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Electrical and Physical Properties of Coimbatore Soils at Microwave Frequency

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ABSTRACT - The aim of this paper was to study the variations of the electrical properties like electrical conductivity and dielectric constant of soils with their physical properties. Eight soil samples were collected from different locations of Coimbatore (Tamilnadu) at the depth of 0 – 15 cm. Soil samples were analysed for physical properties like texture, bulk density and porosity. The electrical conductivity is measured by soil testing kit Model 161E in the laboratory and dielectric constant of dry soil samples was measured at C- band microwave frequency. Correlations between electrical and physical properties of soil samples were studied. The results were analysed statistically to obtain correlation coefficients. Which showed that the electrical conductivity and dielectric constant both dependent on physical properties of soil and have significant correlations with them. Results obtained are useful in the field of remote sensing and agriculture.

KEYWORDS: Dry soil, electrical conductivity, dielectric constant, C-band microwave frequency, physical parameters.

I. INTRODUCTION

The properties of dry soil along with its type have a great importance in agriculture. Soil is an intimate mixture of organic and inorganic materials, water and air. The soil has physical, chemical as well as electrical properties. Colour, texture, bulk density, porosity, wilting point etc. comprise the physical properties; Nutrients, organic matter, pH etc. comprise chemical properties while the electrical properties include electrical conductivity and dielectric constant. Soil electrical conductivity (EC) is one of the simplest, least expensive soil measurements available to precision farmers today. Soil EC measurement can provide more measurements in a shorter amount of time than traditional grid soil sampling. EC of soil is often used to measure salinity, but under non-saline conditions EC can provide an indirect, composite measure of variables that influence soil quality, including clay content, soil organic matter, and the quantity of available nutrients. Dielectric constant of dry soil is another primary important electrical property for microwave remote sensing. 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. Here we studied the variation of electrical conductivity and dielectric constant of dry soils with their physical constituents.

II. LITERATURE REVIEW

Several studies have explored relationship between electrical conductivity of soil and yield (Lund, et al. [1], Kitchen et al. [2]). EC can be affected by soil properties like clay content, water content, depths of layers, and organic matter Heiniger et al. [3] , therefore, variation in yield can partly be explained by soil EC level; they also showed that EC can be a valuable tool in identifying soil properties. 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, the volumetric water content of the soil, the temperature, and the frequencies of interest Hoekstra and Delaney [4], Topp, et al.[5], Ulaby, et al. [6]. The characteristics of soils of Chhaisgarh have studied at X – band frequency and reported that dielectric constant of soils are strongly dependent on soil moisture and texture Srivastav and, G. P. Mishra [7]. The variability of dielectric constant of dry soil with its physical constituents at microwave frequencies have studied and showed that the variations of dielectric constant for different soils depend on the physical composition of soil O P N Calla [8]. They also reported the variation of dielectric constant with the sand content in the dry soil. The dielectric constant by clay mineral and physico – chemical properties of soil have evaluated and showed that texture and mineral content of soil had different impacts on dielectric constant Davood Namdar-Khojasteh et al. [9]. They reported decrease in dielectric constant with increasing of sand percentages, whereas it increases with the increase in silt and

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clay. The present work provides the information about electrical conductivity and dielectric constant of dry soils at C-band microwave frequency 4.5 GHz and their relationship with the physical parameters viz sand, silt, clay contents, bulk density and wilting point, of 8 soil samples collected from different locations of Coimbatore.

III. MATERIALS AND METHODS

A. Study Area: The Coimbatore district is the western zone of Tamil Nadu (India) and located at an elevation of about 411 meters. It lies between 10° 10' and 11° 30' of the northern latitude and 76° 40' and 77° 30' of eastern longitude. The soil types of a particular area play critical role is determining the fertility status and cropping pattern. Red Calcareous soil, Black soil and Red non-calcareous soil are major soil types found in this area. Percentage distribution of Red Calcareous soil is high as compared to other soil types. More than 50 percentage of area comes under Irugur and Palladam series which are poor in productivity. The soil in this region is enriched with organic matter from the hill ranges. The red soils around the Anamalais are fertile.

B. Soil Sampling: The aim of this study was to obtain correlations between electrical properties and physical properties of soil. Before sampling 15 mm topsoil was removed. Soil samples were collected from 8 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. was 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 fine particles are then oven dried to a temperature around 110°C for several hours 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.

C. Soil Properties: The Physico-chemical properties of soil samples are listed in **Table 1.** The samples were analysed for their physical parameters texture, bulk density and also for pH, electrical conductivity and $CaCO_3$ by standard analytical methods from Soil Testing laboratory, Pune. Bulk density is a measurement of the volume of soil composed of solid particles versus air space. Factors affecting bulk density are Pore space, Texture and Organic matter content. Porosity of the soil is expressed as

Porosity = 1 - (bulk density / particle density)

The Wilting Point (WP) of the soils is calculated by using the model Wang and Schmugge [10] as follows:

WP = 0.06774 - 0.00064 x Sand (%) + 0.00478 x Clay (%)

Table 1: Parameters of Soils from Coimbatore

Sample No.	Sand (%)	Silt (%)	Clay (%)	BD (Mgm^{-3})	Porosity (%)	WP	DC	EC (dSm^{-1})	pH	CaCO3 (%)
1	86	4	10	1.43	44.36	0.0605	2.78	0.03	6.80	1.25
2	67	6	27	1.26	48.57	0.15392	2.72	0.12	8.41	3.0
3	89	3	8	1.55	39.22	0.04902	3	0.08	7.08	1.0
4	86	4	10	1.45	40.82	0.0605	3.34	0.07	5.39	2.0
5	89	6	5	1.47	40.96	0.03468	3.54	0.10	6.49	6.0
6	90	3	7	1.44	40.50	0.0436	3.46	0.10	8.40	2.0
7	73	17	10	1.25	48.56	0.06882	3	0.18	8.28	8.5
8	89	3	8	1.57	42.07	0.04902	3.5	0.08	8.85	3.5

D. Measurement of Dielectric Constant of dry Soil Samples: The waveguide cell method is used to determine the dielectric properties of the dry soil samples. An automated C-band microwave set-up in the TE10 mode with Gunn source operating at frequency 4.5 GHz, 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. Other details of dielectric constant measurement with C-band microwave bench set-up can also be seen from **Fig.1** The dielectric constant ε' of the soils is then determined from the following relation:

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

Where, a = Inner width of rectangular waveguide. **λgs** = wavelength in the air-filled guide. $\mathbf{g_\varepsilon}$ = real part of the admittance

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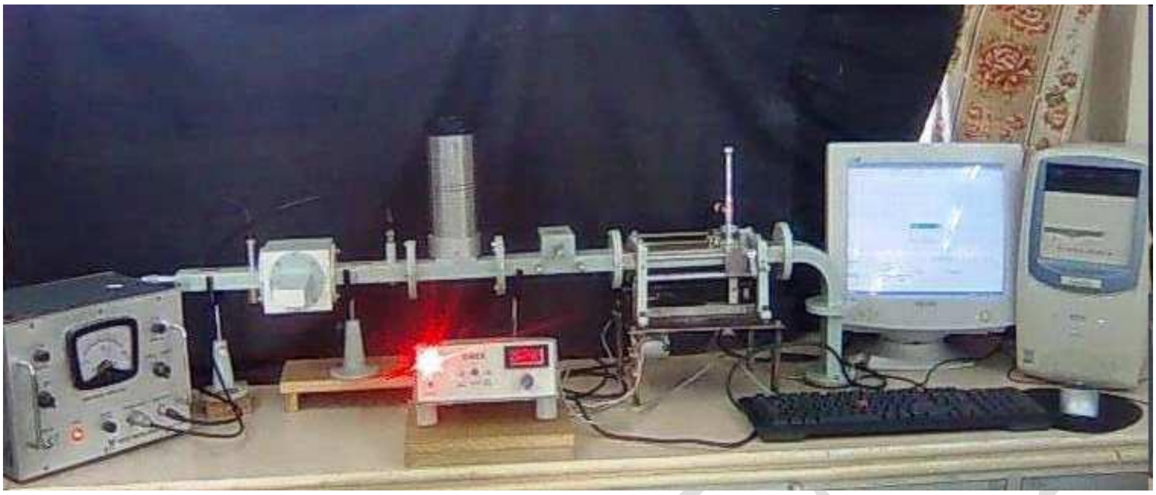

Fig.1: C-band microwave bench set-up for measuring dielectric constant

E. Statistical analysis: The relationship between electrical conductivity and dielectric constant with physical parameters of soils were determined using Correlation coefficient "r". Correlation coefficients (r) between dielectric constant and physical parameters of soils and respective regression equations are listed in **Table 2.**

IV. RESULTS AND DISCUSSION

A. Texture, Bulk Density and Porosity of soil samples

The sand, silt and clay of collected samples ranges 67- 90, 3 - 17 and 5 – 27 % respectively and these soils were categorized as sandy clay loam, loamy sand, sandy loam and sand. Because of more percentage of sand in the soil, Bulk Density and Porosity of soil samples were ranging (1.25 - 1.57 Mg m-3) and (39.22 - 48.57) respectively.

B. $CaCO_3$ and pH of soil samples

Calcium Carbonate ($CaCO_3$) content (1.00 – 8.5 %) of soil samples showed that four samples were slightly calcareous, two samples were moderately calcareous and the remaining two were calcareous in nature. The pH (5.39 – 8.85) values indicated that two samples were acidic, four samples were alkaline and two were neutral.

C. Electrical Conductivity and Dielectric Constant of soil samples

The values of electrical conductivity (0.07- 0.18 ds /m) showed that all soil samples were normal i.e. non saline in nature. Dielectric constant of dry soil samples at 4.5 GHz varied from 2.72 to 3.54.

D. Relationship between bulk density and texture of soil

Effect of sand content on soil bulk density was found to be higher than that of the other soil properties. Clayey soils tend to have lower bulk densities and higher porosities than sandy soils. High degree positive correlation of bulk density was observed with sand content (r = 0.9094). While significant negative correlation of bulk density was observed with clay content (r = - 0.6332) and silt content (r = - 0.7343) of soil samples. The bulk density indirectly provides a measure of the soil porosity. Soil porosity is the ratio of the volume of soil pores to the total soil volume. Thus the bulk density of a soil is inversely related to the porosity. We also found strong negative correlation (r = - 0.8859) between porosity and bulk density of soil samples. The impact of the texture on bulk density because of the organic carbon was reported Jones [11]. Bulk density of soil was estimated by using soil texture parameters along with organic carbon content values Wagner et al. [12].

E. Relationship of Electrical Conductivity with sand, silt and clay content of soil

Because of sandy nature of Coimbatore soils electrical conductivity was found to be dependent on sand content and independent on clay content of soil. Our results showed negative significant and high degree positive correlation of electrical conductivity was observed with sand content (r = - 0.6138) and silt content (r = 0.8369) of soil samples respectively. But no significant relationship was observed between electrical conductivity and clay content (r = 0.1572) of soil samples. Marx et al. [13] reported that the clay-textured soil is highly conductive while sandy soils are poor

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conductors. Farahani et al. [14] and Dan Mummey and Lauren Stoffel [15] found that Electrical conductivity of soil correlated negatively with sand content, and positively with silt and clay.

Table 2: Correlation coefficients (r) and Regression equations

Soil Parameters and BD	**Correlation Coeff. (r)**	**Level of Significance**	**Regression Equations**
BD(x) - Sand%(y)	0.9094	High degree Positive	y = 67.05 x - 11.71
BD(x) - Silt%(y)	- 0.7343	Significant Negative	y = -31.08 x + 49.43
BD(x) - Clay%(y)	- 0.6332	Significant Negative	y = -36.69 x + 62.53
BD(x) - Porosity(y)	- 0.8859	Strong Negative	y = -27.52 x + 82.41
Soil Parameters and EC	**Correlation Coeff. (r)**	**Level of Significance**	**Regression Equations**
EC(x) - Sand%(y)	-0.6138	Significant Negative	y = - 122.92 x + 95.68
EC(x) - Silt% (y)	0.8369	High degree positive	y = 96.212 x - 4.08
EC(x) - Clay%(y)	0.1572	Positive non significant	y = 24.716 x + 7.81
EC(x) - BD(y)	- 0.6611	Significant Negative	y = - 0.244 x + 0.443
EC(x) - Porosity(y)	0.5612	Significant Positive	y = 47.41x + 38.62
Soil Parameters and DC	**Correlation Coeff.(r)**	**Level of Significance**	**Regression Equations**
DC(x) - Sand%(y)	0.6753	Significant Positive	y = 17.70x + 27.91
DC(x) - Silt% (y)	- 0.5550	Significant Negative	y = - 3.856x + 17.27
DC(x) - Clay%(y)	- 0.6856	Significant Negative	y = - 14.11x + 54.86
DC(x) - BD(y)	0.5612	Significant Positive	y = 0.199x + 0.795
DC(x) - Porosity(y)	- 0.6450	Significant Negative	y = - 7.124x + 65.7

F. Relationship between Electrical Conductivity and Bulk Density

Since bulk density is also a function of texture of the soil, it is related with electrical conductivity of soil. Bulk density decreases as porosity of dry soil increases and electrical conductivity increases with porosity of dry soil i.e. electrical conductivity of sandy soils is less as compared to clayey soils. This indicates that there is negative correlation between electrical conductivity and bulk density of dry soil. In our study negative significant correlation (r = - 0.6611) was observed between electrical conductivity and bulk density of soil samples. Jung et al. [16] also reported that bulk density at depths from 15-30 cm electrical conductivity was negatively correlated with bulk density.

G. Relationship of Dielectric Constant with sand, silt and clay content of soil

Soil texture can be expressed significantly by its electrical conductivity and dielectric constant. Simple correlation studies showed high degree of relationship between dielectric constant of soil with its physical constituents viz sand, silt and clay. Significant negative correlation of dielectric constant of soil with silt (r =-0.5550) and clay (r =-0.6856) content respectively was observed. While significant positive relationship was found between dielectric constant of soil and sand content (r = 0.6753). Clay textured soil is highly conductive while sandy soils are poor conductors Wang and Schmugge [10]. The availability of micronutrients increased significantly with the increase in finer fractions (silt and clay) Jones [11].

H. Relationship between Dielectric Constant and Bulk Density of soil

Dielectric Constant was found to be dependent on bulk density and wilting point of soil. It was observed that Dielectric Constant has positive significant correlation (r = 0.5612) with Bulk density and negative significant correlation (r = - 0.7) with wilting point of soils. Similar results were reported Wagner et al. [12] in which Dielectric constant of different materials was evaluated under different moisture and density conditions.

V. CONCLUSIONS

From this study we observed following conclusions

1. Bulk density of soil depends on its texture. Moreover it strongly depends on percent sand content in the soil.
2. Similar to bulk density, electrical conductivity and dielectric constant of soil have significant correlations with the texture of soil.
3. From these correlations one can obtain Wilting point of the soil which helps to indicate the water holding capacity of soil.

4. Significant correlations of electrical conductivity/dielectric constant of soil with bulk density makes easy to obtain bulk density of soil from its electrical conductivity/dielectric constant.
5. By knowing the value of electrical conductivity/ dielectric constant of a given soil in Coimbatore under study; one can easily determine the parameters of the soil by using prediction equations in Table 2.

These results are very useful for the scientists working in the field of microwave remote sensing for soils and also for agriculture scientists. 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.

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REFERENCES

[1] Lund, E. D., Christy, C. S, and Drummond, P.E., "Using Yield and Soil Electrical Conductivity (EC) Maps to Derive Crop Production Performance Information", Proceedings of the 5th InternationalConference on Precision Agriculture, Bloomington,Minnesota, USA, 16-19 July, 2000.
[2] Kitchen, N. R., Drummond, S. T., Lung, E. D., Sudduth, K. A. and Buchleiter, G. W., "Soil electrical Conductivity and Topography Related to Yield for Three Contrasting Soil-Crop Systems", Agron. Journal, 95, pp. 483-495, 2003.
[3] Heiniger, R. W., McBride, R. G. and Clay, D. E., "Using Soil Electrical Conductivity to Improve Nutrient Management", Agron. Journal. (95), pp. 508-519, 2003.
[4] Hoekstra, P. and Delaney, A., "Dielectric properties of soils at UHF and microwave frequencies", J. Of Geophysical Res., 79, pp.1699-1708, 1974.
[5] Topp, G. C., Davis, J. L. and Annan, A. P., "Electromagnetic determination of soil water content: measurements in coaxial transmission lines", Water Resour. Res., 16, pp. 574-582, 1980.
[6] Ulaby, F. T., Moore, R. K. and Fung, A. K., "Microwave remote sensing: active and passive", volume 3, Artech House, Dedham, MA, 1986.
[7] Srivastava, S. K. and Mishra, G. P., "Study of the characteristics of the soil of Chhattisgarh at X-band frequency", Sadhana, 29(4), pp.343-348, 2004.
[8] Calla, O P N, Baruah, A., Das, B., Mishra, K. P. and Haque, S. S., "Variability of dielectric constant of dry soils with its physical constituents of Indian soils at microwave frequencies and validation of CVCG model ", Indian J. of Radio and Space Physics, 33, pp.125- 129, 2004.
[9] Davood Namdar-Khojasteh, Mahdi Shorafa and MahMoud Omid, "Evaluation of dielectric constant by clay mineral and soil physico-chemical properties", African Journal of Agricultural Research, 7(2), pp.170- 176, 2012.
[10] Wang J. R. and Schmugge, T. J., "An empirical model for complex dielectric permittivity of soils as a function of water content", IEEE Transactions on Geoscience and Remote Sensing, 18, pp. 288- 295, 1980.
[11] Jones, C. A., "Effect of Soil Texture on Critical Bulk Densities for Root Growth", Soil Science Soc. Am. J., Vol.47, pp. 1208-1211, 1983.
[12] Wagner, L.E., Ambe, N. M. and Ding, D., "Estimating a Proctor density curve from intrinsic soil properties", Trans. Am. Soc. Agric. Eng, Vol.37, pp. 1121-1125, 1994.
[13] Marx, E. S., Hart, J. and Stevens, R., G., "Soil Testing Interpretation Guide", Oregon State University, Corvallis, 1999.
[14] Farahani, H. J., Buchleiter, G. W. and Brodahl, M.K., "Characterization of apparent soil electrical conductivity variability in irrigated sandy an non-saline fields in Colorado", American Society of Agricultural Engineers, Vol. 48(1): pp.155−168, 2005.
[15] Dan Mummey and Lauren Stoffel, Report on "Analysis of soil chemical and physical properties under the north center-pivot irrigation system", MPG Ranch Research, 2012.
[16] Jung, W. K., Kitchen, N.R., Sudduth, K.A., Kremer, R. J. and Motavalli, P. P., "Relationship of apparent soil electrical conductivity to claypan soil properties", Soil Sci. Soc. Am. J. 69: pp. 883-892, 2005.