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# Investigation of physical and chemical parameters of agricultural soil samples from lakhani tehsil of bhandara district in maharashtra, central India

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**Abstract**
The study focused on assessing soil fertility in the Vidarbha agroclimatic zone of Lakhani tehsil of Bhandara district, Maharashtra, to guide soil resource management in an area experiencing rapid urbanization and industrialization. In 2024, composite soil samples were collected from agricultural fields in 8 villages using GPS. The soil texture classification was clay, sandy clay loam and sandy loam. Key physicochemical properties, including pH, Cation Exchange Capacity (CEC), Electrical Conductivity (EC), Calcium Carbonate, Organic Carbon content, primary nutrients (Nitrogen, Phosphorous, Potassium) and exchangeable cations (Sodium, Potassium, Calcium, Magnesium) were analysed. This investigation was attempted to know the correlation of soil organic carbon and nutrients (N, P, K) to soil minerology, texture aggregation and land use pattern. The study's findings provide a detailed overview of the soil's nutrient status, which can help formulate effective nutrient management strategies. These strategies are crucial for sustaining agricultural productivity, supporting sustainable development, and preserving natural resources in the region.

**Keywords:** Physicochemical analysis, soil sampling, lakhani, bhandara, wainganga river basin

## Introduction

Soil is the critical component of the earth system, functioning not only for the production of food, fodder and fibre but also in the maintenance of local, regional and global environmental quality. Soil samples are often taken to provide an estimate of nutrient availability for crop growth and soil may also be analysed for pH, soil texture and presence of different nutrients. The amount of N, P and K required as fertiliser is dependent on the availability of these elements in the soil, and analysis may also indicate a requirement for other minor elements. In contrast, the content of organic matter affects the mineralization of Nitrogen, but Nitrogen content varies with date of sampling, and a practical, predictive relation with N requirement has not been demonstrated.

Soil texture, which is the relative proportion of sand, silt and clay, is considered a permanent and natural attribute of a given soil [1]. However, over time soil texture can change as primary minerals are weathered into secondary minerals, and with the translocation or deposition of particles [2].

Soil pH is a crucial property that plays a significant role in the functionality of soils, including nutrient availability [3, 29], microbial activity [4, 6]. and plant growth [7, 8]. Moreover, pH levels are an important indicator of soil contamination, because these processes are closely related to soil acidity[9-10].

Soil pH determines the acidity or alkalinity of the soil, which influences nutrient availability for plants. In highly acidic soils (pH below 6), elements like aluminium and manganese can become toxic to crops, while essential nutrients like calcium, phosphorus, iron, zinc and magnesium are less available. In highly alkaline soils (pH above 7.5), phosphorus and many like iron, zinc and manganese are less accessible to plants. A pH range of 6.0 to 7.5 is ideal for most crops as the availability of most plant nutrients is highest in this pH range [24]. Regarding organic matter, it decomposes and releases nitrogen more rapidly in warm, humid climates. This nitrogen release is faster in well-aerated soils and slower in wet, saturated soils.

Soil plays a crucial role in supporting crops that provide food and clothing for the world. The fertility of soil is vital for its productivity. Several external factors influence plant growth, including air, temperature, light, mechanical support, nutrients, and water. Plants rely on various essential elements for growth and completing their life cycle, such as carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, and exchangeable Sodium, Potassium, Calcium, Magnesium ions to determine the availability of nutrients (N, P, K) against pH content in soil.

Soil sampling is a comprehensive process that requires careful planning and interpretation to maximize its usefulness. The presence of macro and micronutrients determines the soil fertility as it is the inherent ability of soil to supply nutrients in plants [11]. Soil sampling is perhaps the most vital is step for any soil analysis. It is a dynamic natural body developed as a result of paedogenic processes during weathering of rocks [12].

Soil analysis is crucial in organic farming for several reasons: it helps with nutrient management (like planning crop rotations, optimizing manure use, and applying fertilizers), prevents long-term nutritional and health issues for both crops and livestock, reduces pollution risks etc. For nutrient analysis, soil in the top 30 cm is usually sampled from several points in each field and sub-sampled to provide a single composite sample for analysis. Texture analysis of the soil to a depth of a metre or more may be carried out to determine the water holding capacity of the soil for irrigation scheduling in addition to determining characteristics of the topsoil which have wider importance.

The amount of nutrients needed for crop production is influenced by the current nutrient content in the soil. Fertilizer recommendations are often based on Soil Test Recommendations (STR), where the major nutrients (Nitrogen, Phosphorus, and Potassium) are analysed using standard methods before sowing. The results indicate whether the soil has high, medium, or low nutrient levels. Based on this, the required nutrients for the upcoming crop are calculated, and the appropriate amount of nutrients to add to the soil is recommended to optimize crop production [13, 14, 24].

There is limited research on soil analysis of Lakhani tehsil in Bhandara district. Effect of different organic sources available with farmers on Paddy (Oryza Sativa L.) in Bhandara district of Maharashtra was reported by Dongarwar et. al. [15]. The study conducted by Sumedh R Kashiwar, Manik Chandra Kundu, and Usha R Dongarwar [16]. between 2015-2018, focused on mapping macro and micronutrients using GPS-GIS technology.

The present study attempts to find out the soil analysis of Lakhani taluk of Bhandara district in Maharashtra. This soil quality survey was conducted in 2023-24. A representative soil sample collected from each village which represent soils of 5 to 10 farms depending upon area of village. Soil samples from 8 villages in the Lakhani block were collected at a depth of 0-15 cm using Khurpi for analysis. The soil samples were collected in polythene bags using standard quadric procedure. In the laboratory, these samples were analysed for different chemical properties following standard methods [17, 25]. For soil analysis, analytical grade reagents and double distilled water were used. Results obtained were compared with standard values to determine the nutrients content of the soil [18].

## Materials and Methods

### 1. Geographical information about the study area

Lakhani tehsil of Bhandara district in Maharashtra falls entirely in the Wainganga River basin and is located in the Vidarbha region of Maharashtra. The terrain of the district is generally flat. Lakhani tehsil is located in north deccan Maharashtra lower plateau in 'Wainganga' sub-basin of 'Godawari' basin. It is bounded by North latitude 21.0736° and East longitude 79.8297°. The region experiences a hot, moist sub-humid climate with moderate winters, harsh summers, and monsoon rainfall (June to September), ranging from 1250 to 1500 mm annually. Wainganga river flows from North to South in the Western part of the tehsil. It forms a major drainage system having the lower elevation ranging from 240 to 280 above MSL whereas, the higher elevation ranging from 350 to 500 above MSL.

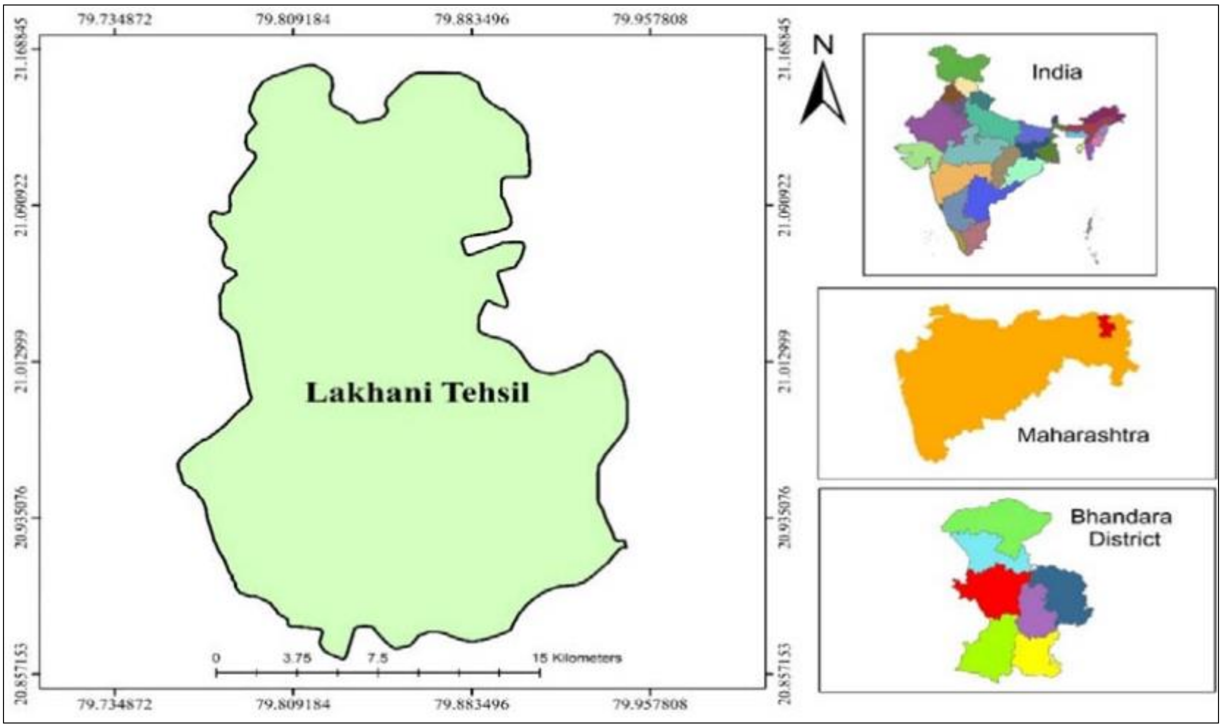


**Fig 1:** Map of Lakhani Tehsil of Bhandara district in Maharashtra

### 2. Physical characteristics of soil in the study area

The study area is characterized by rich alluvial soils, which are widely spread across the region. These soils have a sandy-clay-loamy texture and are very deep. They are also sticky and have high moisture retention capacity, making them suitable for supporting plant growth. The particle size distribution shows that majority of the soils in the study area have high amount of clay. Soils developed on shallow weathered pediments, moderately weathered pediments, deeply weathered pediments and aggraded valley fills have high clay content (up to 50 %).

### 3. Methods

The present study deals with the analysis of 8 composite soil samples which were collected in year 2024 from 8 different villages in Lakhani tehsil of Bhandara District. Soil was collected using a spade or khurpi [19]. and for sampling V shaped holes were dug for collecting a uniform 2 cm thick slice of soil up to a depth of 0-30 cm, which were collected in a plastic bucket. Samples collected [27]. were thoroughly mixed by rolling and turning on a piece of clean cloth, air dried in shade and the soil clods were crushed using wooden pestle and mortar [20]. Then the entire quantity of soil sample was sieved through 2mm stainless steel sieve. After sieving, the remaining coarse material was re-crushed and re-sieved. The remaining stones and organic residues were discarded. Total 8 composite soil samples were collected in clean polythene bags and brought to the Laboratory.

pH was measured using pH meter, Electrical Conductivity was measured using a conductivity meter and normally expressed in dSm [1]. which indicated amount of soluble salt present in the soil. Organic Carbon was measured using Walkley and Black rapid titration method [21], available Potassium was measured using Flame photometer, available phosphorous was estimated through spectrophotometer, available nitrogen is estimated by Kjeldahl's method [22], Exchangeable cations [26]. (Calcium and Magnesium was measured using EDTA complexometric titration method (from ammonium acetate extract of soil). At pH 10, all exchangeable Calcium and Magnesium form complex with Versene to a bright blue end point in the presence of Eriochrome Black-T indicator. At pH 12, Calcium alone complexes with Versene in the presence of Murexide indicator. The orange-red colour that initially formed, turns finally into red-violet coloured end point. The amount of Magnesium can be determined by calculating the difference between first and second titrations. Exchangeable Sodium and Potassium was determined by Flame photometer. Percent Calcium Carbonate was measured by Acid Neutralization method which is a rapid titration method [23]. The standard protocols [27, 28], as described below were followed for soil sample analysis in the laboratory

***soil pH*:** Soil pH was determined by the method described by Mclean (1983).

***Bulk density(gcm$^{-1}$)*:** The bulk density of soil was determined by using the core method as given by the following formula -

Dry mass(gm) of soil

B.D. (gcm$^{-1}$) =

Total volume (cm$^3$) of soil

***Soil texture*:** The distribution of different sized particles was determined by mechanical analysis (USDA System).

## Results and Discussion

Soil testing is considered as a useful tool for identifying the causes of nutrient related plant growth problems and is beneficial to know the concentrations of various parameters present in soil samples. Present study is an attempt to find out the nutrient quantity of the soil in Lakhani tehsil of Maharashtra state. This study of chemical and morphological parameters of composite soil samples showed differing values at different places of the study area, which may be due to the irregular distribution of different parameters present in soil (Table 1 and 2). The interpretation of analytical data for the 8 village soil samples is discussed below

### 1. Soils of Bandrazari

The soils are having clay loamy textural family. These soils are non-calcareous & are non-saline in nature, slightly alkaline in reaction (6.84) and are low in organic carbon content 0.11 %. Clay complex is dominated by $Ca^{++}$ followed by $Mg^{++}$ and indicating very high CEC (36.10 C mol (+)/ kg soil). These soils are moderately well drained with less permeability. These soils are mostly sticky type when wet, and very hard when it became dry. It has low permeability and therefore the bulk density of those soils is usually high (1.29 Mg m) due to its shrink when it dr

These soils are medium in available nitrogen (304.56 kg ha$^{-1}$) and very high in available potassium (663.33 kg ha$^{-1}$) due to presence of montmorillonite group of clay mineral. High CEC indicates greater number of total exchangeable cations leads to higher fertility status of soil.

### 2. Soils of Bhugaon

The Bhugaon soil series is characterized by shallow soil depth, found on very gentle to gentle slope lands, and experiencing moderate erosion. These soils belong to the course loamy textural family and are non-calcareous and non-saline. The soil has a slightly acidic reaction with a pH of 5.18 and a medium organic carbon content (0.51%). The clay complex is primarily composed of calcium ($Ca^{2+}$) followed by magnesium ($Mg^{2+}$), indicating a medium cation exchange capacity (CEC) of 16.40 Cmol (+)/kg soil. The soils are well-drained with rapid permeability.

The soils are low in available nitrogen (215.73 kg ha-1) but high in available potassium (425.88 kg ha-1) due to the presence of a mixed group of clay minerals. The medium cation exchange capacity (CEC) suggests a moderate fertility status, as it indicates a greater number of exchangeable cations. The moderate CEC and percent base saturation (PBS) values point to the medium inherent fertility of the soil.

### 3. Soils of Chichtola

This soil is non-calcareous, low in organic carbon (0.27 %), non-saline, slightly acidic in reaction (pH 5.22). The exchangeable cations $Na^+$, $K^+$, $Ca^{++}$, $Mg^{2+}$ are 0.24, 0.81, 2.50, 1.25 C mol Kg$^{-1}$ respectively in this soil. Exchangeable sodium percentage is low and known to be slightly hazardous for most of the crops. The cation exchange capacity of soil is 7.67 C mol Kg$^{-1}$. These soils have high available nitrogen (207.27 kg ha$^{-1}$) as well as high available potassium (221.13 kg ha$^{-1}$).

### 4. Soils of Kesalwada

The Kesalwada soil is characterized by very deep soil depth, found on very gentle slope lands, and experiencing moderate erosion. These soils belong to the course loamy textural family and are non-calcareous and non-saline. They have a slightly acidic pH (6.26) and show low to medium organic carbon content (0.12%). The cation exchange capacity (CEC) is medium (12.04 C mol (+)/kg soil). These soils are moderately well-drained with moderately slow permeability, which affects their water movement and retention. These soils have medium levels of available nitrogen (334.17 kg ha-1) and available potassium (412.23 kg ha-1). The medium cation exchange capacity (CEC) indicates a moderate number of exchangeable cations, suggesting moderate fertility. The medium values of CEC show that these loamy soils can be easily managed for cultivation with appropriate practices. Adding organic matter will improve the soil structure, enhance fertility, and support better soil function. Proper nutrient management can further boost soil fertility and organic matter content.

### 5. Soils of Morgaon

This soil is non-calcareous, low in organic carbon (0.15%), non-saline, slightly aidic in reaction (pH 5.64). The exchangeable cations $Na^+$, $K^+$, $Ca^{++}$, $Mg^{++}$ are 0.13, 0.08, 7.5, 4.0 C mol ($P^+$) $Kg^{-1}$ respectively in this soil. This soil shows high value of available nitrogen (258.03 kg $ha^{-1}$) and available potassium is also medium (270.27 kg $ha^{-1}$).

### 6. Soils of Murmadi

This soil is non-calcareous, medium in organic carbon (0.61%), non-saline, slightly acidic in reaction (pH 5.63). The exchangeable cations $Na^+$, $K^+$, $Ca^{++}$, $Mg^{++}$ is 0.11, 0.06, 9.5, 5.0 C mol ($P^+$) $Kg^{-1}$ respectively. The cation exchange capacity of this soil is 25.80 C mol ($P^+$) $Kg^{-1}$. In these soils, the available nitrogen is low (213 kg $ha^{-1}$) and available potassium is medium (215 kg $ha^{-1}$).

### 7. Soils of Sindhiar

The soils are having Clay loamy textural family. These soils are non-calcareous & are non-saline in nature, slightly acidic in reaction (5.90) and are low in organic carbon content (0.22%), CEC (12.40 Cmol (+)/ kg soil). These soils are moderately well drained with moderately slow permeability. The exchangeable cations $Na^+$, $K^+$, $Ca^{++}$, $Mg^{++}$ is 0.43, 1.01, 4.25, 2.50 C mol ($P^+$) $Kg^{-1}$ respectively available in this soil. These soils are low in available nitrogen (198.81 kg $ha^{-1}$) and medium in available potassium (275.73 kg $ha^{-1}$). Medium CEC indicates that lesser number of total exchangeable cations leads to moderate fertility status of soil and it also indicate that the loamy soil can easily be managed for cultivation with proper management practices and addition of organics will be helpful. Nutrient management can help to improve the fertility of the soil and the amount of organic matter content, which improves soil structure and function.

### 8. Soils of Somalwada

The Somalwada soils belong to the fine loamy textural family and are non-calcareous and non-saline in nature. They have a neutral pH (6.96) and exhibit low organic carbon content (0.12 %). The cation exchange capacity (CEC) is high (25.70 Cmol (+)/kg soil). These soils are moderately well-drained, with moderately slow permeability, affecting the movement and retention of water. These soils have medium levels of available nitrogen (313.02 kg ha-1) and high levels of available potassium (521.43 kg ha-1). The medium cation exchange capacity (CEC) suggests a moderate number of exchangeable cations, leading to a moderate fertility status. The medium values of CEC indicate that these loamy soils can be easily managed for cultivation with proper management practices. Adding organic matter will improve soil structure, enhance fertility, and support better soil function. Proper nutrient management can further boost soil fertility and organic matter content.

**Table 1:** Chemical characteristics of soils in Lakhani Tehsil (Weighed means)

| Village Name | CEC Cmol (+)/kg | pH 1:2.5 ratio | EC $dSm^{-1}$ | % OC | % $CaCO_3$ | Available N $Kgha^{-1}$ | Available P $Kgha^{-1}$ | Available K $Kgha^{-1}$ | Exchangeable bases Cmol (+)/kg | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | $Ca^{2+}$ | $Mg^{2+}$ | $Na^+$ | $K^+$ |
| Bandrazari | 36.10 | 6.84 | 0.020 | 0.72 | 0 | 304.56 | 12.9 | 663.33 | 17.50 | 9.50 | 1.21 | 2.43 |
| Bhugaon | 16.40 | 5.18 | 0.009 | 0.51 | 0 | 215.73 | 9.14 | 425.88 | 5.75 | 3.50 | 0.49 | 1.56 |
| Chichtola | 7.61 | 5.31 | 0.011 | 0.49 | 0 | 207.27 | 9.58 | 221.13 | 2.75 | 1.25 | 0.24 | 0.81 |
| Kesalwada | 24.10 | 6.26 | 0.022 | 0.79 | 0 | 334.17 | 8.99 | 412.23 | 10.25 | 5.75 | 1.04 | 1.51 |
| Morgaon | 9.10 | 6.19 | 0.028 | 0.61 | 0 | 258.03 | 10.21 | 270.27 | 2.75 | 1.75 | 0.28 | 0.99 |
| Murmadi | 16.40 | 5.75 | 0.013 | 0.45 | 0 | 190.35 | 9.14 | 256.62 | 6.00 | 3.50 | 0.61 | 0.94 |
| Sindhipar | 12.40 | 5.90 | 0.011 | 0.47 | 0 | 198.81 | 7.86 | 275.73 | 4.25 | 2.50 | 0.43 | 1.01 |
| Somalwada | 25.70 | 6.96 | 0.017 | 0.74 | 0 | 313.02 | 10.42 | 521.43 | 10.25 | 5.75 | 1.24 | 1.91 |

**Table 2:** Physical characteristics of soils in Lakhani Tehsil

| Village Name | Soil texture | Clay % | Sand % | Silt % | Gravel | Bulk density |
|---|---|---|---|---|---|---|
| Bandrazari | Clay | 44 | 23 | 33 | 10.31 | 1.29 |
| Bhugaon | Sandy Clay loam | 27 | 47 | 26 | 13.61 | 1.31 |
| Chichtola | Sandy loam | 15 | 66 | 19 | 14.62 | 1.40 |
| Kesalwada | Clay loam | 34 | 31 | 35 | 13.14 | 1.52 |
| Morgaon | Loam | 19 | 51 | 30 | 13.20 | 1.26 |
| Murmadi | Sandy Clay loam | 24 | 51 | 25 | 13.84 | 1.16 |
| Sindhipar | Sandy Clay loam | 22 | 53 | 25 | 14.20 | 1.33 |
| Somalwada | Clay loam | 35 | 39 | 26 | 13.20 | 1.39 |

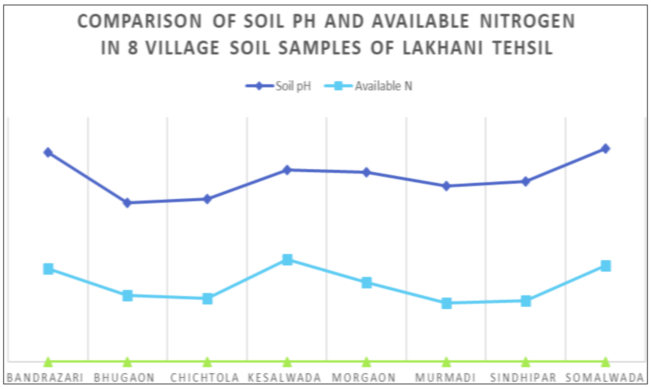


**Fig 2:** Comparison of Soil pH and available Nitrogen in 8 villages soil samples of Lakhani Tehsil

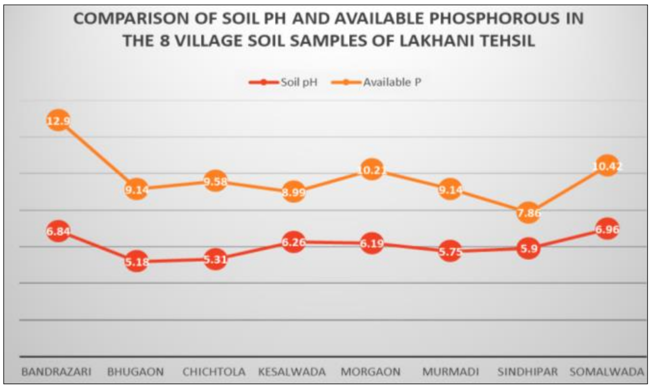


**Fig 3:** Comparison of Soil pH and available Phosphorous in 8 villages soil samples of Lakhani Tehsil

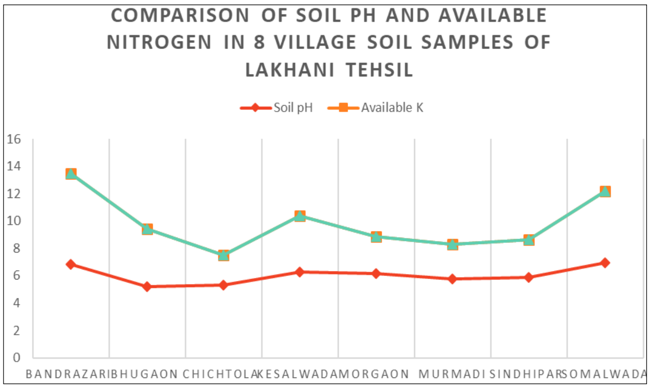


**Fig 4:** Comparison of Soil pH and available Potassium in 8 villages soil samples of Lakhani Tehsil

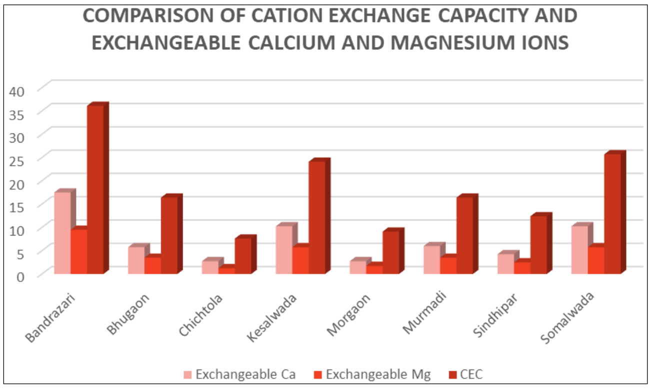


**Fig 5:** Comparison of CEC and Exchangeable Calcium and Magnesium in 8 villages soil samples of Lakhani Tehsil

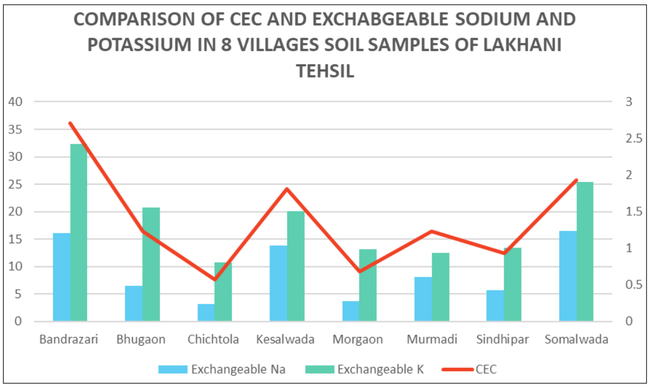


**Fig 6**: Comparison of CEC and Exchangeable Sodium and Potassium in 8 village soil samples of Lakhani Tehsil

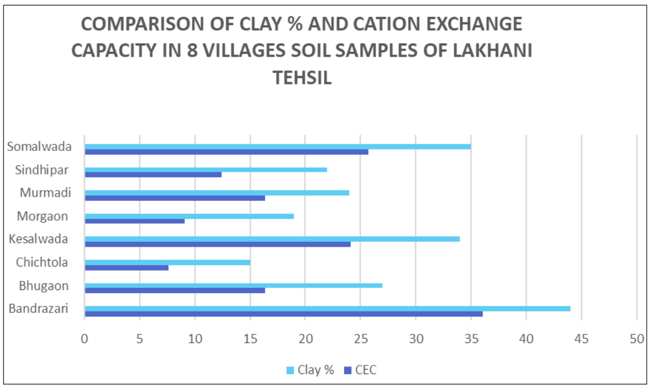


**Fig 7:** Comparison of Clay % and Cation Exchange Capacity in 8 villages soil samples of Lakhani Tehsil

## Conclusion

The research examined soil characteristics across 8 villages in Lakhani block of Bhandara district in Maharashtra. The results showed that the soils were primarily neutral to alkaline in nature, with most being non-saline. The organic carbon content was low in most of the soil samples. Additionally, the soil's nitrogen levels were deficient in the majority of the area, while phosphorus availability was moderate and potassium availability was high. The study found that most soil samples in the area were moderately well-drained with moderate permeability, and the soils are used for multiple cropping systems. Common crops include Paddy, Bengal gram, Green gram, Pigeon pea, and Grass pea. These soils have the potential for growing vegetables and fruit crops with proper management, particularly in terms of integrated nutrient and water management.

With low organic matter and available nitrogen, soil productivity is currently limited. The study recommends using organic fertilizer to improve physical conditions and drainage of soil. Also adopting smart agricultural practices such as crop rotation, organic compost application, mulching, and cover cropping to improve soil structure, increase organic carbon, and enhance available nitrogen, thus boosting crop productivity. The incorporation of green manure crops (e.g., legumes) would also boost yields and fertilizer efficiency.

The study assessed soil texture, nutrient levels, and their impact on crop yield in the area. The key findings are:

a. Soil texture ranged from clay to sandy clay loam, with a bulk density between 1.16 to 1.53 Mg $m^{-3}$.

b. The soil pH was mostly neutral, slightly acidic to slightly alkaline, with no salinity concerns.

c. Organic carbon levels were low, and the soil was non-calcareous.

d. Macronutrient levels varied:

- Nitrogen: Medium to moderately high (190.35 to 334.17 kg $ha^{-1}$)
- Phosphorus: Low (7.86 to 12.9 kg $ha^{-1}$)
- Potassium: Medium to very high (221.13 to 663.33 kg $ha^{-1}$)

e. Based on the Soil Nutrient Index, nitrogen was medium, phosphorus was low, and potassium was high.

f. A correlation study showed a positive relationship between yield and pH, electrical conductivity (EC), organic carbon, available nitrogen, phosphorus, and potassium.

These findings highlight the importance of proper nutrient management to enhance soil quality and improve crop productivity.

The study's results offer valuable insights for farmers to strategically use fertilizers for cost-effective crop production. Farmers are encouraged to adopt integrated nutrient management (INM) practices to maintain an optimal balance of essential nutrients in the soil. Additionally, the use of bio-fertilizers containing organic carbon and nitrogen-solubilizing bacteria is recommended to further enhance soil health and nutrient availability. By implementing these practices, farmers can protect their soil resources, which are crucial for sustainable agriculture and long-term productivity.


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