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Analysis of soil clay mineral in NMDC Dantewada, Chhattisgarh of India: X-ray diffraction and mineralogical studies

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Abstract

The mineralogical analyses of soil around NMDC Dantewada, Chhattisgarh, India are depicted in this report. Various physical and chemical analyses were performed on this soil sample. The properties of soil clay mineral were studied using a traditional X-ray diffraction spectrum. It is possible to extract information from the reflected wave that can be used to measure dielectric characteristics. The chemical composition and physical qualities of a material determine its dielectric properties. Soil samples were collected from Dantewada district agriculture land, including the NMDC Dantewada agricultural zone (Villages- Dantewada, Geedam, Bacheli, Kirandul, Ktekalyan and Kuaakonda). Chemical and physical parameters of soil sample were examined to determine the availability of micronutrients. The dielectric constant of soil has been found to be dependent on the moisture content of the soil. The dielectric constant of soil increases slowly as the moisture content of the soil increases. The X-ray diffraction spectrum revealed the presence of clay minerals in the soils, but the other spectrum revealed no indication of their presence. X-ray diffraction has superior resolution, compactness, and scanning range than the traditional approach. As a result, it appeared to be a better fit for agricultural soil spectroscopic research.

1. Introduction

Soil is the natural covering that covers the majority of the land surface on the planet. Soil, in its most basic sense, is the natural medium in which terrestrial plants develop. By definition, all necessary components are required for plant growth and the successful completion of the plant life cycle from seed to seed. Some important elements are required in vast amounts, while others are required in much lesser amounts. The complicated dielectric permittivity of geological material determines how electromagnetic waves interact with it in relation to free space. The physical features of soil, such as sand, clay, and silt as well as its chemical nature, such as nitrogen, potassium, sodium, magnesium, and iron as well as the micronutrient present, influence its dielectric characteristics. Researchers investigating the dielectric properties of soils used a number of approaches [1–6] to evaluate the dielectric characteristics of various materials.

In agriculture, the dry soil's qualities, as well as its type, are extremely important. Physical, chemical, and electrical qualities exist in soil. The physical features involve texture, colour, and grain; and chemical properties involve organic matter, nutrients, pH, and so on; and electrical properties include dielectric constant, electrical conductivity, and permeability.

Each substance has its own set of electrical properties, which are determined by its dielectric properties. Scientists and engineers can use accurate measurements of these qualities to correctly combine the material into its proposed function. The effect of the dielectric constant on many soil parameters is investigated using measurement of the soil dielectric constant. Moisture content is given extensive importance for its practical significance in remote sensing and since it is the single most relevant factor in terms of soil dielectric properties. The findings of various studies on the dielectric characteristics of fertilised soils at microwave frequencies have been reported. According to Wang J. R. and Schmugge T. J. [7], the dielectric constant is proportional to soil pore space.

In the Carvarron horticulture township of Western Australia, clay mineralogy on clay separates was evaluated using X-ray fluorescence (XRF) assessment after barium saturation was also assessed for the correlation among clay mineralogy as well as the hard setting characteristics of the soil to use for rigorous, irrigated horticulture [8]. According to XRD, the soil clays were primarily illite with some kaolinite but little smectite.

The X-ray intensity ratio of mica basal reflections 001 and 002, according to Pal and coworkers [9], is an efficient diagnostic criterion for ensuring mica quality and judging the potassium releasing capacity of soils. The authors proposed that real quantification of fine-grained biotites in soils be required for detailed calculation of K reserves in soils and prediction of K release for long-term K management in Indian soils.

Clay mineralogy of spatially related nonvertic and vertic soils was studied quantitatively and qualitatively. Despite its significant occurrence, soil vertic features are just a factor of smectite concentration, even when present in trace proportions, with a determined ratio of interstratified sm/k, and cannot be created by kaolinite [10].

Vertisol smectites are highly cyrstallized and exhibit no signs of transition, according to XRD analysis of clays, save for hydroxy-interlayering in climatic vertisols. The dearth of revolution of fundamental minerals and the perversion of smectite's crystallinity. Bhattacharyya [11], discovered hydroxy interlayered vermiculite (HIV) Kaolinite, vermiculite, and gibbsite in ultisols from north eastern India while investigating the formation of gibbsite.

2. Materials and Methods

2.1 Soil Sampling

Samples of soil were collected in a crisscross pattern from several areas in the Dantewada district around NMDC Dantewada agricultural land (Villages- Dantewada, Geedam, Bacheli, Kirandul, Ktekalyan and Kuaakonda) at depths ranging from 0 to 20 cm. Five holes were drilled for each sample. After properly integrating all the preceding soil specimens, and a composite specimen weighing 3-4 kg was taken, suggesting on site. This procedure was used again whilst organizing composite samples that represented all the sites. The finer particles are removed first using the gyrator sieve shaker, which also aids in the removal of topsoil samples. These fine particles are sieved out and then dried in a hot air oven for nearly 24 hours at a temperature of around 60°C to remove any remaining moisture.

2.2 Theory

The research facility measures the physical and chemical characteristics of soil samples. The examination uses a large number of soil samples with a variety of physical and chemical characteristics. This study only looks at the physico-chemical and dielectric properties of soils. An empirical computation based on soil composition can be used to estimate field capacity (FC).

FC = 25.1 - 0.21 (% Sand) + 0.22 (% Clay) Wilting coefficient (Wp) is calculated by using the

Wang and Schmugge model.

$$wp = 0.06774 - 0.00064 \times sand\ \times 0.00478\ \times clay$$

$$Weight = 0.45\ \times WP\ + 0.165$$

The complex dielectric constant is calculated using the relation

$$\varepsilon^* =\ \varepsilon' - J\varepsilon''$$

Where, ε' is the dielectric constant and ε" is the dielectric loss factor. The salt content of water will have an impact on its dielectric characteristics since the moisture content of soil determines its dielectric constant. Salt makes it more difficult for crops to absorb water from the soil, reducing plants growth and output. To keep records of salinity fluctuations and predict additional deterioration, surveillance was required. This study presents the dielectric constant and dielectric loss estimates for soil with varied salt levels.

The following relationships are used to calculate the dielectric constant ε', dielectric loss ε", emissivity ep (q), and a.c. conductivity (σ) of these soil samples:

$$\varepsilon^* =\ \varepsilon' - J\varepsilon''$$

Where ε' describes the dielectric constant, and ε" describes the dielectric loss factor. Because of moisture content of a soil determines its dielectric constant, the existence of salts in water will affect its dielectric properties.

The following relationships are used to calculate the dielectric constant ε', dielectric loss ε", emissivity ep (q), and a.c. conductivity (σ) of various soil samples:

$$\varepsilon' = \frac{g_e\ + \left(\frac{\lambda_{gs}}{2a}\right)^2}{1\ + \left(\frac{\lambda_{ge}}{2a}\right)^2}$$

$$\varepsilon' = \frac{\beta_e}{1\ + \left(\frac{g_e}{2a}\right)^2}$$

Where, a is the rectangular waveguide's inner width.

λgs denotes the wavelength in an air-filled guide.

λge = real component of the admittance.

βϵ = imaginary part of the admittance.

By adding a defined quantity of distilled water to the dry soil, soil samples of various moisture levels can be created. The moisture content is stated as a percentage of dry weight. The following equation is used to determine Wc (%).

$$Wc\ (\%) = [(weight\ of\ wet\ soil - weight\ of\ dry\ soil)/(weight\ of\ dry\ soil)\ \times 100$$

This soil sample is classified as dry or having a moisture content of 0%. The dielectric constant was determined using an X band microwave set up and 4.62%, 4.64%, 4.15%, 5.01%, 4.9%, and 4.34% moisture content soil samples were created based on volumetric analysis. A block schematic of a microwave bench setup for measuring the dielectric constant of soils is shown in Figure 1.

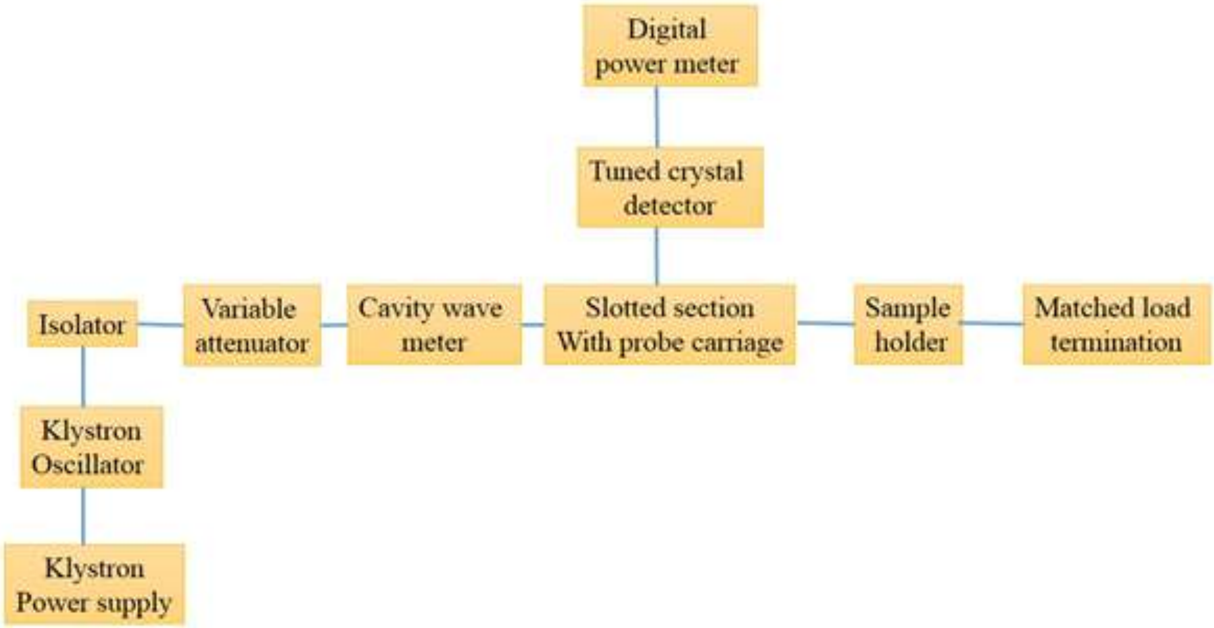

Figure 1. The microwave bench configuration for measuring the dielectric constant of soils is shown in this block diagram.

3. Result and discussion

The research aids in estimating the proportions of several physicochemical characteristics as well as nutrient levels in Dantewada district soil, including the NMDC Dantewada agricultural area (Villages- Dantewada, Geedam, Bacheli, Kirandul, Ktekalyan and Kuaakonda).

3.1 Chemical properties

Chemical analysis is also important parameters to check the soil quality. Table 1 and figure 2, 3 & 4 shows various chemical parameters like pH, electrical conductivity, organic carbon, micronutrients and macronutrients. The relationship between electric conductivity and sand content was found to be substantial in this investigation. Sandy soils are weak conductors, whereas clay textured soils are very conductive. Soil electric conductivity was found to be negatively connected with sand concentration and certainly correlated with the clay and silt.

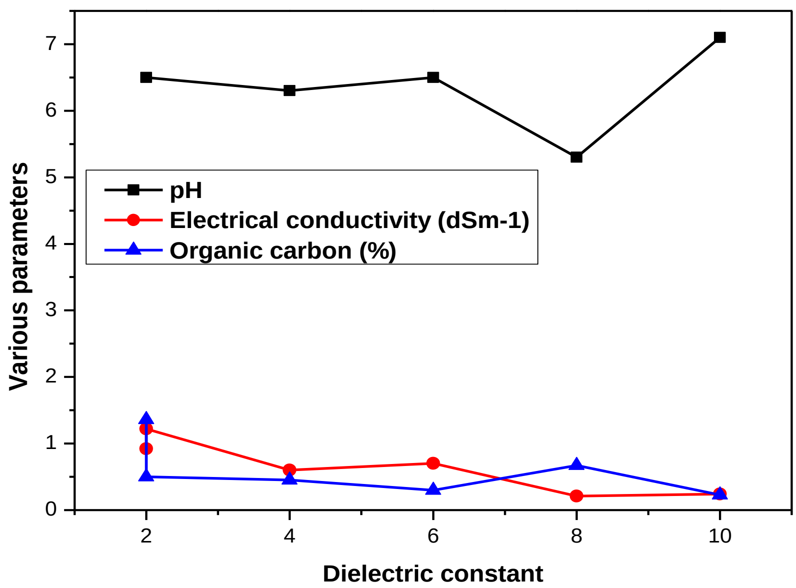

Figure 2. Deviation of Dielectric constant with various physical parameters of soil sample.

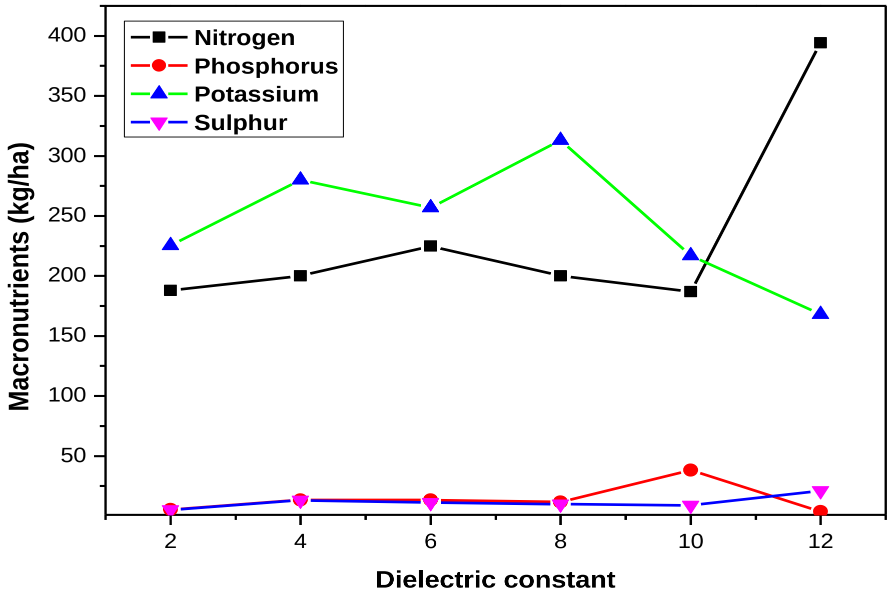

Figure 3. Deviation of Dielectric constant with various macronutrients for soil sample.

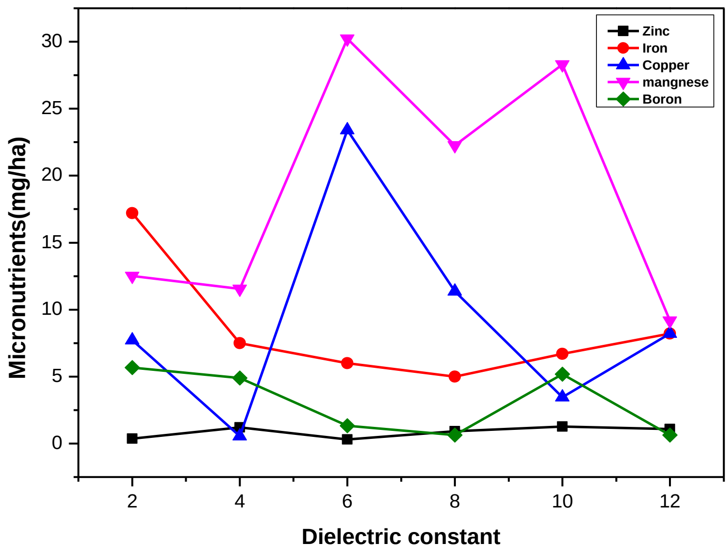

Figure 4. Deviation of Dielectric constant with various micronutrients for soil sample.

TABLE 1: Chemical characterization of soil samples of Dantewada district.

S. No.	Location	pH value	Electrical conductivity	Organic carbon	Macronutrients				Micronutrients				
			dSm^{-1}	%	N Kg/ha	P Kg/ha	K Kg/ha	S Kg/ha	Zn Kg/ha	Fe Kg/ha	Cu Kg/ha	Mn Kg/ha	B Kg/ha
1.	Dantewada	5.880 Mac	0.9270 N	1.3600 VH	188.10 L	5.4600 L	225.34 M	5.3300 D	0.37 D	17.29000 S	7.7100 S	12.52000 S	5.6800 S
2.	Geedam	6.54 MAc	1.22 N	0.50 VL	200.64 L	13.44 M	280.05 M	13.28 S	1.2 S	7.560 S	0.55 S	11.54 S	4.901 S
3.	Bacheli	6.3 MAc	0.6 N	0.45 VL	225.00 L	13.44 M	257.0 M	11.25 S	0.302 D	6.0 S	23.45 S	30.22 S	1.335 S
4.	Kirandul	6.5 MAc	0.7 N	0.30 VL	200.00 L	11.64 M	313.0 M	10.00 S	0.932 S	5.0 S	11.36 S	22.36 S	0.641 S
5.	Katekalyan	5.35 MAc	0.21 N	0.67 VL	187.00 L	38.150 M	217.05 M	8.92 S	1.27 D	6.7 S	3.45 S	28.31 S	5.177 S
6.	Kuaakonda	7.1 MAc	0.2400 N	0.2300 VL	394.23 L	3.77 M	168.23 M	21.2 S	1.084 D	8.21 S	8.21 S	9.17 S	0.64 S

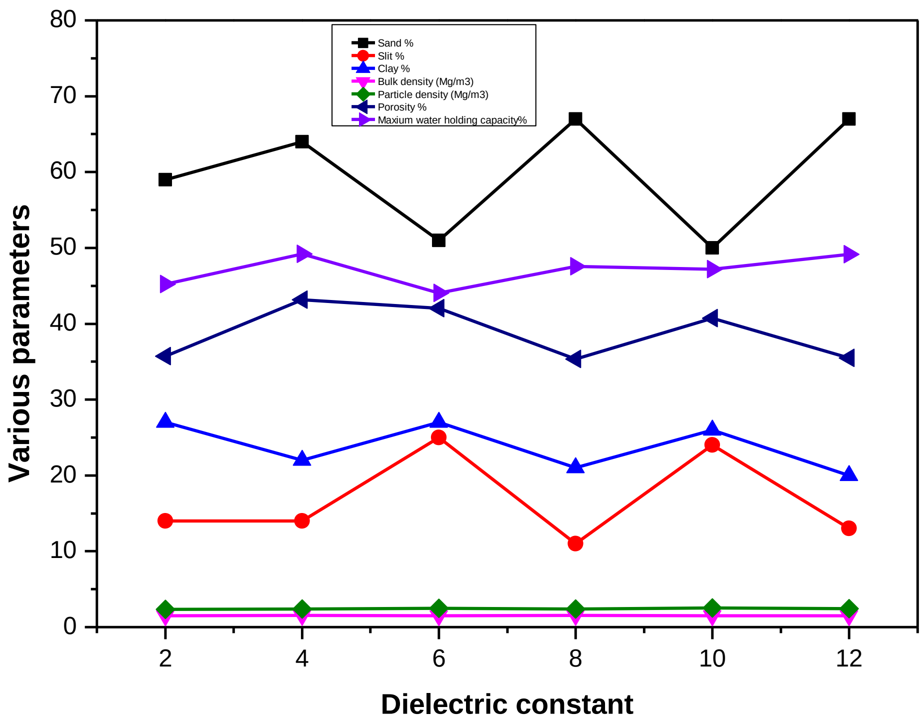

Figure 5. Variation of Dielectric constant with various physical parameters for soil sample.

TABLE 2: Physical analysis reports.

S. No.	Location	Sand %	Slit %	Clay %	Textural name	Bulk density (Mg/m^3)	Particle density (Mg/m^3)	Porosity %	Maximum water holding capacity (%)
1.	Dantewada	59	14	27	Clay loam	1.50	2.36	35.70	45.20
2.	Geedam	64	14	22	Clay loam	1.53	2.41	43.14	49.21
3.	Bacheli	51	25	27	Sandy loam	1.52	2.50	42.02	44.05
4.	Kirandul	67	11	21	Loam	1.53	2.41	35.32	47.56
5.	Katekalyan	50	24	26	Clay Loam	1.51	2.55	40.73	47.20
6.	Kuaakonda	67	13	20	Slity loam	1.52	2.42	35.49	49.16

1.1 Physical properties

The bulk density of a soil, the quality of the soil particles (sand, clay or silt), and the density of the soil particles are all elements that influence its dielectric properties [12]. According to Marx et al [13], clay texture of soil is highly conductive, but sandy soils are poor conductors. We discovered a strong positive relationship between bulk density and sand content. Bulk density of soil samples is found to have a substantial negative association with silt and clay content. Furthermore, there is a substantial negative relationship between bulk density and porosity in soil samples. Wagner et al. [13] used soil texture factors and organic carbon content measurements to estimate bulk density of soil.

Our reports showed significant correlation between electric conductivity with sand content. Sandy soils are weak conductors, but clay textured soils are very conductive [14]. Electric conductivity of soil correlated negatively with sand content and positively with silt and clay [15]. Different studies predict that the dielectric properties of soil at microwave frequencies are the function of its physico-chemical constituents [16]. Figure 5 and table 2 shows the physical properties of soil.

The dielectric constant of soil and sand content have a substantial positive association, but the dielectric constant of soil and silt and clay content have a considerable negative correlation. The dielectric constant has a good association with bulk density but a negative relationship with porosity.

3.2 XRD analysis

X-ray diffraction (XRD) is mainly useful for the determination of crystal structure of the molecules. Here figure 6 shows the XRD data of soil of Dantewada region, diffraction peak is obtained at 21.39 ˚ and 27.17 ˚. Figure 7 shows the XRD data of Geedam, the diffraction peak was obtained around at 26.98˚. Similarly figure 8 and figure 9 shows the XRD data of Bacheli and Kirandul, the diffraction peak is obtained for Bacheli is 21.01˚, 26.9˚, 36.5˚, 50.3˚, 68.06˚ and 81.8˚, and for Kirandul region the diffraction peak is obtained at 27.17˚ and 39.9˚. figure 10 and 11 shows the XRD data of Katekalyan and Kuaakonda region, the diffraction peak was obtained at 28.9˚, 36.5˚, 60.09˚, 68.6˚, and 80.03˚ and for Kuaakonda region; peak is obtained at 21.12˚, 26.19˚, 36.5˚, 50.3˚, 60.28˚, 68.24˚, 76.05˚ and 81.28 ˚ respectively.

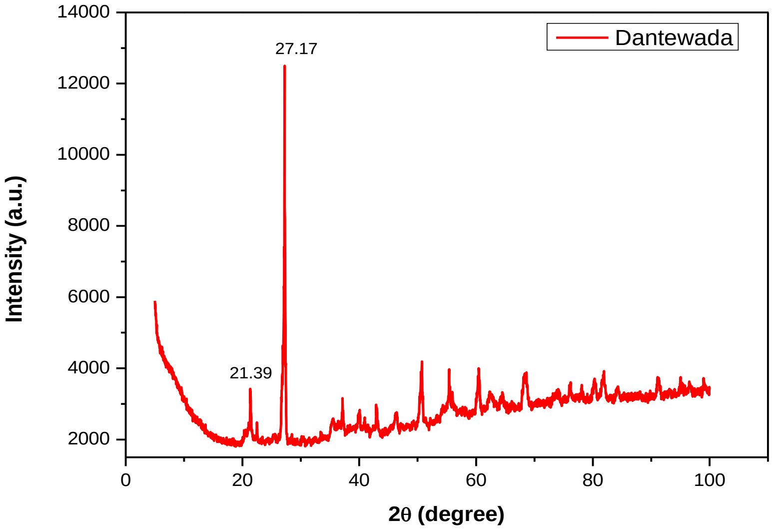

Figure 6. XRD of Dantewada region soil sample.

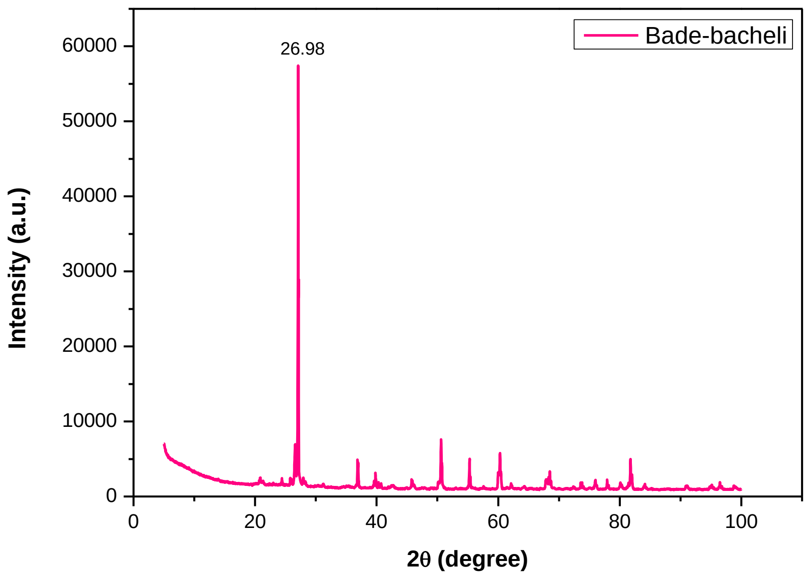

Figure 7. XRD of Geedam region soil sample.

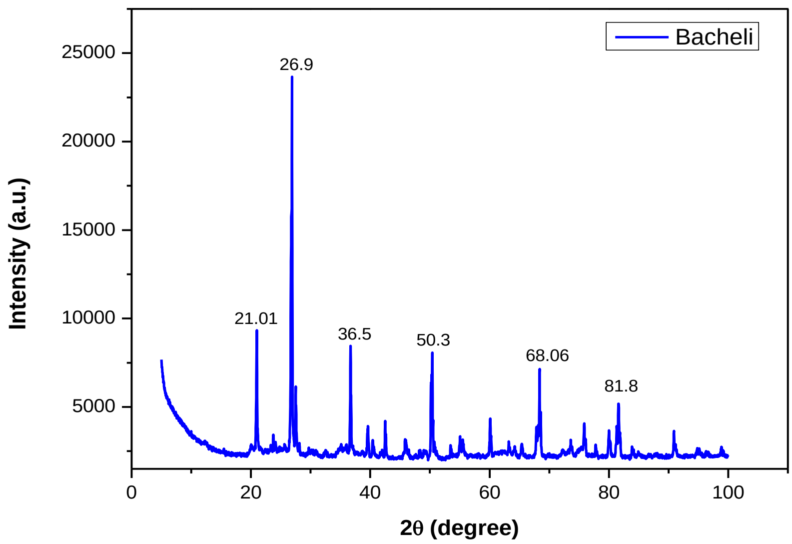

Figure 8. XRD of Bacheli region soil sample.

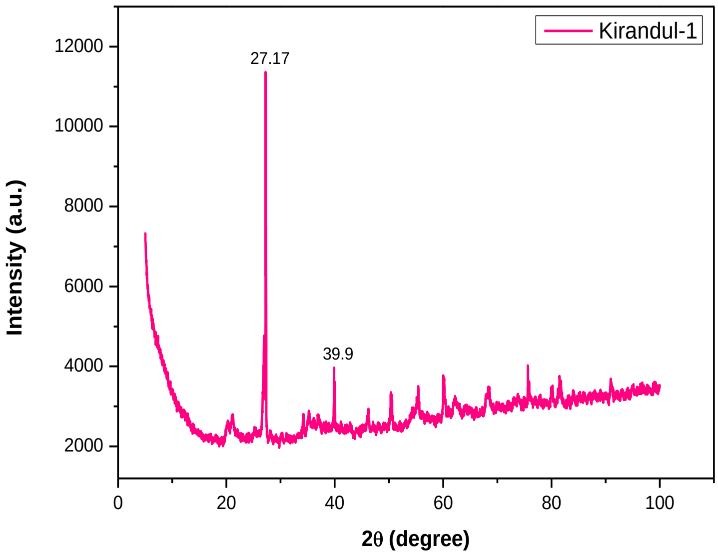

Figure 9. XRD of Kirandul region soil sample.

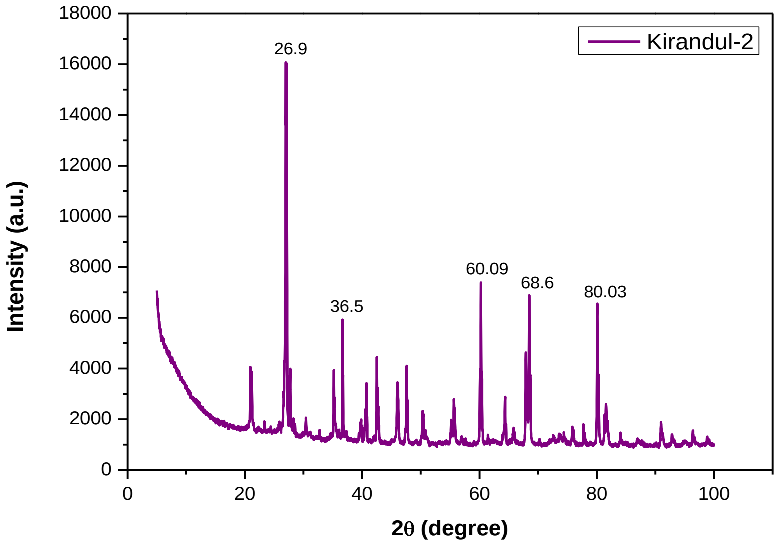

Figure 10. XRD of katekalyan region soil sample.

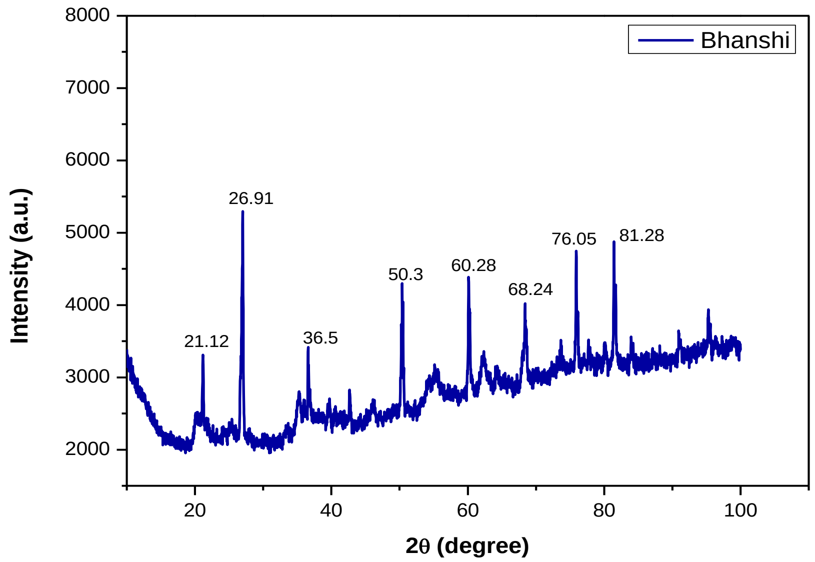

Figure 11. XRD of Kuaakonda region soil sample.

4. Conclusions

The dielectric characteristics of soil's naturally accessible macronutrients vary. Inorganic compounds have a considerable impact on the dielectric properties of soil. Such dielectric qualities will be beneficial to agricultural experts. The texture of the soil determines its bulk density. The texture of soil has a strong relationship with its electric conductivity. The wilting point of soil can be calculated using this data. These anticipated dielectric constant figures can also be used to determine scattering coefficient and emissivity, which could be useful in the development of microwave remote sensing systems. XRD study also investigated for soil samples of various region. These findings are beneficial to agricultural scientists as well as scientists who work in the field of remote sensing.

5. Acknowledgement

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6. Conflict of Interest

There is no conflict to declare.

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