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Dielectric Constant related with Physico-Chemical Characteristics of Soil samples from Chandavad Tahsil of Nashik District

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Abstract: This paper consists of the measurement of dielectric properties of soil samples of Nasik region. Soil samples were collected from agricultural land of Nashik region. The soils were categorized as loamy sand, sandy loam and clay. The soils were analyzed for the status of available nutrients. These properties are important in better understanding of soil physics, agricultural application and analyzing the satellite data in remote sensing. The dielectric constant of Chandwad soil varies with the texture of the soil. These variations have been found to be strongly dependent on the texture of soils. Our results show that dielectric constant has negative correlation with sand and positive correlation with silt and clay. Our results show significant positive correlation of electrical conductivity and dielectric constant. Also, the dielectric constant 2.71-2.74 may be suitable for maize, bajra, onion and 2.77-2.78 for grapes crops.

Keywords: Dielectric constant, Dielectric loss, Emissivity etc.

1. INTRODUCTION:

The quality of soil is controlled by physical, chemical and biological components of a soil and their interactions [1]. Measurements of complex dielectric permittivity in this frequency range were also carried out for different concentration of cow manure in soil [2]. Dielectric properties of soil–organic matter mixtures using coaxial impedance dielectric reflectometry are measured [3]. The dielectric properties of soil with increasing percentage of humus at S-band microwave frequency are reported [4]. Dielectric properties of different soil textures collected from Karnataka state, at X-band microwave frequency using infinite sample method has been studied [5]. The measurement of dielectric constant of soil as a function of moisture content has been carried out over wide frequency range in the past several years using soils of widely different texture structures by Wang and Schmugge [6]. Calla et al [7] have studied the dielectric properties of dry and wet soil at microwave frequencies and reported that the dielectric constant of soil is strongly dependent on moisture content. Sengwa and Soni [8] have studied the variation of dielectric constant with density of dry minerals of soil at 10.1 GHz. Abidin Kaya and Hsai-Yang Fang studied the dielectric properties of contaminated soils and the objective of this study is to investigate the possibility of using dielectric constant and electrical conductivity to characterize and identify contaminated finegrained soils [9]. D.H. Gadani and A.D. Vyas measured the complex dielectric constant of soils of Gujrat at X-band and C-band microwave frequencies. This study shows that the dielectric constant of soils increases slowly with increase in the moisture content in the soil up to transition moisture, after which it increases rapidly with moisture content [10]. A.D. Vyas [11] measured the values of dielectric constant and dielectric loss of sand and sandy loam for various moisture contents at X-band microwave frequency.

He observed that the permittivity of sandy loam soil increases slowly up to 8% moisture content, after which it increases linearly with moisture content. For sandy soil he observed a small increase in permittivity up to 8% moisture content after which it increased sharply. He also calculated the emissivity values for normal incidence for the sand and sandy loam soil with moisture content from the dielectric data. It has been observed that the emissivity of sandy loam change from 0.93 to 0.60 for the moisture content variation from 0 to 20% by dry weight of the soil. The emissivity of sand decreased from 0.93 to 0.49 for the same variation in the moisture content. It has been explained that the decrease in emissivity with increase in permittivity which causes a total increase in reflected energy and thereby a total decrease in emitted energy. The properties of dry soil along with its type have a great importance in agriculture. For microwave remote sensing applications, dielectric constant is the primary important electrical property for dry soil. It is now confirmed that the dielectric properties of soils are mainly depend on their MC. Soil is an intimate mixture of inorganic and organic materials, air and water. The soil has chemical, physical and electrical characteristics. Chemical characteristics are organic matter, micro-macronutrients, pH etc. and physical characteristics are colour, texture, grain, bulk density, water holding capacity etc. whereas electrical characteristics comprise dielectric constant, electrical conductivity and permeability. The dielectric constant is the most important parameter in microwave remote sensing for the study of dry and wet soils and in microwave remote sensing of soil moisture, both active and passive. For microwave remote sensing dielectric constant is the primary important electrical property for dry soil. However 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. The naturally available macronutrients of soil show variation in dielectric properties. Inorganic matter in soil appreciably affects its dielectric properties [12].

2. MATERIALS AND METHODS:

Study Area

Chandwad belongs to Khandesh and Northern Maharashtra region. In recent years, efforts have been made to analyze and find out the nature of soil and their characteristics for suitable and proper growth of crops and their productions. Chandwad is a small town in the state of Maharashtra, India, with the population close to 20,000 people. The latitude of Chandwad, Maharashtra, India is 20.327127, and the longitude is 74.247276. It is surrounded by big mountains and is like a hill station. Onion, tomato, pomegranate, bajra and maize continue to be the major crops grown in Chandwad. However, farmers are experimenting to encash more money with modern agricultural practices with grapes and sugarcane too.

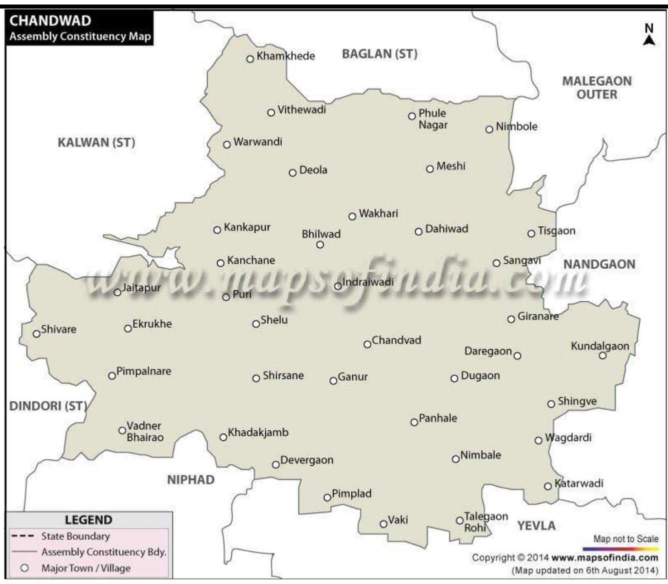

Fig. 1 Study area

Soil Sampling

Before sampling 15 mm topsoil was removed. Soil samples were collected from ten different agricultural locations of Chandwad in zigzag pattern as per fig 5.1.Represented soil samples were collected with wooden tools to avoid any contamination of the soils. Four to six pits were dug for each sample. From each pit sample was collected at a depth 0-20cm. A composite sample of about 1kg was taken through mixing of represented soil sample. The sieved out fine particles are then dried in the hot air oven to a temperature around 110oC for about 24 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. After sieving all the samples were packed in the polythene bags for laboratory investigations.

Soil Properties

The samples were analyzed for their physical parameters texture, bulk density particle density, porosity. Also soil samples are analyzed for chemical parameters such as pH, electrical conductivity, organic carbon and $CaCO_3$ by standard analytical methods. 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.

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

$$Wt = 0.45 \times Wp + 0.165$$

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,

$$\text{Porosity} = 1 - \frac{Bulk\ Density}{Particle\ Density}$$

Measurement of Dielectric Constant of dry Soil Samples

The waveguide cell method is used to determine the dielectric properties of the dry soil samples. An X-band microwave set-up in the TE10 mode with Gunn source operating at frequency 9.85 GHz, 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.

Soils samples of various moisture contents are prepared by adding an exact amount of distilled water to dried soil. The moisture content is percentage by dry weight Wc (%) is calculated using following relation.

Wc (%) = [(weight of wet soil - weight of dry soil) / (weight of dry soil)] x 100 ------- (1)

This soil sample was considered as dry or 0 % moisture content soil sample. Then on the basis of volumetric analysis 5%, 10% and 15% moisture content soil samples were prepared and the dielectric constant of soil samples at microwave frequency 9.56 GHz.

The X-band microwave set-up consists of a Gunn oscillator in combination with Pin modulator as a microwave source. The waveguide cell method was used for measurement of dielectric constant and dielectric loss of soil samples. The complex dielectric permittivity is the fundamental electrical property which describes these interactions, which is mathematically expressed as

$$\varepsilon = \varepsilon' - j\varepsilon''$$

Where ε'= dielectric constant and ε'' = dielectric loss factor

Since the dielectric constant of a soil depends on the moisture, the presence of salts in water will also affect its dielectric properties. In irrigation, soil salinity makes it more difficult for plants to absorb soil moisture which affects the plant growth and ultimately crop yield. To keep track of changes in salinity and anticipate further degradation, monitoring was needed. In that paper, the experimentally measured values of the dielectric constant and dielectric loss have been shown for soil with varied salinity levels.

The following table no.1 gives Physical parameters of soil samples.

Sample No.	Bulk Density (gmcm-1)	Particle Density (gmcm-1)	WHC (%)	Hydraulic conductivity (cm/hr)	Sand (%)	Silt (%)	Clay (%)	Textural Class	Wilting point (Wp)
1	1.24	2.49	40	3.95	69.92	11.68	18.4	Sandy Loam	0.1109
2	1.3	2.44	40	3.39	84.22	10.38	5.4	Loamy Sand	0.0396
3	1.49	2.43	37	3.67	78.17	17.08	4.75	Loamy Sand	0.0404
4	1.31	2.36	41	3.67	89	7.17	3.83	Loamy Sand	0.0290
5	1.34	2.4	35	3.95	71.22	21.88	6.9	Loamy Sand	0.0551
6	1.25	2.34	38	4.8	70.15	25.52	4.33	Loamy Sand	0.0435
7	1.29	2.43	40	4.52	63.5	24.32	12.18	Sandy Loam	0.0853
8	1.18	2.2	59	1.97	35.05	26.5	38.45	Clay Loam	0.2290
9	1.21	2.29	48	1.83	38	30.3	31.2	Clay Loam	0.1925
10	1.19	2.21	49	2.53	64.07	12.9	23.03	Sandy clay Loam	0.1368

Table 1: Physical parameters of soil samples

Sample No.	Dielectric constant	Dielectric loss	Tangent loss	Microwave conductivity	Transient temperature	Emissivity
1	2.7176	0.2403	0.08668	0.126472	3.96194E+10	0.937727
2	2.7185	0.2445	0.08809	0.128677	4.03567E+10	0.937592
3	2.7410	0.2526	0.09012	0.132946	4.21070E+10	0.936437
4	2.7561	0.2562	0.09114	0.134840	4.28290E+10	0.936100
5	2.7710	0.2569	0.09071	0.135209	4.32684E+10	0.935213
6	2.7721	0.2633	0.09281	0.138577	4.44230E+10	0.935007
7	2.7763	0.2870	0.10116	0.151051	4.84250E+10	0.934998
8	2.7813	0.2927	0.10265	0.154051	4.96339E+10	0.934402
9	2.7819	0.2929	0.10269	0.154156	4.96818E+10	0.934369
10	2.7926	0.3030	0.10569	0.159472	5.16598E+10	0.933752

Table .2: Electrical parameters of soil samples of Chandavad Tahsil

The above table .2 electrical parameters of soil samples of Chandavad Tahsil.

3. RESULTS AND DISCUSSIONS:

3.1 Relationship between electrical conductivity and dielectric constant of soils:

In fig. 2 variation of Electrical Conductivity with Dielectric constant of soil samples are shown. Our results give a positive correlation between dielectric constant and electrical conductivity (R2=0.4413) for the soil samples.

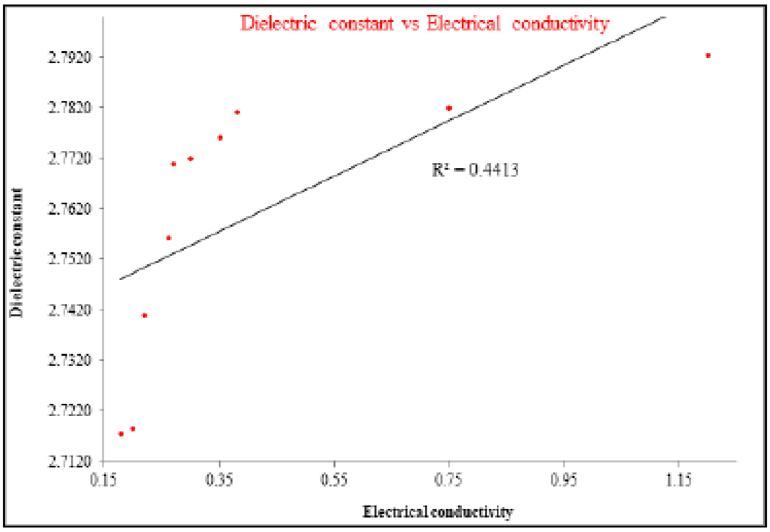

Fig.2: Variation of Dielectric constant with Electrical Conductivity of soil samples

3.2 Relationship of electrical conductivity and dielectric constant with soil texture:

Statistical correlation between electrical conductivity and dielectric constant of soil with its physical constituents, i.e., sand, silt and clay shows high degree correlation.

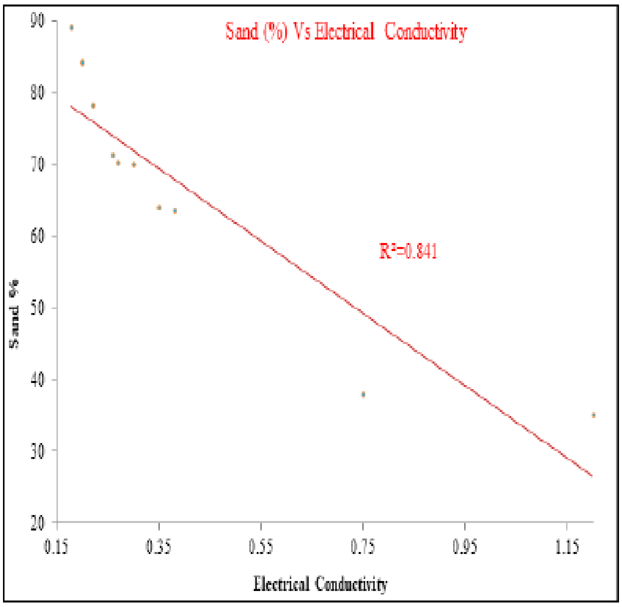

Fig.3 (a): Variation of electrical conductivity with sand (%)

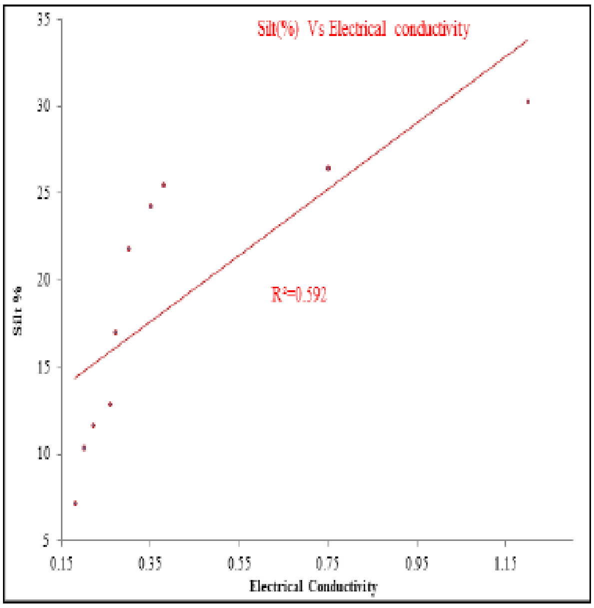

Fig.3 (b): Variation of electrical conductivity with silt(%)

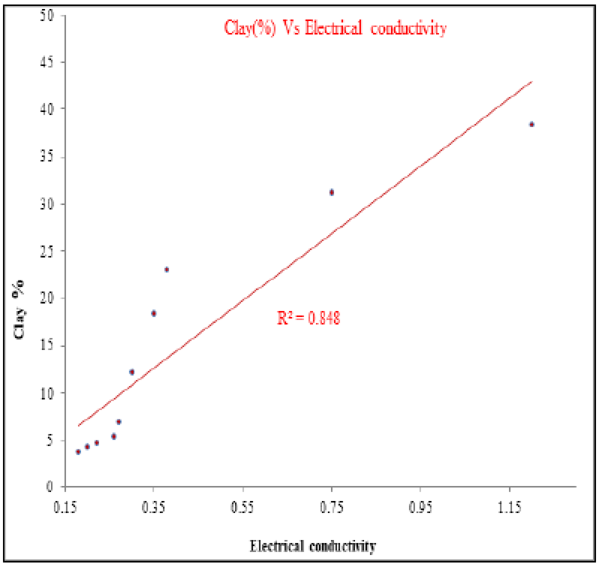

Fig.3 (c): Variation of electrical conductivity with clay (%)

Fig. 3 (a-c) shows variation of electrical conductivity with sand, silt and clay of soil samples. Our results thus show that the electrical conductivity has strong positive and strong negative relationship with clay content (R2=0.848) and sand content (R^2=0.841) of soil samples respectively, whereas there is positive but less significant correlation was observed between electrical conductivity of soil with silt content (R^2=0.592).

Sample No.	Name of the farmer	Area	Previous crop	New crop	Dielectric constant ε'	Favourable Crop
1	Sharad Shivaji Ushir	Khadakjamb	Onion	Bitter guard	2.7176	Maize, Onion, Bajra
2	Nimba Yashwant pansare	Puri	Tomato,Onion	Tomato,Onion	2.7185	Maize, Onion, Bajra
3	Sahebrao Murlidhar Jadhav	Shelu	Grapes	Grapes	2.7410	Maize, Onion, Bajra
4	Raman Kondaji Jadhav	Chandwad	Grapes	Grapes	2.7561	Maize, Onion, Bajra
5	Kisan Vaman Yashwante	Indraiwadi	Methi,Brijal	Bajra,Onion	2.7710	Grapes
6	Shavan Bhikaji Sonawane	Dugaon	Maize,Bajra,Onion	Maize,Onion	2.7721	Grapes
7	Aananda Paru Thombare	Shingave	Bajra,Onion	Moong,Onion	2.7763	Grapes
8	Madhav Namdeo Gangurde	Nimbole	Maize	Bajra,Soyabean	2.7813	Grapes
9	Sakubai Muralidhar Kumbharde	Panhale	Maize,Onion,Tomato	Maize,Onion,Bajra	2.7819	Grapes
10	Hemant Jairam Patil	Ganur	Grapes	Grapes	2.7926	Grapes

As per our observations and data, the above table 2 shows dielectric constant 2.71-2.74 may be suitable for maize, bajra, onion and 2.77-2.78 for grapes crops.

Conclusion:

From the above results and discussion we have concluded that the dielectric constant of soils depends on many factors like frequency, moisture, and its physical and chemical compositions. It is observed that the value of dielectric constant increases as moisture content increases. The value of dielectric loss increases as moisture content increases. Also it is observed that the dielectric loss is directly proportional to the ac microwave conductivity and transition temperature. It has been found that emissivity decreases with increase in moisture content. In the interpretation of various remote sensing data, the dielectric constant and dielectric loss of soil samples measured at X band microwave frequency plays important role.

The dielectric constant of Chandwad soil varies with the texture of the soil. These variations have been found to be strongly dependent on the texture of soils. Our results show that dielectric constant has negative correlation with sand and positive correlation with silt and clay. Our results show significant positive correlation of electrical conductivity and dielectric constant. Also, dielectric constant 2.71-2.74 may be suitable for maize, bajra, onion and 2.77-2.78 for grapes crops.

The dielectric constant of Chandwad soil depends on the bulk density and hence porosity. Results show that dielectric constant has negative correlation with bulk density and positive correlation with porosity. By knowing the correlation coefficient of various soil properties and nutrients with dielectric constant, it is easy to understand and analyse the satellite data. Results will be helpful for the prediction of soil texture, nutrients type and their concentrations present in the soil.

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