Correlations between Physico-Chemical Characteristics with Dielectric Constant of Soil from Nasik Region

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Abstract: *Soil is an important natural resource and plays a crucial role in maintaining environmental balance. The objective of this paper was to study the variability of the dielectric constant of dry soils with their physical constituents and available nutrients. It describes the correlation of physico-chemical characteristics with dielectric constant of soil sample from Sinnar Tahasil in Nasik District. Soil samples are collected from agriculture land of different villages in Sinnar Tahasil (Nashik). An automated X- band microwave set-up in the TE_{10} mode with Reflex Klystron source operating at frequency 9 GHz is used for measuring dielectric constant. The physical characteristics, pH and electrical conductivity of soil samples were measured. All these characteristics are helpful in better understanding of soil physics, agricultural application and analyzing the satellite data in remote sensing. Also this study helps to farmer for their proper crop choice.*

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

1. Introduction

Soil may be defined as a thin layer of earth's crust which serves as a natural medium for the growth of plants. Soil provides a medium for plant growth to meet our food and fibre need. Fertility of soil is one of the most important factors which regulate growth and yield of crops [1]. Soil Testing is well recognized as a sound scientific tool to assess inherent power of soil to supply plant nutrients. The benefits of soil testing have been established through scientific research, extensive field demonstrations, and on the basis of actual fertilizer use by the farmers on soil test based fertilizer use recommendations. Plants need a sufficient volume of quality soil to host roots and supply needed resources. Human societies depend on soil to grow food, fibre, timber, ornamental plants, and increasingly, bio fuels. Different agricultural uses require different soil management practices [2].

The soil has physical, chemical as well as electrical properties. Bulk density, particle density, porosity, colour, texture etc, compromises the physical properties; pH, nutrients, organic matter etc., comprise chemical properties whereas dielectric constant, electric conductivity, tangent loss, microwave conductivity, relaxation time emissivity etc., comprise electric properties.

Soil testing is the only way to determine the available nutrient status in soil and the only way we can develop specific fertilizer recommendations. Characterization of soil helps in determining soil potentials and identifying the constraints in crop production besides giving detailed information about different soil properties [3].

Many investigators have used soils covering different parts all over world with different structure. The variability of dielectric constant of dielectric constant of dry soil with its physical constituents at microwave frequencies has studied by Calla O.P.N. et.al [4]. Different studies predict that the dielectric properties of soil at microwave frequencies are the function of its physic- chemical constituents. The physical capacities of a soil are influenced by the size, proportion, arrangement and composition of the soil particles [5]. Organic matter is an important source of nutrients for plants. Nitrogen, phosphorus and sulphur are considered macronutrients; essential micronutrients are iron, manganese, zinc, copper, boron and chlorine. Due to dependence of dielectric constant on the physical constituents and chemical composition of the soil, the study of its variability with physical constituents and chemical composition is required [6].

2. Materials and Methods

Study Area

Nasik District has an area of 15530.00 km. Nasik is amongst the largest districts of Maharashtra State. Nasik district has situated partly in the Tapi basin and partly in the upper Godavari basin. Sinnar is located at 19.85°N 74.0°E. It has an average elevation of 651.4 metres (2135 feet). Sinnar is one of the major industrial zones of Malegaon (MIDC) built around the city of Nashik which have multiple international production companies. It lies 30 km southeast of Nashik city on the Pune - Nashik Highway. Increasing irrigation facilities, development of credit cooperatives and political developments at different levels further enlarged the disparity between the small farmers dominated, undeveloped.

Soil Sampling

The purpose of this study is to determine the dielectric constant of dry soil samples and its variation with the physical properties of soil of Sinnar Tahsil. Before sampling 15 mm topsoil was removed. Soil samples were collected from different locations at the depth of 15cm in zigzag pattern across the required areas. Five pits were dug for each sample. A composite sample of about 2 Kg is taken through mixing of represented soil sample. These soils were first sieved by gyrator sieve shaker with approximately 2 mm spacing to remove the coarser particles. The sieved out finer particles are then oven dried to a temperature around 110°C in order to completely remove any trace of moisture. Such dry sample is then called as oven dry or dry base sample when compared with wet samples.

Soil Properties

The samples were analysed for their physical and chemical parameters .The characteristics of the soil were measured in the soil mechanics lab at the Pune and the dielectric constants were measured at the Department of physics in JES College Jalna. The moisture content in percentage by dry weight, Wc(%) is calculated using the following relation

$$W_g = 0.06774 - 0.00064 \times sand + 0.00478 \times clay$$

$$W_t = 0.49 \times W_g + 0.165$$

Porosity of the soil is expressed as,

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

Measurement of Dielectric Constant of dry Soil Samples

The waveguide cell method is used to determine the dielectric properties of the dry soil samples. X-band microwave bench set-up for measurement of dielectric constant of soil samples is used. An automated X-band microwave set-up in the TE10 mode with Reflex Klystron source operating at frequency 9 GHz is used for measuring dielectric constants .PC-based slotted line control and data acquisition system is used for this purpose. The solid dielectric cell with soil sample is connected to the opposite end of the source. The signal generated from the microwave source is allowed to incident on the soil sample. The sample reflects part of the incident signal from its front surface. The reflected wave combined with incident wave to give a standing wave pattern. These standing wave patterns are then used in determining the values of shift in minima resulted due to before and after inserting the sample. Experiments were performed at room temperatures ranged between 25°-35° C. The dielectric constant ε' of the soils is then determined from the following relation:

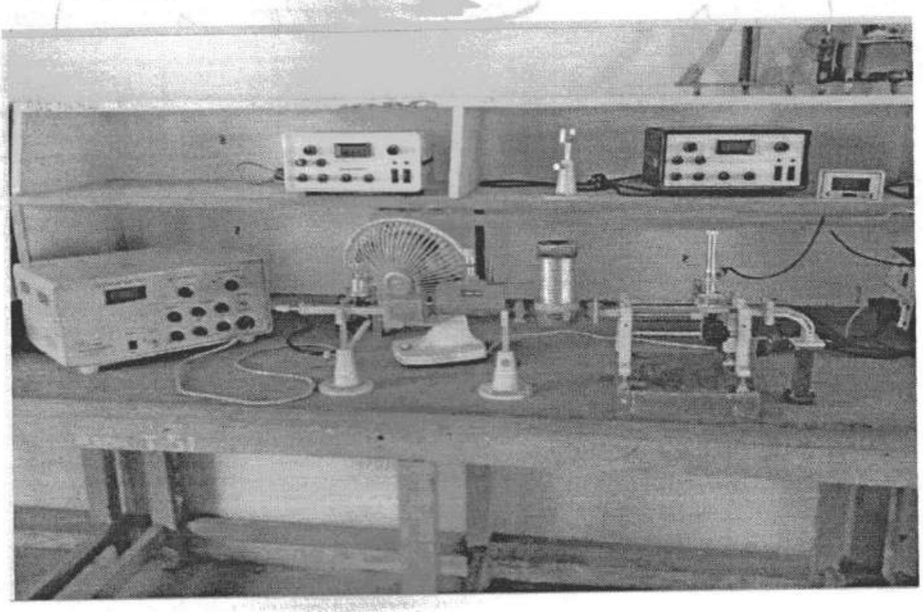
$$\varepsilon' = \frac{g_\varepsilon + (\lambda_{gs}/2a)^2}{1 + (\lambda_{gs}/2a)^2}$$

and

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

Where, a = Inner width of rectangular waveguide.
λ_{gs} = wavelength in the air-filled guide.
g_ε = real part of the admittance
β_ε = imaginary part of the admittance

Figure shows Experimental set up of x-band microwave bench set up



The relationship between electrical and dielectric constant with physical parameters of soils were determined using Correlation coefficient r. The following table no. 1 shows the parameters of soil from Sinnar Tahisal.

Table 1
Parameters of soil from Sinnar Tehsil

sample no.	sand (%)	silt (%)	clay (%)	BD (Mgm-3)	porosity (%)	EC (dSm-1)	Ph	CaCO3	WP
1	45	23.85	6.2	1.45	42.91338583	0.13	8.7	23	0.068576
2	42	25.5	7.8	1.3	49.01960784	0.13	8.4	22.75	0.078144
3	41.4	32	13.4	1.33	48.24902724	0.12	8.4	22	0.105296
4	40.6	36.5	14	1.29	49.80544747	0.13	8.5	8.5	0.108676
5	39.5	37.5	20.75	1.27	50.96525097	0.1	7.6	7.5	0.141645
6	35.4	50.8	28	1.26	51.35135135	0.2	7.1	5.1	0.178924
7	23.75	51.09	31.75	1.19	54.40613027	0.25	6.9	2	0.204305
8	23.25	52	32.35	1.19	54.58015267	0.25	6.7	2	0.207493
9	22	55.25	32.75	1.14	56.6539924	0.2	6.7	1.5	0.210205
10	46	63.75	38.75	1.4	46.96969697	0.19	6.5	0.75	0.223525

In the present study we have made the measurements on dielectric constant, relaxation time, tangent loss, and emissivity of soils at x –band microwave frequency (9 GHz) and studied their statistical correlation factors with physical and chemical properties of ten soil samples collected from Nasik region. The main purpose of this investigation is to evaluate status of available nutrients in soil of Nasik region and the Soil Parameters and BD Correlation Coefficient (r) Level of Significance Regression Equations. The following table no.2 shows the correlation of sand ,silt, clay and porosity with bulk density.

Correlation coefficients (r) and Regression equations

Table 2: Correlation coefficients (r) and Regression equations

Soil Parameters and BD	Correlation Coeff (r)	Level of Significance	Regression Equations
BD(x) - Sand%(y)	0.9115	High degree Positive	y = 89.08 x – 21.78
BD(x) - Silt%(y)	-0.4343	Significant Negative	y = -61.54 x+ 12.17
BD(x) - clay%(y)	-0.4878	Significant Negative	y = -59.38 x+ 68.70
BD(x) - porosity%(y)	-0.9894	Strong Negative	y = -49.96 x+ 10.42

Table 3: The above table no.3 shows correlation of soil parameters with electric conductivity.

Soil Parameters and EC	Correlation Coeff. (r)	Level of Significance	Regression Equations
EC(x) - Sand%(y)	-0.7635	Significant Negative	y= -130.0 x+ 57.99
EC(x) - Silt%(y)	0.7106	Significant Positive	y= 85.4 x+ 11.29
EC(x) - clay%(y)	0.7771	Significant Positive	y= 64.8 x+ 5.443
EC(x) - porosity%(y)	0.6488	Significant Positive	y= 47.98 x+ 42.33

Table 4

Soil Parameters and DC	Correlation Coeff(r)	Level of Significance	Regression Equations
DC(X)-Sand%(y)	0.6892	Significant Positive	17.81x+33.75
DC(X)-Silt%(y)	-0.5909	Significant Negative	-3.713x+27.27
DC(X)-Clay%(y)	-0.6929	Significant Negative	-32.04x+26.41
DC(X)-BD%(y)	0.6156	Significant Positive	0.192x+0.624
DC(X)-Porosity(y)	-0.6120	Significant Negative	-4.489x+52.27

The above table no.4 shows correlation of soil parameters with dielectric constant.

3. Result and Discussion

The dielectric properties of a soil depend on a number of factors, including its bulk density, the texture of the soil particles (sand, silt, or clay), the density of the soil particles [7,8].

(a) Relationship of Bulk density with sand, silt and clay content of soil

Clay textured soil is highly conductive while sandy soils are poor conductors; reported by Marx et al [9].We found high degree positive correlation of bulk density with sand content. Whereas significant negative correlation bulk density is observed with silt and clay content of soil samples. And strong negative correlation between bulk density and porosity of soil samples. Bulk density of soil was estimated by using soil texture parameters along with organic carbon content values Wagner et al.[10].

(b) Relationship of Electric conductivity with sand, silt and clay content of soil

Our reports showed significant correlation between electric conductivity with sand content. Clay textured soil is highly conductive while sandy soils are poor conductors [11].Electric conductivity of soil correlated negatively with sand content and positively with silt and clay[12,13]. Different studies predict that the dielectric properties of soil at microwave frequencies are the function of its physico-chemical constituents [14].

(c) Relationship of dielectric constant with sand, silt and clay content of soil

Significant positive correlation ship is found between dielectric constant of soil and sand content whereas significant negative correlation of dielectric constant of soil and silt, and clay content is observed. Dielectric constant has positive correlation with bulk density and negative significant correlation with porosity. Similar results are reported by Wagner et al.[10].

4. Conclusions

The naturally available macronutrients of soil show variation in dielectric properties. Inorganic matter in soil appreciably affects its dielectric properties. Bulk density of soil depends on its texture. Electric conductivity of soil has significant correlation with the texture of soil. From this information one can calculate wilting point of soil. From these estimated values of dielectric constant one can estimate emissivity and scattering coefficient that will provide the tools for designing the microwave remote sensing sensors. These results are helpful for agriculture scientists and also for the scientists working in the field of remote sensing.

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