Relationships between the Physico-Chemical Properties and the Dielectric Constant of Kota Area Soil

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Abstract:

Soil is a valuable natural resource that is vital to preserving environmental equilibrium. The goal of this article was to look at how dry soils' dielectric constant varied based on the nutrients that were available as well as their physical makeup. It describes the correlation between the soil sample's dielectric constant and physico-chemical characteristics from the Kota Block of the Bilaspur District. From diverse agricultural lands in Shivtarai, Bardwar, Khurdur, Kargikalan, Kota, and Gobaripat, soil samples were collected. An automatic X-band microwave setup in the TE10 mode with a Reflex Klystron resource operating at 9 GHz was used to determine the dielectric constant. The physical characteristics, pH, and electrical conductivity of soil samples were examined. All of these characteristics contribute to a better understanding of soil physics, agricultural applications, and data processing via remote sensing. The best crop decisions may be made by farmers with the help of this research.

Keywords: physio-chemical properties of soil, Dielectric constant, correlation coefficient, electric conductivity.

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1. Introduction

A fine covering of the earth's outer layer that works as a natural medium for plant development is known as soil. For plants to develop and produce the food and fibre we need, soil provides a growing substrate. One of the most important factors influencing crop development and yield is soil fertility [1]. The intrinsic ability of the soil to provide plant nutrients can be determined through soil testing, which is largely regarded as an accurate scientific procedure.Scientific studies, comprehensive field demonstrations, and real fertiliser use by farmers on soil test-based fertiliser use recommendations have all demonstrated the benefits of soil testing. Plants require a sufficient amount of good soil to house their roots and provide them with the resources they require. Food, fibre, lumber, aesthetic plants, and, increasingly, biofuels are all grown in soil.Various agricultural use necessitates different soil management techniques [2]. The soil has physical, chemical, and electrical properties. Physical attribute are particle density, bulk density, porosity, colour, texture, and so on; chemical properties are pH, nutrients, organic matter, and so on; and electric properties are dielectric constant, electric conductivity, tangent loss, microwave conductivity, relaxation time emissivity, and so on.Soil testing is the sole approach to establish the soil's accessible nutrient composition and to produce particular fertiliser recommendations. Soil characterization aids in determining soil potentials and recognizing

crop production constraints, as well as providing thorough information on various soil parameters [3]. Many researchers have used soils from all over the world, all with various structures. Calla O.P.N. et al. [4]. At microwave frequencies, the fluctuation of the dielectric constant of soil sample with its physical characteristics was investigated. According to various studies, the dielectric properties of soil at the frequencies of microwave are a measure of its physicochemical constituents. The size, ratio, organisation, and content of soil particles have an impact on the physical capacities of a soil [5]. Plants rely heavily on organic stuff for their nutrition. Iron, manganese, zinc, copper, boron, and chlorine are necessary micronutrients.The research of dielectric constant variability with physical elements and chemical composition is essential due to the reliance of dielectric constant on the physical characteristics and the chemical formation of the soil [6].

2. Materials and Methods

2.1Study Area

Kota District has an area of 5217.00 km^2. It is the fourth major city of Rajasthan area. The goddess Danteshwari Temple is commemorated in the town's name.It is Located at Latitude-25.1, Longitude-75.8. This district is part of India's Hindi Belt. The Kota district is situated because Bundi District surrounds it on all sides, and Kota City, which is well-known for its IIT JEE preparation, serves as the district's administrative centre. Because it is home to numerous significant power plants and companies, Kota city is referred to as the "Industrial Center of the State." In Kota is also the biggest fertiliser facility in Asia. Kota is renowned for its historic palaces, havelis (traditional homes), and castles. The gap between the prevailing, underdeveloped small farmers and the rest of the population grew as a result of expanded irrigation infrastructure, the development of credit cooperatives, and numerous political actions.

2.2Soil Sampling

The goal of this research is to find out how the soil sample's dielectric constant varies with its physical parameters of Kota District soil. 15mm of top-soil was eliminated prior to sampling. Samples of soil were taken in a zigzag pattern across the required areas from various sites at a depth of 15cm. For each sample, five pits were created. Through the blending of representative soil samples, a composite sample of around 2 kg is obtained.To remove the coarser particles, the soils were sieved using a gyrator sieve shaker with a 2mm space. The finer bits are sifted out and then it is oven dried at a temperature of roughly 60oC to remove any remaining moisture. When comparing to wet samples, such a dry sample is referred to as dry base samples or oven dry.

2.3Properties of Soil

The samples had beeninvestigated for their chemical and physical constraints. Theattributes of the soil were evaluated in the Indira Gandhi Agriculture College at the Raipur and its dielectric coefficients were evaluated at the branch of physics inRajeev Gandhi Govt.P.G. College Ambikapur.To determine the moisture content by its dry weight in percentage, Wc, apply the equation below (percent)

Wp = 0.06774 − 0.00064 × sand + 0.00478 × clay

weight = 0.45 ×wp + 0.165

Soil Porosity is expressed as,

$$\text{porosity}=1-\frac{bulk\ density}{particle\ density}$$

Measuring Dielectric Constant of Soil Samples

The dielectric characteristics of dry soil samples are determined using the wave-guide cell method. The dielectric constant of soil sample is evaluated using an X-band microwave bench set-up.The dielectric constants were measured using acomputerized X-band microwave set-up in the TE10 mode with a Reflex Klystron source running at 9 GHz. This is accomplished using a data gathering system and PC-based slotted line control. The opposite end of the source is connected to the solid dielectric cell containing the soil sample. The microwave source's signal is permitted to pass through to the soil sample.The sample's front surface indicates a portion of the incident signal. A standing wave pattern is formed by combining the incident wave and the reflected wave. The

standing wave forms are now utilised to calculate the rates of the shift in minima caused by adding the sample before and after. Experiments were carried out at room temperatures ranging from 25 to 35 degrees Celsius. The dielectric constant of soil is then calculated using the equation below:

$$\varepsilon' = \frac{g_\varepsilon + (\lambda_{gs}/2a)^2}{1 + (\lambda_{gs}/2a)^2}$$

and

$$\varepsilon'' = -\frac{\beta_\varepsilon}{1 + (\lambda_{gs}/2a)^2}$$

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

gs = the guide's air-filled wavelength. G= the actual admissions component

$\beta\epsilon$ = fictitious portion of admission

the connection between electrical resistance and dielectric strength coefficient of correlation (r). The subsequent Table 1 displays with physical properties of soils were defined using the parameters of soil from Kota District.

Table 1: Physical properties of soilsfrom Kota block of Bilaspur.

SAMPLE NO.	SAND %	SILT %	CLAY %	POROSITY	BULK DENSITY GM/CM^3
Shivtarai	70.5	7.3	22.2	0.160	1.73
Bardwar	71.5	4.6	23.9	0.188	1.51
Khurdur	72.8	4.4	22.8	0.190	1.49
Kargikalan	72.8	5.2	22.1	0.185	1.47
Kota	72.7	5.1	22.2	0.206	1.42
Gobaripat	72.5	5.3	22.2	0.203	1.37

In the current study We've taken measurements of soil emissivity, relaxation time, tangent loss, and dielectric constant at the x-band microwave frequency (9 GHz) and 10 soil samples were gathered from the Kota region were investigated for its statistical association aspects with chemical and physical parameters. The main purpose of this investigation is to assesscondition of existing nutrients in soil of Kota region. The table 2 shows the soil's dielectric properties are listed in table 3, along with its chemical characteristics, for the Kota block in Bilaspur.

Table 2: Chemical Properties of Soil at Kota Block of Bilaspur District

Sample	Shivtarai	Bardwar	Khurdur	Kargikalan	Kota	Gobaripat
pH	6.3	6.28	6.52	6.27	6.16	6.11
EC(Dsm^{-1})	0.11	0.06	0.08	0.1	0.09	0.13
OC(%)	0.59	0.53	0.52	0.56	0.58	0.58
$CaCO_3$(%)	1.45	1.62	1.93	1.04	1.08	1.49
N(Kg/Ha)	134	136	139	151	156	144
P(Kg/Ha)	8.1	12.33	10.54	12.23	14.12	15.02

K(Kg/Ha)	216.1	308.06	352.51	326.1	361.62	368.97
Fe(ppm)	15.2	16.3	16.9	14.8	16.7	16.8
Zn(ppm)	0.71	0.66	0.84	0.60	0.94	0.88
Cu(ppm)	0.69	0.42	0.53	0.55	0.70	0.68
Mn(ppm)	26.3	22.4	24.5	21.2	25.3	25.6

Table 3 : Dielectric Constant of Soil at Kota Block of Bilaspur District

S. No.	**Sample**	**Dielectric Constant**				
		Dry soil	**10%**	**20%**	**30%**	**40%**
1	**Shivtarai**	3.13	7.31	10.61	15.79	19.33
2	**Bardwar**	3.16	7.34	10.63	15.82	19.35
3	**Khurdur**	3.18	7.36	10.65	15.86	19.37
4	**Kargikalan**	3.2	7.39	10.66	15.89	19.38
5	**Kota**	3.23	7.41	10.69	15.92	19.41
6	**Gobaripat**	3.27	7.44	10.72	15.96	19.44

The association between soil characteristics and dielectric constant is seen in table no.4 above.

3.**Result and Discussion**

Available macronutrients status of soils:

Available N status: The range of the available N content is 163.46-289.21 kg ha^{-1}. The soil sample was found to have a low to medium available N content when taking into account table 3's soil test rating for available N (500 as high in the status of N) (Table 2, Fig. 1). In this manner, it was discovered that practically all soil samples examined for N availability were N deficient. Although it is true that Subbiah and Asija's recommended alkaline $KMnO_4$ technique for N analysis is accessible

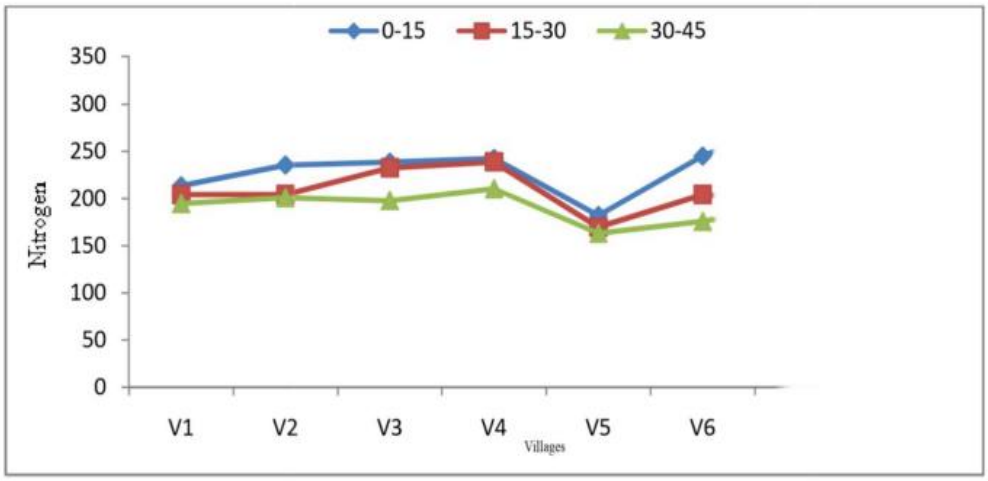

Fig. 1:Available Nitrogen (Kg ha^{-1}) at various depths in various villages in the Kota area of Chhattisgarh, India (0-15, 15-30, and 30-45 cm).

Available P status:

In the research area, the range of soils' accessible P contents was 9.24 to 17.06 kg ha^{-1}. Taking into account the available phosphorus rating of the majority of the soils (0–10 kg ha^{-1} as very low, 11–20 kg ha^{-1} as low, 21–40 kg ha^{-1} as medium, and >40 kg ha^{-1} as high) (Table 2, Fig. 2) Samples of soil were found to have very low to low levels of phosphorus that was readily available.

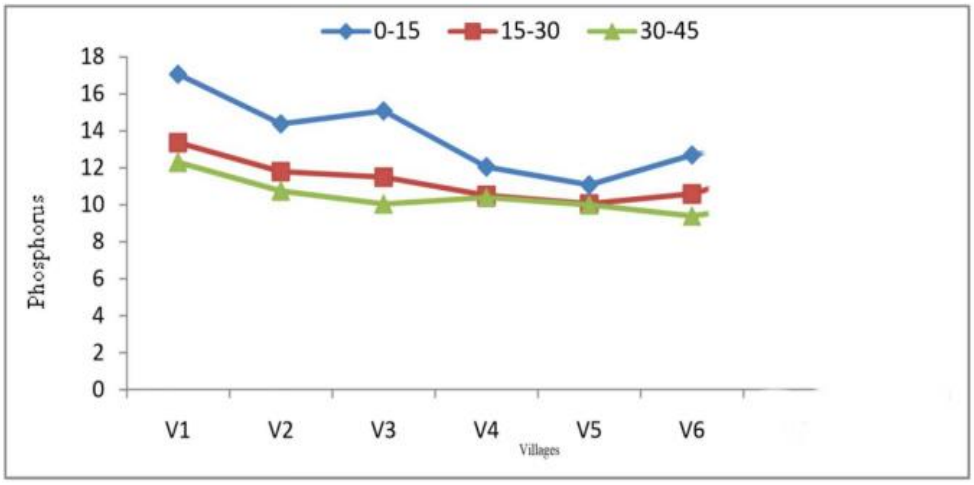

Fig. 2:Accessible Phosphorus (Kg ha^{-1}) at various depths in various villages in the Kota area of Chhattisgarh, India (0-15, 15-30, and 30-45 cm).

Relation between thesand, clay and silt content of soil and Bulk density

A soil's dielectric characteristics are influenced by its bulk density, the consistency of the soil particles (such as sand, clay, or silt), and the concentration of these soil particles [7,8]. a) The bulk density and composition of the soil's sand, silt, and clay. Marx et al. [9] claim that while sand-like soils are weak conductors, clay-like soils are particularly conductive. Our research revealed a significant correlation between bulk density and sand concentration. It is discovered that silt and clay content have a significant negative correlation with bulk density of soil samples. Additionally, bulk density and porosity in soil samples have a strong negative association. Measurements of the organic carbon content and soil texture variables were utilised by Wagner et al. [10] to determine the bulk density of the soil.

Relation between the sand, clay and silt content of soil and Electric conductivity

Our findings revealed a strong link between electric conductivity and sand substance.

Sandy Soils are poor conductors, whereas soils with a clay texture are excellent conductors [11]. It was discovered that clay and silt were positively correlated with soil electric conductivity and negatively correlated with sand concentration[12,13]. According to numerous studies, the dielectric properties of soil at microwave frequencies are projected to be a result of its physicochemical constituents [14].

Relationship between soil sand, silt, and clay concentration and the dielectric constant

Sand concentration and soil dielectric constant have a sizable positive correlation, however silt and clay content and soil dielectric constant have a sizable negative correlation.The dielectric constant and bulk density the have a positive connection but a negative relationship with porosity. Wagner et al. [10] reported similar findings.

4.Conclusions

The readily available macronutrients in soil exhibit a variety of dielectric properties. Soil's dielectric properties are heavily influenced by inorganic components. The bulk density of the soil depends on its texture. A significant correlation exists between soil conductivity and texture. This information can be used to determine the soil's wilting point. The development of microwave remote sensing systems may benefit from using these projected dielectric constant ratios to calculate the scattering coefficient and the emissivity. Both scientists who study agriculture and those who study remotely sensed data will find value in these findings.

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