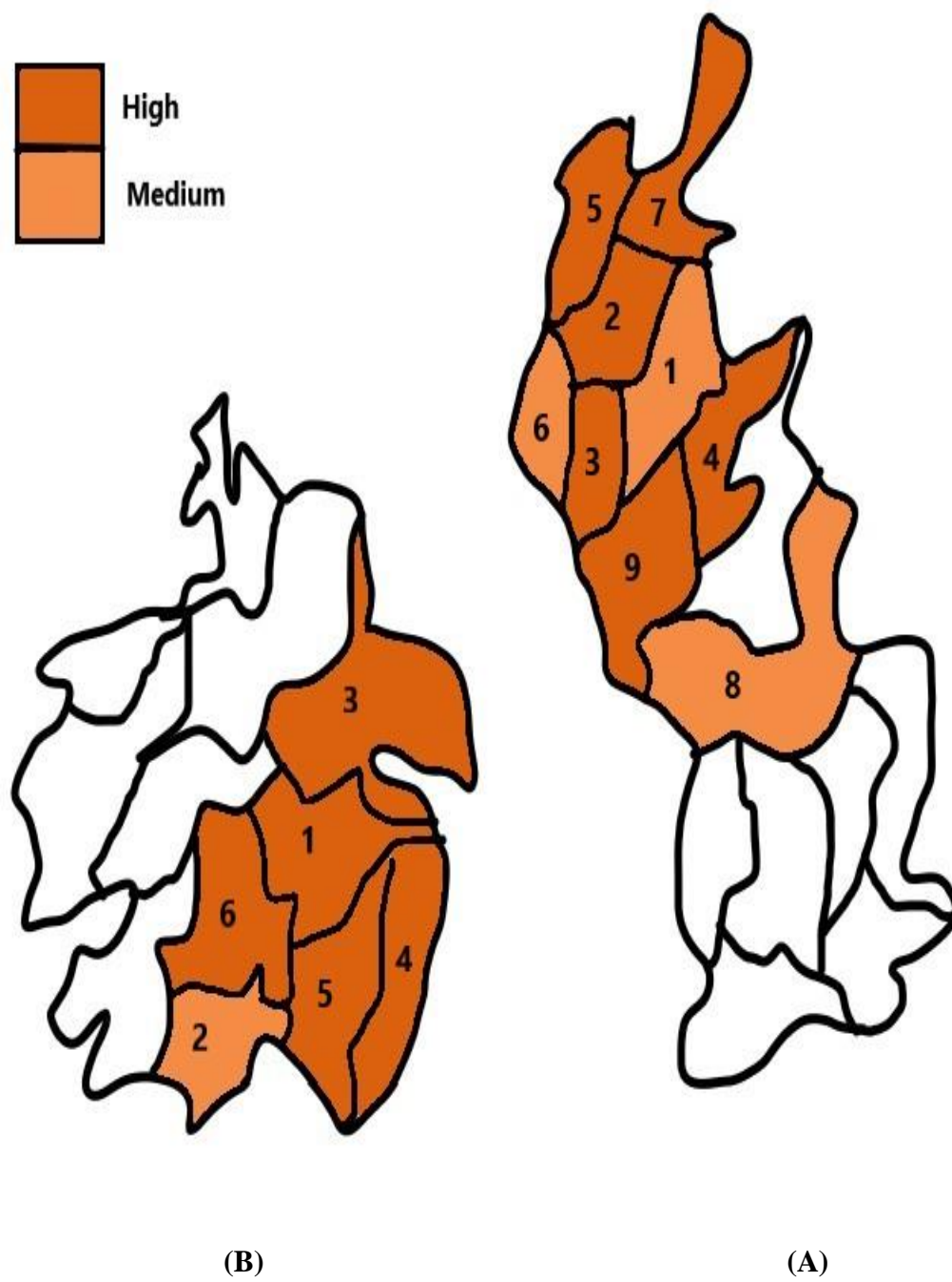


Fig 4.2 : Soil Organic Carbon of Balaghat (A) & Malajkhand (B) Block of Balaghat District

4.2 Status of available macro-nutrient in soil

4.2.1 Nitrogen

The research area's soil available N status was observed to range from 87.81-275.97 kg ha⁻¹ for cultivated area near mines and 75.26-388.86 kg ha⁻¹ in cultivated area away from mines with a mean value of 146.12 kg ha⁻¹ for area near mines and 199.38 kg ha⁻¹ in area away from mines (Table: 4.2.1) and a standard deviation for both the area near mines and away from the mines were 46.41 and 79.22, respectively. Coefficient variation 31.76% and 39.73% for both the areas, respectively. The village of Chakarwahi had the highest nitrogen content value (sample no.M2S6) from area near mines and village Dhapewada (sample no.C1S23) had highest nitrogen content from cultivated area away from mines, whereas the village Awlajhari & hirapur (sample no. M1S3 & M1S22) from mining area and village Godaritola (sample no. C2S5) from cultivated area away from mines had the lowest nitrogen content value. It was found that the research area had no available N in any portion of it (Table: 4.2.1). However, we should also consider the fact that the alkaline KMnO₄ method of Subbiah and Asija (1956) only recovers the oxidizable N component of the dry soil N pool, with a soil available N recovery efficiency of about 70–76%. Similar findings were reported by Yadav *et.al.* (2018) in the soils of Alirajpur district of M.P.

Table 4.2.1 : Distribution of Soil Samples under different Available Nitrogen Rating

Class	Range (kg ha ⁻¹)	No. of samples	% of samples
Low	<280	68	90.66
Medium	280-560	7	9.33
High	>560	0	0

(Source: Ramamoorthy and Bajaj,1969)

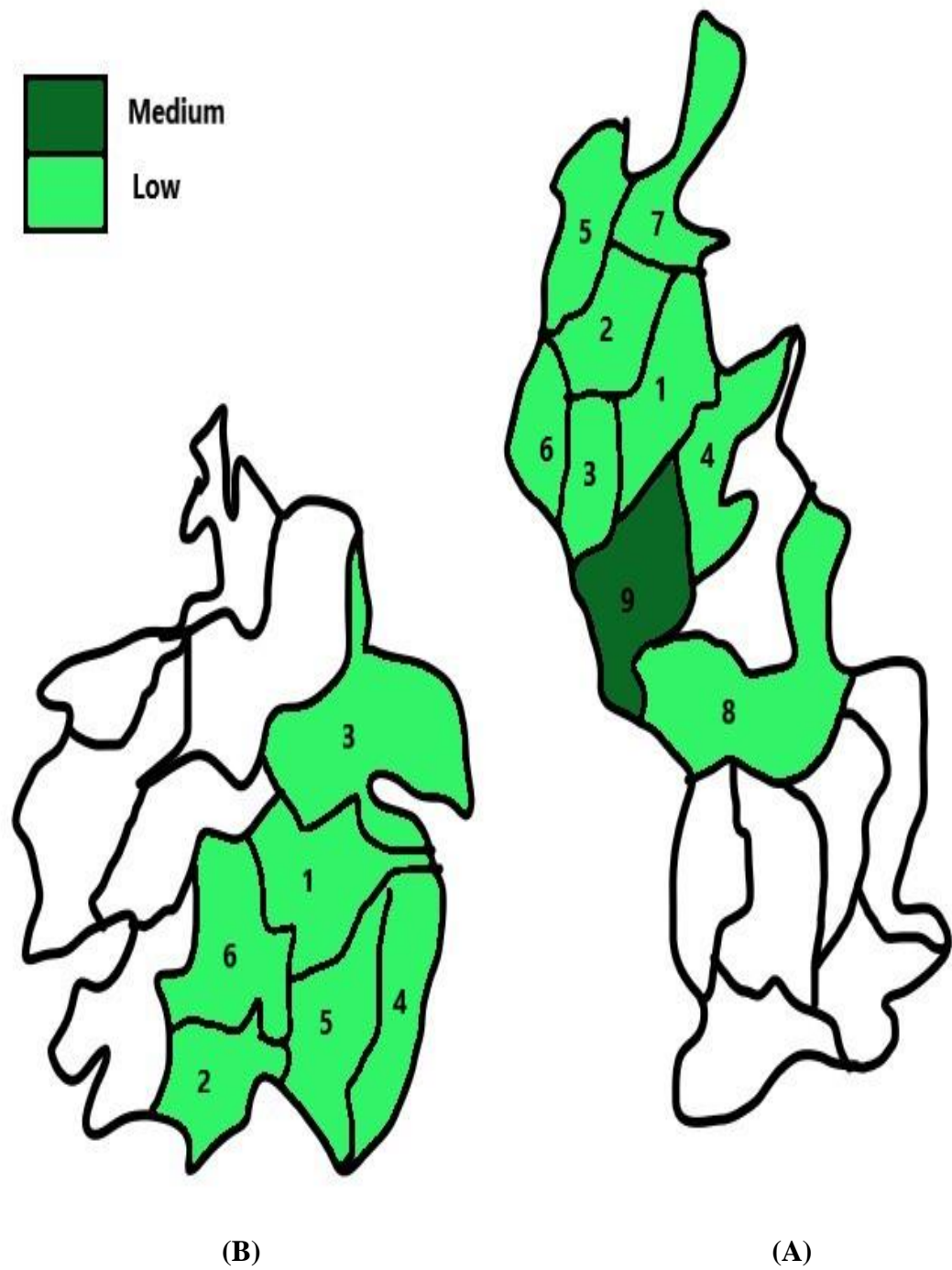


Fig 4.3 : Status of available Nitrogen of Balaghat (A) & Malajkhand (B) Block of Balaghat District

4.2.2 Phosphorus

The research area's soil available Phosphorus status was observed to range from 10.12-20.64 kg ha⁻¹ for cultivated area near mines and 11.89-20.99 kg ha⁻¹ in cultivated area away from mines with a mean value of 13.95 kg ha⁻¹ for area near mines and 16.17 kg ha⁻¹ in area away from mines (Table: 4.2.2) and a standard deviation for both the area near mines and away from the mines were 2.37 and 2.69, respectively. Coefficient variation were 17.0% and 16.62% for both the areas, respectively. The village of Awlajhari had the highest phosphorus content value (sample no.M1S3) from area near mines and village Dhapewada (sample no.C1S17) had highest phosphorus content from cultivated area away from mines, whereas the village Bhanderi (sample no. M2S3) from mining area and village Khairi (sample no. C1S7) from cultivated area away from mines had the lowest phosphorus content value.

Different crops including wheat, maize, groundnuts, chickpeas, and garlic as well as the use of phosphatic fertilisers like SSP, di-ammonium phosphate, and other could be too responsible for the variation in available phosphorus in the Balaghat block soil sample. As a result, there are some low and some moderate to high phosphorus availability soils in the Balaghat and malajkhand block of the Balaghat district. The deficient P status can be attributed to low organic carbon content and P fixation by montmorillonite clay and Al and Fe oxide present in the soil of study area. Similar results were also reported by Meena *et al.* (2006) and Singh *et.al.* (2014) in Chambal region of M.P.

Table 4.2.2 : Distribution of Soil Samples under different Phosphorus rating

Class	Range (kg ha ⁻¹)	No. of samples	% of samples
Low	<12.5	15	20
Medium	12.5-25	60	80
High	>25	0	0

(Source: Ramamoorthy and Bajaj,1969)

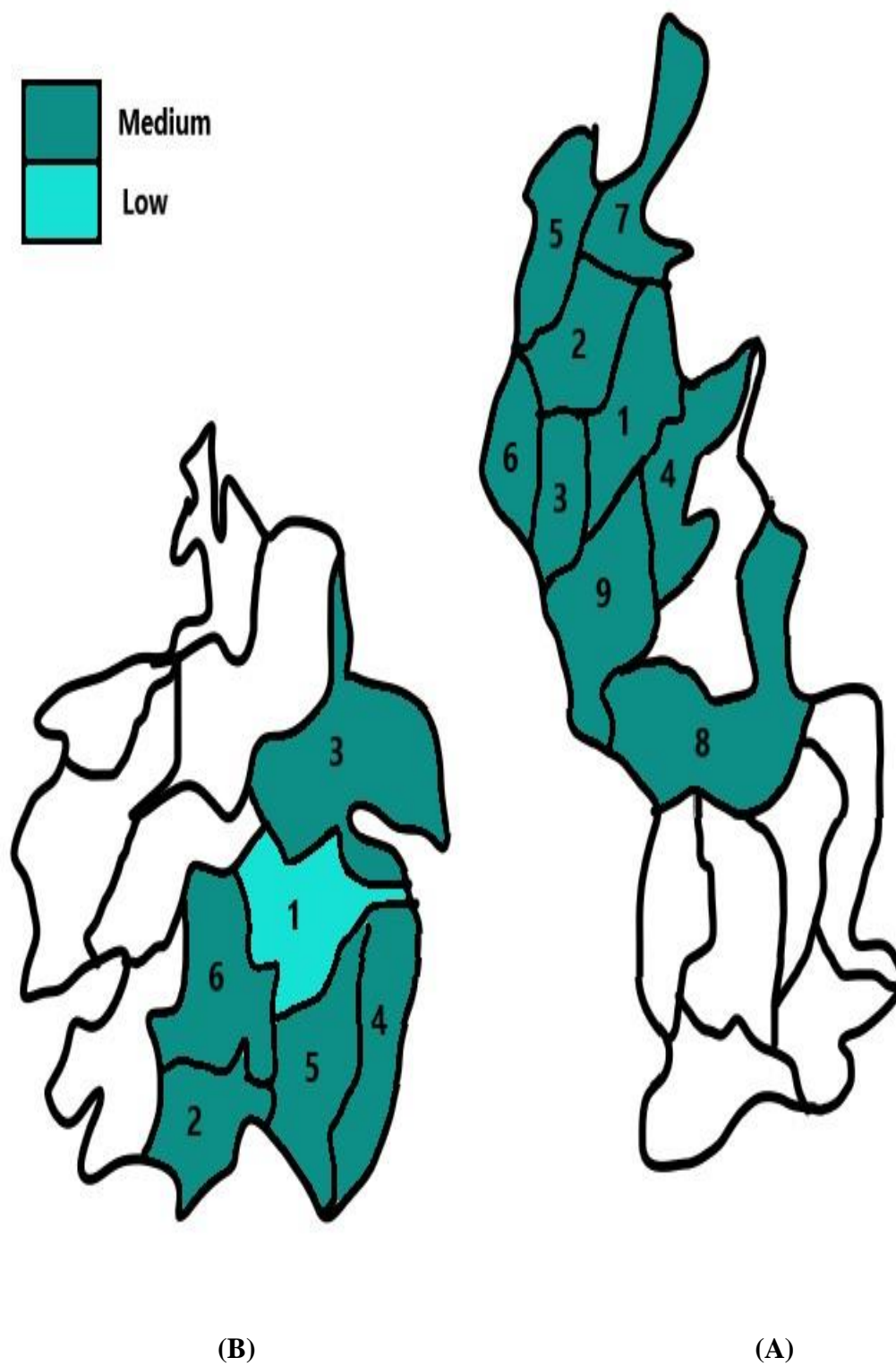


Fig 4.4 : Status of available Phosphorus of Balaghat (A) & Malajkhand (B) Block of Balaghat District

4.2.3 Potassium

The study area's soil samples were found to have medium to high potassium availability levels. The soil's available K content ranged 112-306.88 kg ha⁻¹ for cultivated area near mines and 166.88-378.56 kg ha⁻¹ in cultivated area away from mines with a mean value of 204.17 kg ha⁻¹ for area near mines and 267.92 kg ha⁻¹ in area away from mines (Table: 4.2.3) and a standard deviation for both the area near mines and away from the mines were 48.91 and 54.13, respectively. Coefficient variation were 23.95% and 20.20% for both the area, respectively. Similar results were obtained by Wani *et.al.* (2014) in the soils in Gwalior M.P.

The medium to high potassium status of soil can be ascribed to the expanding clay mineral (Montmorillonite) of the study area. It has a tendency of adsorption onto surface negative sites and trapping of K inside clay lattice. But it releases these K as the K reserve outside depleted maintaining a healthy K pool as per plant requirement. It may also be due to other factors like fertilization and reserve from parent material. As most of the samples fall in medium to high.

The village of Hirapur had the highest potassium content value (sample no.M1S23) from area near mines and village Dhapewada (sample no.C1S20) had highest potassium content from cultivated area away from mines, whereas the village Awlajhari (sample no. M1S1) from mining area and village Godaritola (sample no. C2S5) from cultivated area away from mines had the lowest potassium content value.

Table 4.2.3 : Distribution of Soil Samples under different Potassium rating

Class	Range (Kg ha ⁻¹)	No. of samples	% of samples
Low	<135	4	5.33
Medium	135-335	67	89.33
High	>335	4	5.33

(Source: Ramamoorthy and Bajaj,1969)

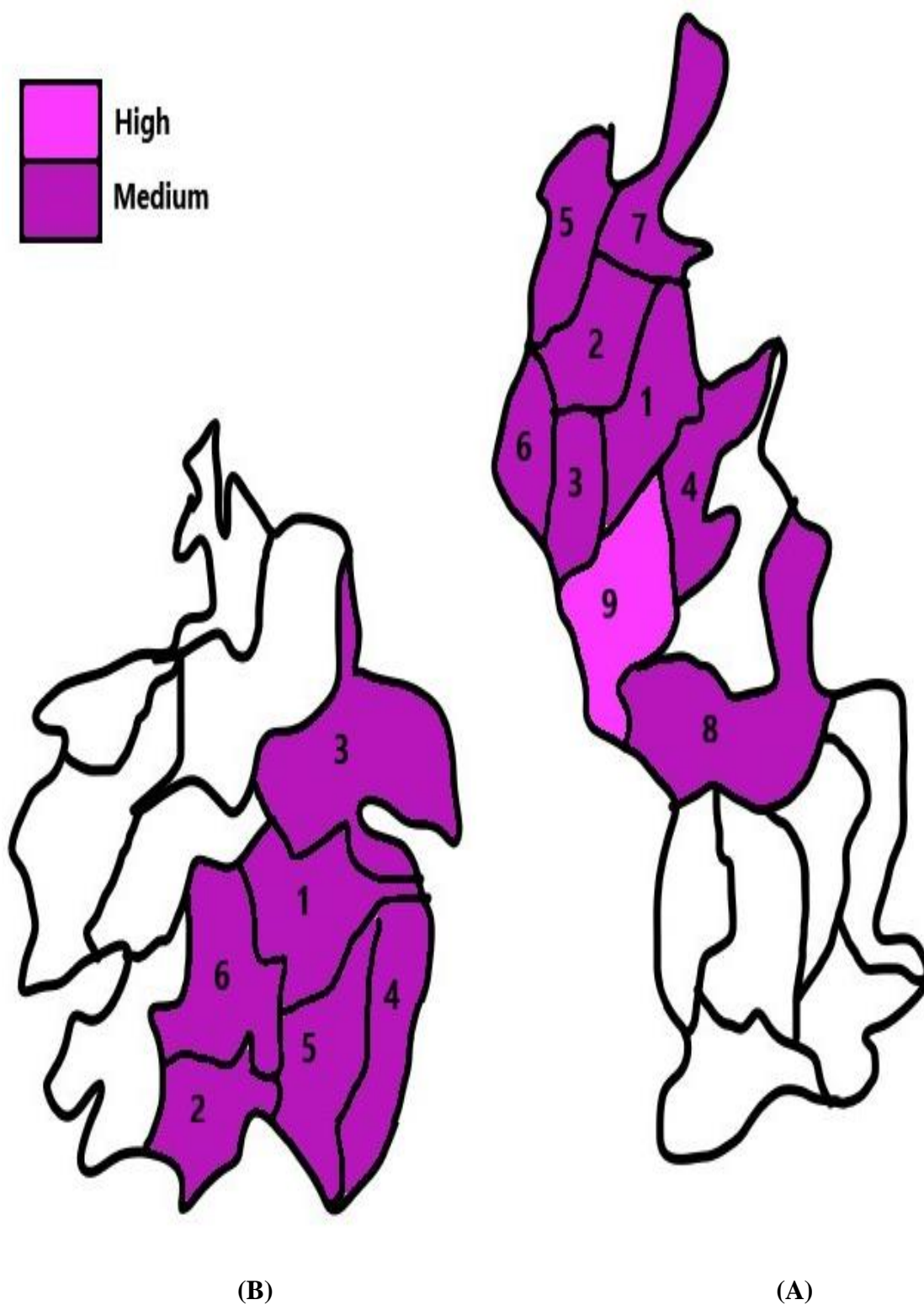


Fig 4.5 : Status of available Potassium of Balaghat (A) & Malajkhand (B) Block of Balaghat District

4.2.4 Sulphur

Available Sulphur content in soil of study area was determined and classified in various classes based on standard rating values (Table: 4.2.4). Sulphur content of the study area found to be ranging from 1.11-9.36 mg kg⁻¹ for cultivated area near mines and 2.51-13.43 mg kg⁻¹ in cultivated area away from mines with a mean value of 3.83 mg kg⁻¹ for area near mines and 8.34 mg kg⁻¹ in area away from mines (Table: 4.13) and a standard deviation for both the area near mines and away from the mines were 2.10 and 2.60, respectively. Coefficient variation 54.74% and 31.14% for both the areas, respectively. The village of Chakerwahi had the highest Sulphur content value (sample no.M2S5) from area near mines and village Rupjhar (sample no.C2S13) had highest Sulphur content from cultivated area away from mines, whereas the village Plehara (sample no. M2S9) from mining area and village Shitalpani (sample no. C2S1) from cultivated area away from mines had the lowest Sulphur content value. Similar findings were recorded by Tagore *et.al.* (2014) in Indore M.P.

Out of 75 samples analyzed 88% were found in low, 12% samples in medium and not a single sample reported in sufficient rating classes (Table: 4.2.4).

Table: 4.2.4 Distribution of Soil Samples under different Sulphur rating

Class	Range (mg kg ⁻¹)	No. of samples	% of samples
Low	<10	66	88
Medium	10-20	9	12
High	>20	0	0

(Source: Ramamoorthy and Bajaj,1969)

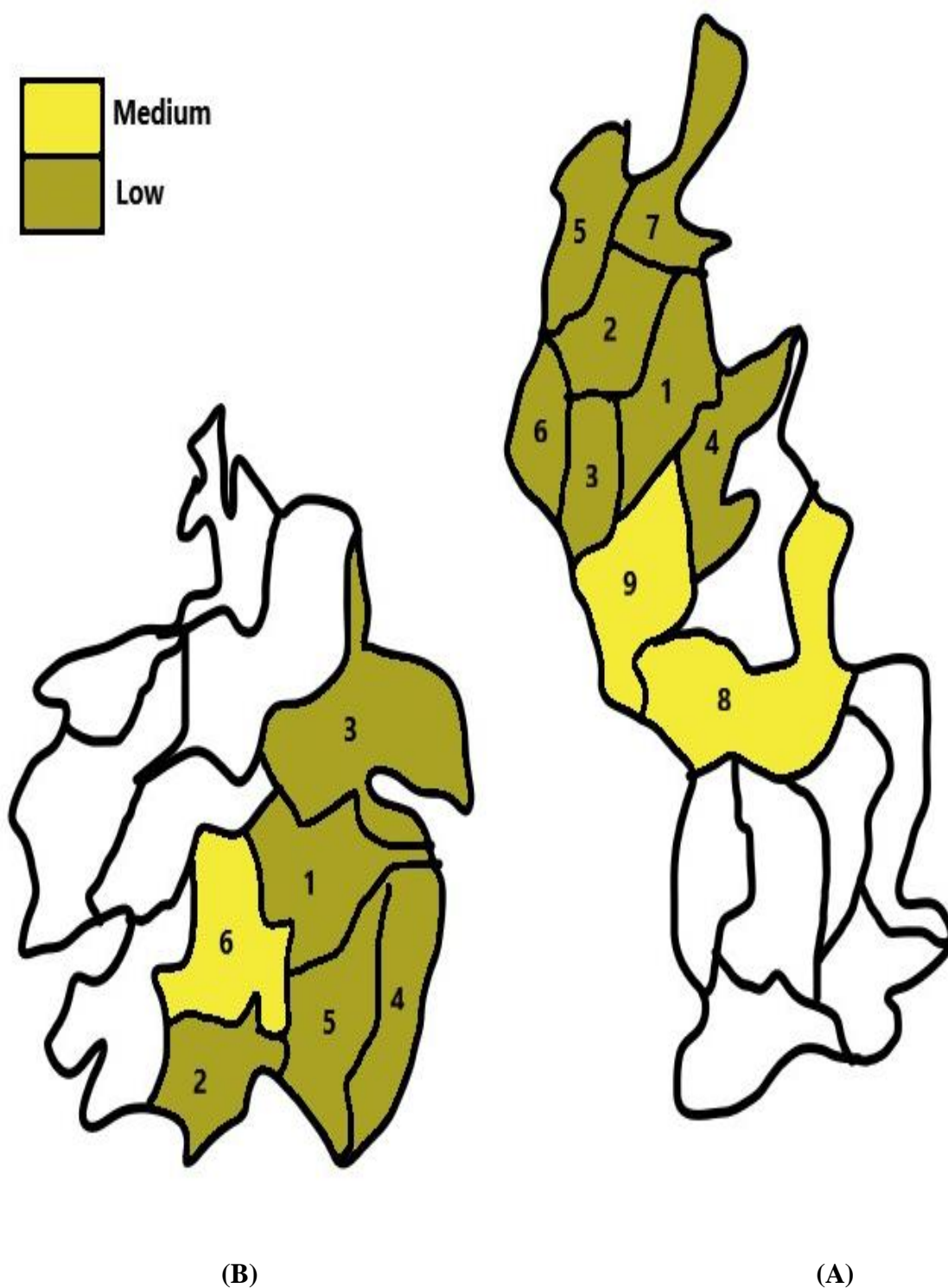


Fig 4.6 : Status of available Sulphur of Balaghat (A) & Malajkhand (B) Block of Balaghat District

Table 4.2.5 : Physical properties of soil of cultivated area near Mines in Balaghat and Malajkhand blocks:

Soil characteristics	Range	Mean	S.D.	C.V. (%)
pH	6.9-8.3	7.59	0.36	4.76
EC (dSm ⁻¹)	0.12-0.68	0.34	0.15	42.31
B.D. (g cm ⁻³)	1.27-1.48	1.38	0.06	4.60
P.D. (g cm ⁻³)	1.54-2.58	2.10	0.25	12.06
W.H.C (%)	46.52-82.98	67.52	7.94	11.75
O.C. (%)	0.10-1.68	0.83	0.40	48.18

Table 4.2.6 : Physical properties of soil of cultivated area away from Mines in Balaghat and Malajkhand blocks:

Soil characteristics	Range	Mean	S.D.	C.V. (%)
pH	7.1-8.20.	7.58	0.29	3.79
EC (dSm ⁻¹)	0.13-0.69	0.42	0.15	35.53
B.D. (g cm ⁻³)	1.20-1.35	1.27	0.04	3.19
P.D. (g cm ⁻³)	1.73-2.82	1.98	0.29	14.66
W.H.C (%)	57.74-89.61	69.23	6.91	9.98
O.C. (%)	0.18-2.33	0.98	0.56	57.59

Table 4.2.7 : Status of available macro-nutrient of soil of cultivated area near mines in Balaghat and Malajkhand block:

Soil characteristics	Range	Mean	S.D.	C.V. (%)
Available N (kg ha ⁻¹)	87.81-275.97	146.12	46.41	31.76
Available P (kg ha ⁻¹)	10.12-20.64	13.95	2.37	17.00
Available K (kg ha ⁻¹)	112-306.88	204.17	48.91	23.95
Available S (mg kg ⁻¹)	1.11-9.36	3.83	2.10	54.74

Table 4.2.8 : Status of available macro-nutrient of soil of cultivated area away from mines in Balaghat and Malajkhand block:

Soil characteristics	Range	Mean	S.D.	C.V. (%)
Available N (kg ha ⁻¹)	75.26-388.86	199.38	79.22	39.73
Available P (kg ha ⁻¹)	11.89-20.99	16.17	2.69	16.62
Available K (kg ha ⁻¹)	166.88-378.56	267.92	54.13	20.20
Available S (mg kg ⁻¹)	2.51-13.43	8.34	2.60	31.14

4.3 Nutrient Index of soil of Balaghat and Malajkhand blocks:

The nutrient index values for available macronutrient (N, P, K, S) of Balaghat and Malajkhand block of Balaghat district are presented in Table 4.3.

The Nutrient value index for soil of Balaghat and Malajkhand blocks was “Medium” for Phosphorous and Potassium and “Low” for Nitrogen and Sulphur. The nutrient index values of Nitrogen, phosphorus, potassium and Sulphur were reported as 1.09, 1.8, 1.99 and 1.12, respectively. Patidar *et.al.* (2017) recorded the similar results for the macronutrient in the soil of Jhabua district of Madhya Pradesh Based on nutrient index values of soils and the criteria suggested by Parker *et al.* (1951) and Ramamurthy and Bajaj (1969), the Nutrient index value ranged for fertility status of a particular area are as:

<1.67 – Low

1.67-2.33 – Medium

>2.33 – High

Table 4.3 : Nutrient Index values of Balaghat and Malajkhand blocks of Balaghat district:

S.No.	Available Nutrient	NIV	Category
1	Nitrogen	1.09	Low
2	Phosphorous	1.80	Medium
3	Potassium	1.99	Medium
4	Sulphur	1.12	Low

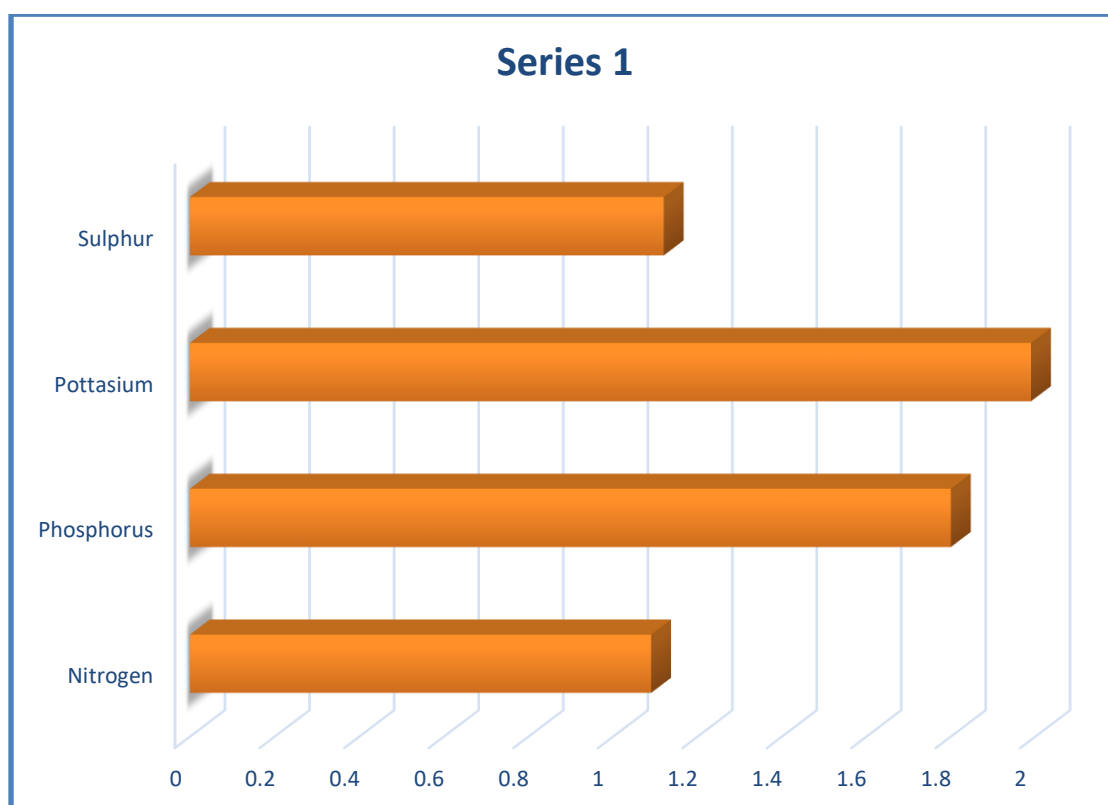


Fig 4.7 : Nutrient index of different macro nutrient (N, P, K and S)

Table 4.4 : Comparison between soils near mining area and area away from mines.

S.N.	Parameter	Cultivated area near Mines	Cultivated area away from mining
1	pH	7.59	7.58
2	EC	0.34	0.42
3	BD	1.38	1.27
4	PD	2.10	1.98
5	WHC	67.52	69.23
6	OC	0.83	0.98
7	N	146.12	199.38
8	P	13.95	16.17
9	K	204.17	267.92
10	S	3.83	8.34

On analyzing of various parameters near mining area and far away from mining area following differences were seen:

- I. While the pH in the far-off location of mines was 7.58 and it was 7.59 in the cultivated area near mines. The constant addition of mineral dusts from the mines or the effluent from the mines may be to blame for the elevated pH.
- II. Mean EC values were 0.34 in the area near both the mines and 0.42 in the area away from the mining region. E.C levels did not show any appreciable change.
- III. The average bulk density of soil is 1.38 g cm⁻³ in areas close to both the mines, and 1.27 g cm⁻³ in places far from both the mines. This shows that due to excess of mineral ore bulk density did not affect much.

- IV. Particle density near the mining area was 2.10 g cm^{-3} and 1.98 g cm^{-3} near the normal cultivated area.
- V. WHC and OC in the area of mining and areas away from mining were respectively 67.52%, 69.23% and 0.83%, 0.98%. It may be because of the deposition of waste from Manganese and copper mines. It was concluded that the organic carbon is higher near mining area. Ahirwar *et al.* in 2021 reported similar findings.
- VI. N, P, and K were different in fields close to and far from mining area, demonstrating variation in those areas at 146.12, 13.95, 204.17 kg ha^{-1} and 199.38, 16.17, 267.92 kg ha^{-1} , respectively. In villages near mines, nitrogen and phosphorus levels were found to be low while potassium levels were somewhat higher. This could be because to the presence of the clay mineral illite. In compare to area away from mines, there are low N, P and K levels.
- VII. Sulphur which showed variance in area near mining and area distant from mining, were 3.83 mg kg^{-1} and 8.34 mg kg^{-1} respectively. S concentration was higher in area away from mines as normal cultivated area, and fields near by mines reported low Sulphur level which may be related to the deposition of ores of Mn.

Due to manganese and copper mines, recent establishment, the soil's qualities have not been significantly impacted. However, studies show that pH, Bulk density, Particle density and Organic carbon levels were greater close to mining regions. While these levels currently serve as a source of nourishment, if they are surpassed beyond the recommended level, it may eventually affect the soil's fertility. There is not much difference in soil organic carbon from both the areas. Even the EC is low as the salinity below the level. Water holding capacity is also in the proper range.

4.5 Correlation of physico-chemical properties with nutrient availability of Balaghat and Malajkhand blocks.

We have also looked for intercorrelation between themselves because it is very common to have different types of interactions between plant nutrients in soil that affect how readily available, they are to one another, and because soil pH also plays a very significant role in how readily available the nutrients elements are to plants for their uptake. A correlation matrix was created for more practical and better interpretation of the relationship between various parameters.

The results of nutrients were correlated at different ranges for all soil samples falling into that specific category in order to study the effect of soil pH, EC, organic C, WHC, BD and PD on various Macronutrient statuses of both the mining and normal cultivated area and how they were correlated. Results were displayed in table-4.5.1 and 4.5.2 for ease of understanding and to observe the changing pattern. The correlation status of **mining area** is explained below:

The available nitrogen was shown to negatively correlated with the soil pH ($r = -0.099^*$). The available nitrogen showed negative correlation with organic carbon ($r = -0.153$) and EC ($r = -0.114^*$). This negative correlation might be due to the mining area which are rich in manganese and copper. Bulk density had significant relationship with Nitrogen ($r = 0.148$). Particle density was also showing the positive and non-significant relationship with available Nitrogen ($r = 0.078$). Available Nitrogen showed a significant negative correlation with water holding capacity ($r = -0.157$) in mining area. These findings were somewhat similar with the report of Kumar (2015) in the mining area and the soil of Balaghat district M.P.

In mining area available Phosphorus was negatively correlated with pH ($r = -0.148$) because calcium can precipitate with phosphorus as Ca - phosphate at higher pH levels and decrease phosphorous availability. Organic carbon was also not showing any significant relation with phosphorus ($r = -0.143$). Bulk density, particle density and water holding capacity were showing on significant positive correlation

with phosphorus, i.e. ($r=0.194$), ($r=0.034$) and ($r=0.065$) respectively. Phosphorus and electrical conductivity showed positive correlation ($r= 0.210$).

A negative correlation ($r= -0.346$) was found between available Potash and pH. Available Potash showed significant positive relationship with organic carbon ($r= 0.225$). Potash showed the positive correlation with Electrical conductivity ($r= 0.512$) and water holding capacity ($r= 0.333$) and negatively correlated with Bulk density ($r= -0.521^{**}$) and Particle density ($r= -0.042$). Similar finding was recorded by Singh *et.al.* (2014) in the Chambal region of M.P.

The available Sulphur in the soils were negatively correlated with pH ($r= -0.216^*$), Bulk density ($r= -0.510$) and Particle density ($r= -0.172$). Sulphur had significant and positive correlation with EC ($r= 0.253$), Water holding capacity ($r= 0.031^*$) and Organic carbon ($r= 0.209$).

The correlation between physico-chemical properties and available nutrients of soil in normal cultivated area:

The available nitrogen in normal cultivated soil was shown to positively correlated with the soil pH ($r= 0.104$). The available nitrogen showed negative correlation with organic carbon ($r= -0.063$) and positively correlated with electrical conductivity ($r= 0.662$). Bulk density had significant relationship with Nitrogen ($r= 0.367$). Particle density was also showing the positive and non-significant relationship with available Nitrogen ($r= 0.011$). Available Nitrogen showed a significant negative correlation with water holding capacity ($r= -0.058$). Kushwaha *et al.* (2017) evaluated the long-term effect of nutrient management in soil N dynamics on Vertisol at Jabalpur and calculated various correlation coefficient between soil available N and other fractions from which they conclude that all fractions of soil N had a significantly high positive correlation with soil organic carbon. The results indicated that available N increased with rise in pH. Kumar *et al.*, (1995) also reported the identical results. Similarly, OC level also markedly affects the soil N status and the results are in agreement with those of workers like Meena *et al.* (2006), Sharma *et al.* (2008), Jatav (2010) and Shukla (2011).

In normal cultivated area available Phosphorus was positively correlated with pH ($r= 0.008$). Similar results were also reported by Singh and Singh (1985) in Beel soils of Assam, Jatav (2010) in the soils of Inceptisols group of Baloda block of Janjgir-Champa district of Chhattisgarh and Shukla (2011) in the Inceptisols, Alfisols and Vertisols orders of Pamgarh block in Janjgir-Champa district (C.G.), Organic carbon was also not showing any significant relation with phosphorus ($r= -0.392$). Bulk density had shown positive relation with phosphorus ($r= 0.091$), particle density and water holding capacity were showing on significant negative correlation with phosphorus, i.e. ($r= -0.008$) and ($r= -0.0733$) respectively. Phosphorus and electrical conductivity showed positive correlation ($r= 0.535$).

A positive correlation ($r= 0.324$) was found between available Potash and pH. Available Potash showed significant negative relationship with organic carbon ($r= -0.0892$). Potash showed the positive correlation with Electrical conductivity ($r= 0.512$), Bulk density ($r= 0.165^{**}$) and Particle density ($r= 0.006$). Potash showed the negative correlation with the water holding capacity (-0.121^*). Verma *et al.* (2015) finds the similar results in the soil of Malkharauda block in Janjgir-Champa district of Chhattisgarh.

The available Sulphur in the soils were negatively correlated with pH ($r= -0.126^{**}$) and water holding capacity ($r= -0.016^*$). Bulk density ($r= 0.007$) and Particle density ($r= 0.132$) showed the positive relation with Sulphur. Organic carbon ($r= 0.165$) and electrical conductivity ($r= 0.543^*$) had a significant relation with Sulphur. Similar finding was reported by Raj *et.al.* (2012) as they showed positive and significant correlation between Sulphur and organic carbon in the soils of Balaghat and Mandala district of M.P.

Table 4.5.1 : Correlation between physico-chemical properties and available nutrients in soil of mining area of Balaghat and Malajkhand blocks:

	N	P	K	S
pH	-0.099*	-0.148	-0.346	-0.216*
EC	-0.114	0.210	0.512	0.253
BD	0.148	0.194	-0.521**	-0.510
PD	0.078	0.034	-0.042	-0.172
WHC	-0.157	0.065	0.333	0.031*
OC	-0.153	-0.143	0.225	0.209

** Significant at 1 % level.

* Significant at 5 % level.

Table 4.5.1 : Correlation between physico-chemical properties and available nutrients in soil of normal cultivated area of Balaghat and Malajkhand blocks:

	N	P	K	S
pH	0.104	0.008	0.324	-0.126**
EC	0.662	0.535	0.714	0.543*
BD	0.367	0.091	0.165**	0.007
PD	0.011	-0.008	0.006	0.132
WHC	-0.058	-0.073	-0.121*	-0.016*
OC	-0.063	-0.392	-0.089	0.165

**Significant at 1% level.

*Significant at 5% level.

Table 4.6 : Fertility map of Balaghat and Malajkhand blocks of Balaghat district

Balaghat Block			Malajkhand Block		
S.No.	Name of village	No. on map	S.No.	Name of village	No. on map
1	Hirapur	5	10	Shitalpani	4
2	Tawejhari	2	11	Bhanderi	1
3	Khairi	7	12	Rupjhar	6
4	Dhapewada	9	13	Palehara	3
5	Bharweli	4	14	Godaritola	5
6	Awlajhari	1	15	Chakerwahi	2
7	Kumhari	8			
8	Manjhara	3			
9	Bhatera	6			



Summary and Conclusion

The present experiment entitled “Characterization of soil quality parameters of Balaghat and Malajkhand blocks in Balaghat district of Madhya Pradesh”. The study was carried out during winter season 2021. The present investigation was carried out for the analysis of available macronutrients (N, P, K and S) and physicochemical properties of Farmer’s field. Altogether, 75 surface soil samples (0-15 cm) were collected before sowing of Rabi season crop in the month of November 2021. The soil samples were processed and analyzed for its physicochemical properties (pH, EC, organic carbon, WHC, porosity, BD and PD) in the laboratory. An effort has been made to create a soil fertility map of the area, to investigate the correlations between important soil characteristics and important nutrients, and to compare the disparities in nutrient status between areas near mines and away from mines.

Overall, the outcome of the study with the various findings are summarized and concluded as follows:

5.1 STATUS OF PHYSICAL PROPERTIES OF SOIL

- ❖ The bulk density of the soil sample in the Balaghat and Malajkhand block of Balaghat district ranged from 1.270 - 1.480 g cm⁻³ for Mining area and 1.200 - 1.350 g cm⁻³ for normal cultivated area away from mines, with a mean of 1.38 g cm⁻³ for mining area and 1.270 g cm⁻³ for away from mining area. Overall, normal range of Bulk density for all the samples of both the areas were found.

- ❖ The particle density of soil sample was varied from 1.536-2.583 g cm⁻³ for mining area and 1.733-2.816 g cm⁻³ for area away from mines, with the mean value of 2.098 g cm⁻³ for mining area and 1.984 g cm⁻³ for area away from the mines.
- ❖ The porosity of the sample in Balaghat and Malajkhand block of the Balaghat district ranged from 40.61-63.28 % with the mean value of 54.98% for mining area and for the normal cultivated area it ranged from 45.30-70.21% with the mean value 61.15%. It was found that the soils of Balaghat and malajkhand had maximum pore space.
- ❖ Water holding capacity ranged from 57.74-89.61% and 46.52-82.98%, respectively. The mean value for mining area and normal cultivated area were 67.52% and 69.23%, a standard deviation of 7.94 and 6.91, and a coefficient variation were 11.75% and 9.98%, respectively.

5.2 STATUS OF CHEMICAL PROPERTIES OF SOIL

- ❖ The soil pH of mining area and normal cultivated area ranged from 6.9-8.3 and 7.1-8.2, respectively. With a mean value of 7.59 and 7.57 for both mining and normal cultivated area, respectively. The pH of the soil is neutral to slightly alkaline for both the sites. It was found that a majority of soil samples (48 percent) were in the neutral reaction range and the remaining 52 percent samples (Table: 4.1.5) were in the slightly alkaline reaction range.
- ❖ The soil EC of the study regions as area near mines and cultivated area away from the mines was found to vary from 0.12-0.68 dSm⁻¹ and 0.13-0.69 dSm⁻¹ with a mean value of 0.34 dSm⁻¹ and 0.41 dSm⁻¹, respectively. Result concluded that EC was relatively low within a very narrow range, that was suitable for growing any crop. All the soil samples (100%) were low in EC.
- ❖ An organic carbon content that ranged from 0.10-1.67% in area near mines and 0.17-2.33% in cultivated areas away from mines, with a mean value of 0.82% and 0.97 respectively. Majority of samples were high in organic carbon

as 61.33% of samples were recorded high OC, 16% samples were medium in category and 22.6% were in low category.

5.3 STATUS OF MAJOR NUTRIENTS (N, P, K, S) IN SOIL

- ❖ Soil available N status was observed to range from 87.81-275.97 kg ha⁻¹ for cultivated area near mines and 75.26-388.86 kg ha⁻¹ in cultivated area away from mines with a mean value of 146.12 kg ha⁻¹ for area near mines and 199.38 kg ha⁻¹ in area away from mines. Maximum number of samples were categorized in low category (90.66%), and 9.33% of samples were in medium category. No samples were high in Nitrogen level.
- ❖ Phosphorus status was observed to range from 10.12-20.64 kg ha⁻¹ for cultivated area near mines and 11.89-20.99 kg ha⁻¹ in cultivated area away from mines with a mean value of 13.95 kg ha⁻¹ for area near mines and 16.17 kg ha⁻¹ in area away from mines. 20% of samples were classified under low category and 80% were in medium category. No sample came under high category.
- ❖ The soil's available K content ranged 112-306.88 kg ha⁻¹ for cultivated area near mines and 166.88-378.56 kg ha⁻¹ in cultivated area away from mines with a mean value of 204.17 kg ha⁻¹ for area near mines and 267.92 kg ha⁻¹ in area away from mines. The study area's soil samples were found to have medium to high potassium availability level. Overall experiment proved that the 5.33% of soil sample were low in potash, 89.33% were medium and 5.33% were high in potash.
- ❖ Sulphur content of the study area found to be ranging from 1.11-9.36 mg kg⁻¹ for cultivated area near mines and 2.51-13.43 mg kg⁻¹ in cultivated area away from mines with a mean value of 3.83 mg kg⁻¹ for area near mines and 8.34 mg kg⁻¹ in area away from mines. Out of 75 samples analyzed 88% were found in low, 12% samples in medium and not a single sample reported in sufficient rating classes.

- ❖ The Nutrient value index for soil of Balaghat and Malajkhand blocks was “Medium” for Phosphorous and Potassium and “Low” for Nitrogen and Sulphur. The nutrient index values of Nitrogen, phosphorus, potassium and Sulphur were reported as 1.09, 1.8, 1.99 and 1.12, respectively.
- ❖ When cultivated areas near mines and areas away from mines were compared, it was found that there was not a significant difference in the pH of the two areas, and that there was only a slight difference in the EC, P.D., and B.D. values from the mining area and away from mining area. The water holding capacity was also almost in the same range for both areas. All of the N, P, K, and S values are marginally higher in the area far from mines than in the area close to mines.
- ❖ Correlation study for the mining area displayed that pH had negative correlation with N, P, K and S in the soil. EC was positively correlated with Phosphorus, Potash, Sulphur and negatively correlated with Nitrogen. Bulk Density and Particle Density showed positively correlation with Nitrogen and Phosphorus, and negative correlation with Potash and Sulphur. Water holding capacity had positive correlation with Phosphorus, Potash, Sulphur and negatively correlated with Nitrogen. Organic Carbon had negative relation with Nitrogen and Phosphorus, positive correlation with Potash and Sulphur.
- ❖ Correlation study for normal cultivated area away from mines revealed that pH had positive correlation with N, P, K and negative correlation with S. EC and BD had significant positive correlation with N, P, K and S. Particle Density was positively correlated with N, K and S and negatively correlated with P. Water holding capacity had negative correlation with Nitrogen, Phosphorus, Potash and Sulphur. Organic carbon had negative correlation with Nitrogen, Phosphorus and Potash and positive correlation with Sulphur.

CONCLUSION

It can be concluded from the above results that the soils of Balaghat and Malajkhand block of Balaghat district are classified as neutral to alkaline in terms of soil reactivity (pH), and all soils with soluble salt contents that are less than one dS m^{-1} which were considered safe for the plant growth. The level of the organic carbon was found medium to high. Out of a total 75 soil samples, the available Nitrogen was found low, Phosphorus was low to medium, Potassium was medium, and Sulphur was low in range. Water holding capacity was observed medium to high in both the area. Bulk density and Particle density were also observed in normal range. The soil was observed Nitrogen and Phosphorus deficient. To correct this, farmer should add composed manure, grow more Nitrogen fixing plants and N boosting fertilizers. For phosphorus, apply correct ratio of fertilizer i.e., bone meal.



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Appendices

APPENDIX – 1

S.No.	Sample no.	pH	EC dSm ⁻¹	Bulk density g cm ⁻³	Particle density g cm ⁻³	Porosity (%)	WHC (%)
1	M1S1	7.6	0.25	1.28	1.98	51.93	69.98
2	M1S2	8.0	0.21	1.31	1.54	44.21	62.30
3	M1S3	8.2	0.32	1.33	2.39	57.36	66.86
4	M1S4	7.9	0.24	1.29	1.81	47.27	68.82
5	M1S5	7.6	0.19	1.3	2.31	55.07	64.38
6	M1S6	7.2	0.2	1.28	2.20	54.28	53.13
7	M1S7	7.8	0.22	1.34	2.06	51.50	46.52
8	M1S8	7.6	0.12	1.36	1.81	56.81	70.19
9	M1S9	8.1	0.26	1.38	1.81	57.94	61.86
10	M1S10	8.0	0.28	1.32	2.13	54.18	82.98
11	M1S11	8.3	0.29	1.35	2.54	59.65	75.92
12	M1S12	7.1	0.31	1.39	1.85	55.88	71.72
13	M1S13	7.0	0.34	1.31	2.56	60.77	50.14
14	M1S14	7.9	0.35	1.4	1.81	56.15	62.90
15	M1S15	7.7	0.36	1.46	1.98	54.76	63.79
16	M1S16	7.2	0.26	1.44	2.16	53.46	63.34
17	M1S17	7.5	0.24	1.42	2.43	58.41	73.36
18	M1S18	7.6	0.28	1.45	2.21	55.92	66.31
19	M1S19	7.9	0.32	1.43	2.02	56.15	65.74
20	M1S20	7.3	0.36	1.47	1.74	54.86	75.85
21	M1S21	7.4	0.38	1.41	2.36	63.28	77.39
22	M1S22	7.1	0.4	1.46	2.25	58.75	82.36
23	M1S23	7.5	0.46	1.38	1.97	61.16	66.66

S.No.	Sample no.	pH	EC dSm ⁻¹	Bulk density g cm ⁻³	Particle density g cm ⁻³	Porosity (%)	WHC (%)
24	M1S24	8.0	0.48	1.27	1.92	60.43	71.75
25	M1S25	7.2	0.66	1.3	2.10	60.02	74.22
26	M2S1	8.1	0.21	1.33	2.16	51.17	67.41
27	M2S2	7.9	0.19	1.35	2.58	57.51	51.79
28	M2S3	7.5	0.23	1.37	2.11	48.77	75.90
29	M2S4	7.7	0.24	1.31	2.16	59.68	72.90
30	M2S5	7.8	0.28	1.45	1.77	47.94	60.54
31	M2S6	7.4	0.32	1.48	2.06	46.67	68.06
32	M2S7	7.2	0.41	1.44	2.30	57.07	69.32
33	M2S8	7.7	0.56	1.46	2.51	62.43	66.91
34	M2S9	7.6	0.59	1.42	2.14	54.84	72.47
35	M2S10	7.1	0.61	1.39	2.08	47.78	68.83
36	M2S11	6.9	0.66	1.41	1.77	40.61	67.41
37	M2S12	7.3	0.68	1.46	2.05	59.68	68.27
	Mean	7.59	0.34	1.38	2.10	54.98	67.52
	SD	0.36	0.15	0.06	0.25	5.22	7.94
	Range	6.9-8.3	0.12-0.68	1.27-1.48	1.54-2.58	40.61-63.28	46.52-82.98
	CV%	4.76	42.31	4.60	12.06	9.49	11.75

APPENDIX – 2

S.no.	Sample no.	pH	EC dSm⁻¹	Bulk density g cm⁻³	Particle density g cm⁻³	Porosity (%)	WHC (%)
38	C1S1	7.3	0.14	1.22	1.79	52.32	65.07
39	C1S2	7.2	0.19	1.24	2.17	60.44	69.27
40	C1S3	7.5	0.23	1.28	2.10	63.59	89.61
41	C1S4	7.6	0.27	1.23	2.15	60.85	75.69
42	C1S5	7.4	0.34	1.2	1.73	58.40	66.99
43	C1S6	7.8	0.37	1.27	2.44	69.82	65.13
44	C1S7	8.2	0.42	1.3	2.07	61.30	62.81
45	C1S8	8	0.46	1.28	2.25	64.57	66.68
46	C1S9	7.9	0.45	1.31	1.81	58.58	60.41
47	C1S10	7.1	0.53	1.25	2.75	69.94	79.47
48	C1S11	7.4	0.55	1.2	2.22	55.95	62.82
49	C1S12	7.5	0.59	1.23	2.66	63.83	66.20
50	C1S13	7.7	0.51	1.33	1.77	48.28	89.36
51	C1S14	7.3	0.48	1.32	2.05	59.77	68.32
52	C1S15	8.1	0.53	1.29	1.84	58.71	72.70
53	C1S16	7.1	0.58	1.28	2.01	56.18	57.74
54	C1S17	7.3	0.67	1.34	1.89	60.91	67.66
55	C1S18	7.4	0.69	1.32	2.66	65.26	65.12
56	C1S19	7.7	0.54	1.26	2.35	65.02	59.21
57	C1S20	7.8	0.47	1.35	2.27	52.02	70.56
58	C1S21	8.2	0.49	1.27	1.99	60.59	64.16
59	C1S22	8.1	0.5	1.24	1.98	57.66	68.79
60	C1S23	7.9	0.52	1.22	1.81	51.79	70.71
61	C1S24	7.6	0.61	1.25	2.44	61.23	71.33
62	C1S25	7.5	0.66	1.31	2.17	58.46	65.21
63	C2S1	7.5	0.13	1.34	2.09	53.83	59.01
64	C2S2	7.6	0.18	1.33	1.81	45.31	72.40

S.no.	Sample no.	pH	EC dSm⁻¹	Bulk density g cm⁻³	Particle density g cm⁻³	Porosity (%)	WHC (%)
65	C2S3	7.5	0.26	1.28	2.06	56.16	69.00
66	C2S4	7.7	0.28	1.24	2.26	62.65	70.06
67	C2S5	7.4	0.2	1.27	2.62	69.21	69.53
68	C2S6	7.6	0.32	1.29	2.82	70.22	72.84
69	C2S7	7.3	0.37	1.21	1.97	61.29	72.64
70	C2S8	7.4	0.39	1.25	1.92	60.01	77.33
71	C2S9	7.2	0.42	1.27	2.03	58.87	78.11
72	C2S10	7.5	0.43	1.32	2.25	66.48	68.92
73	C2S11	7.7	0.36	1.28	2.62	66.92	68.55
74	C2S12	7.6	0.32	1.24	2.12	56.70	63.72
75	C2S13	7.4	0.44	1.27	1.98	61.15	67.67
	Mean	7.58	0.42	1.27	1.98	61.15	69.23
	SD	0.29	0.15	0.04	0.29	5.72	6.91
	Range	7.1-8.2	0.13-0.69	1.20-1.35	1.73-2.82	45.31-70.22	57.74-89.61
	CV%	3.79	35.53	3.19	14.66	9.36	9.98

APPENDIX – 3

S.no.	Sample no.	Organic carbon (%)	Nitrogen kg ha ⁻¹	Phosphorus kg ha ⁻¹	Potassium kg ha ⁻¹	Sulphur mg kg ⁻¹
1	M1S1	0.18	137.98	13.90	112.00	3.07
2	M1S2	0.70	112.90	16.21	127.68	2.16
3	M1S3	0.45	87.81	20.64	154.56	1.25
4	M1S4	1.37	175.62	11.13	165.76	1.16
5	M1S5	0.62	213.25	14.15	170.24	1.21
6	M1S6	0.22	238.34	13.76	174.72	1.89
7	M1S7	0.83	150.53	11.19	196.00	2.91
8	M1S8	1.56	137.98	12.74	200.48	6.87
9	M1S9	0.15	188.16	13.26	204.96	3.97
10	M1S10	1.50	150.53	13.86	178.08	2.23
11	M1S11	0.50	100.35	12.33	210.56	2.81
12	M1S12	0.98	112.90	12.46	198.24	3.12
13	M1S13	1.14	175.62	13.28	208.32	6.20
14	M1S14	0.74	100.35	11.97	218.40	3.73
15	M1S15	1.07	87.81	12.04	221.76	4.03
16	M1S16	0.70	137.98	15.27	203.84	2.07
17	M1S17	1.10	100.35	14.03	225.12	2.12
18	M1S18	0.45	100.35	13.30	231.84	3.83
19	M1S19	0.92	137.98	16.16	234.08	2.42
20	M1S20	0.85	150.53	14.84	285.60	4.18
21	M1S21	1.02	175.62	11.24	303.52	5.96
22	M1S22	0.97	87.81	19.16	276.64	6.09
23	M1S23	1.22	125.44	11.96	306.88	8.06
24	M1S24	1.14	100.35	13.21	282.24	7.53
25	M1S25	1.07	225.79	12.27	287.84	5.24
26	M2S1	1.29	163.07	10.59	116.48	2.73

S.no.	Sample no.	Organic carbon (%)	Nitrogen kg ha ⁻¹	Phosphorus kg ha ⁻¹	Potassium kg ha ⁻¹	Sulphur mg kg ⁻¹
27	M2S2	1.14	150.53	15.49	122.08	3.50
28	M2S3	0.10	137.98	10.12	163.52	3.16
29	M2S4	0.55	225.79	13.29	166.88	4.03
30	M2S5	0.86	150.53	14.24	176.96	9.36
31	M2S6	0.52	275.97	15.36	187.04	1.57
32	M2S7	0.62	87.81	15.90	189.28	5.87
33	M2S8	0.85	163.07	12.29	199.36	2.93
34	M2S9	0.33	188.16	17.72	204.96	1.11
35	M2S10	1.68	137.98	13.84	209.44	1.60
36	M2S11	1.14	100.35	19.09	212.80	5.24
37	M2S12	0.36	112.90	13.69	226.24	6.39
	Mean	0.83	146.12	13.95	204.17	3.83
	SD	0.40	46.41	2.37	48.91	2.10
	Range	0.10-1.68	87.81-275.97	10.12-20.64	112-306.88	1.11-9.36
	CV (%)	48.18	31.76	17.00	23.95	54.74

APPENDIX – 4

S.no.	Sample no.	Organic carbon (%)	Nitrogen kg ha⁻¹	Phosphorus kg ha⁻¹	Potassium kg ha⁻¹	Sulphur mg kg⁻¹
38	C1S1	0.77	87.81	14.48	201.60	7.82
39	C1S2	0.40	175.62	13.29	226.24	8.22
40	C1S3	1.54	175.62	13.21	232.96	8.42
41	C1S4	0.18	137.98	14.24	265.44	2.80
42	C1S5	0.62	150.53	15.60	286.72	5.10
43	C1S6	1.00	137.98	15.58	221.76	5.06
44	C1S7	1.96	112.90	11.89	290.08	5.92
45	C1S8	0.25	137.98	14.37	302.40	6.80
46	C1S9	0.77	175.62	14.74	274.40	7.99
47	C1S10	1.59	213.25	13.16	306.88	8.51
48	C1S11	0.30	225.79	14.95	294.56	10.07
49	C1S12	0.52	250.88	18.95	318.08	8.34
50	C1S13	1.00	213.25	18.58	323.68	8.46
51	C1S14	0.18	150.53	19.72	318.08	11.32
52	C1S15	0.48	200.70	20.33	269.92	9.91
53	C1S16	0.70	263.42	20.19	287.84	9.44
54	C1S17	1.22	288.51	20.99	250.88	10.95
55	C1S18	0.19	301.06	20.66	311.36	11.49
56	C1S19	1.29	351.23	19.72	347.20	8.88
57	C1S20	1.04	376.32	19.17	378.56	11.41
58	C1S21	0.70	213.25	17.98	362.88	8.51
59	C1S22	1.59	313.60	17.17	336.00	8.18
60	C1S23	0.77	388.86	17.60	285.60	8.91
61	C1S24	0.33	301.06	17.42	299.04	9.27
62	C1S25	1.14	225.79	15.45	302.40	9.03
63	C2S1	1.37	150.53	13.79	166.88	2.51

S.no.	Sample no.	Organic carbon (%)	Nitrogen kg ha⁻¹	Phosphorus kg ha⁻¹	Potassium kg ha⁻¹	Sulphur mg kg⁻¹
64	C2S2	0.62	200.70	16.36	187.04	3.38
65	C2S3	1.44	100.35	13.73	201.60	4.19
66	C2S4	0.85	87.81	12.00	200.48	6.29
67	C2S5	1.22	75.26	18.12	166.88	6.55
68	C2S6	1.59	112.90	17.75	193.76	7.98
69	C2S7	0.70	150.53	17.42	206.08	8.25
70	C2S8	0.33	137.98	18.49	218.40	8.59
71	C2S9	0.89	250.88	12.87	228.48	8.82
72	C2S10	2.03	225.79	12.27	259.84	11.00
73	C2S11	2.33	188.16	14.31	252.00	12.71
74	C2S12	1.81	175.62	13.07	291.20	12.36
75	C2S13	1.44	150.53	14.90	313.60	13.43
	Mean	0.98	199.38	16.17	267.92	8.34
	SD	0.56	79.22	2.69	54.13	2.60
	Range	0.18-2.33	75.26-388.86	11.89-20.99	166.88-378.56	2.51-13.43
	CV%	57.59	39.73	16.62	20.20	31.14

