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# Electrical Conductivity as a Tool for Determining the Physical Properties of Indian Soils

**Pravin R. Chaudhari[*], Dodha V. Ahire[*], Manab Chkravarty[**] and Saroj Maity[**]**

[*]Microwave Research Laboratory, Z. B. Patil College, Dhule - 424002, India
[**]Space Application Centre, ISRO, Ahmedabad – 380015, India

***Abstract-*** In the present research work, studies on correlation factors of electrical conductivity of soils in India with their physical properties like texture, bulk density and porosity were reported. We collected 29 soil samples from different locations of Karnatakta, Tamilnadu, Uttarakhand and Madhya Pradesh states of India. Soil samples were analyzed for physical parameters. Statistical correlations were obtained between electrical conductivity and different parameters of soil samples. Our results show significant correlations between electrical conductivity and physical parameters of soils. Besides agricultural applications, such studies may find importance in better understanding of soil physics and also for analyzing the satellite data in remote sensing.

***Index Terms***- Electrical Conductivity, Indian soils, Texture and bulk density of soil.

## I. Introduction

Farmers practicing precision agriculture can now collect more detailed information about the spatial characteristics of their farming operations than ever before. In addition to yield, boundary and field attribute maps, new electronic, mechanical, and chemical sensors are being developed to measure and map many soil and plant properties. Soil EC is one of the simplest, least expensive soil measurements available to precision farmers today. Electrical conductivity (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. EC may provide a rapid and inexpensive way to estimate soil quality on the ranch after calibration.

Soil Electrical Conductivity (EC) is one of the soil properties which have a good relationship with the other soil characteristics. As measuring soil electrical conductivity is easier, less expensive and faster than other soil properties measurements, it can be used as a good tool for obtaining useful information about soil.

Soil texture is a soil property used to describe the relative proportion of different grain sizes of mineral particles in a soil. Particles are grouped according to their size into what are called soil separates. These separates are typically named clay, silt, and sand. Soil texture classification is based on the fractions of soil separates present in a soil. Soil electrical conductivity (EC) is a measurement that correlates with soil properties that affect crop productivity, including soil texture, cation exchange capacity (CEC), drainage conditions, organic matter level, salinity, and subsoil characteristics.

The soil has physical as well as electrical properties. Colour, texture, grain size, bulk density etc., comprise the physical properties while, electrical properties include dielectric constant, electrical conductivity and permeability. The quality of soil is controlled by physical, chemical and biological components of a soil and their interactions [1]. The concept of soil health and soil quality has consistently evolved with an increase in the understanding of soils and soil quality attributes. Perveen S. et al. [2] have studied micronutrient status of soils and their relationship with various physico-chemical properties. Chhabra G. et al. [3] have shown that available manganese decreased with soil pH and available copper increased with clay and organic carbon content. Results of physical and chemical tests provide information about the capacity of soil to supply mineral nutrients. Martin C. et al. [4] have shown that the electrical conductivity of soil water is a good indicator for absorbing the amount of nutrients available for crops.

## II. MATERIALS AND METHODS

### *A. Study Area*

Haridwar district is located in south – western part of Uttarakhand State. It lies from 290 35' to 300 40' North latitude and 770 43 ' to 780 22' East longitude. The geographical area of the district is 2360 km2. Haridwar district has been divided into three Tehsils viz. Roorkee, Bhagwanpur and Laksar. The topography of Haridwar is characterized by sandy soils which do not retain water for long time. Due to unavailability of moisture in the soil the crop productivity is not very good in the region. Also, due to variation in altitude the rainfall also differs from place to place affecting the crop production.

Coimbatore is located at an elevation of about 411 meters in Tamilnadu. It lies between 10° 10' and 11° 30' of the northern latitude and 76° 40' and 77° 30' of eastern longitude. The mean maximum and minimum temperatures varies between 35 °C and 18 °C highest temperature ever recorded is 41 °C and lowest is 12 °C. On an average, the district gets 695 mm. of rainfall in a year. Coimbatore receives high rainfall from North East Monsoon of 444.3 mm. followed by South West Monsoon Period and hot weather period. Rainfall distribution is also good. 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 Coimbatore district.

Bangalore is situated in the southeast of the South Indian state of Karnataka. It is positioned at 12.97° N 77.56° E and covers an area of 2,190 square kilometers. Due to its

elevation, Bangalore enjoys a pleasant and equable climate throughout the year. Winter temperatures rarely drop below 11°C and summer temperatures seldom exceed 36°C. Bangalore receives about 970 mm of rain annually, the wettest months being August September, October and in that order. The summer heat is moderated by fairly frequent thunderstorms and occasional squalls causing power outages and local flooding.
Indore is located in the western region of Madhya Pradesh, on the southern edge of the Malwa plateau. It lies on the Saraswati and Khan rivers, which are tributaries of the Shipra River and has an average elevation of 553.00 meter above mean sea level. It is located on an elevated plain, with the Vindhyachal range to the south.

### *B. Soil Sampling and physical analysis*

The aims of this study was to measure electrical conductivity of soil samples from four states of India and obtain its relationship with the soil particle distribution and bulk density of soil. Before sampling 15 mm topsoil was removed. Soil samples were collected from eight 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 and then allowed to dry in air for 1 hour. The proposed samples were analyzed for physical properties using standard procedures.

### *C. Measurement of EC and pH of Soil Samples*

A pH and Electrical Conductivity of soil samples were measured by Soil Testing Kit Model 161E. A 20 gm of collected soil was weighed out into a 150 ml plastic jar and 100 ml distill water was added to it. Lid of jar was packed tightly and stirred continuously for 5 minutes. Then it was kept overnight and stirred again. Allowed to set for 15 minutes and strained sample into clean measuring cup. A pH and Electrical conductivity readings were taken.

## III. DISCUSSION

### *A. Texture, Bulk Density and Porosity of soil samples*

The ranges of sand, silt, clay, bulk density and porosity of samples collected from four sites are listed in **Table 1.** The soils collected from Rookie are categorized as Sandy Loam, from Coimbatore as Loamy sand and Sandy, from Indore as Loam Sandy and Loamy and that from Bangalore as Loamy and Sandy Loam.

### *B. CaCO3, pH and EC of soil samples*

The ranges of CaCO3, pH and Electrical Conductivity of soils collected from four sites are also listed in **Table I.** The Calcium Carbonate (CaCO3) content of soil samples from four sites showed that the soils from Rookie are Slightly Calcareous; soils from Coimbatore and Indore are Moderately Calcareous and that from Bangalore are Slightly Calcareous and Moderately Calcareous. The pH values indicated that soils from Rookie and Indore are Moderately Alkaline, while from Coimbatore and Bangalore soils are Moderately Alkaline and acidic. The values of electrical conductivity showed that all soils from all four sites are normal i.e. non saline in nature.

## IV. RESULTS

Correlation coefficients (r) between soil properties and Regression Equations are shown in **Table II.**

### *A. Relationship of bulk density with texture and porosity 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. Positive significant third order polynomial correlation of bulk density was observed with sand content (r = 0.6656). While significant negative third order and fifth order polynomial correlation of bulk density was observed with silt content (r = -0.5788) and clay content (r = -0.4722) of soil samples respectively. 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 linear correlation (r = -0.8967) between porosity and bulk density of soil samples.

It was observed that the bulk density is dependent on calcareous and saline nature of soils but independent on whether the soil is acidic or alkaline.

Jones [5] reported that the impact of the texture on bulk density is much, because of the organic carbon. Wagner et al. [6] estimated soil bulk density using soil texture parameters along with organic carbon content values. Bernoux, et al [7] found a correlation between texture and bulk density. Dinesh Kumar et. al. [8] indicated that soil texture specific tests would be required to determine the correct organic matter level to achieve a target bulk density to avoid the problem of compaction.

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**Table I : Parameters of Soils from four sites of India**

| Name of Site | Sand (%) | | Silt (%) | | Clay (%) | | Bulk Density ($Mgm^{-3}$) | | E.C. ($dSm^{-1}$) | | pH | | CaCO3 (%) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max |
| Rookie (Uttarakhand) | 58 | 67 | 18 | 24 | 13 | 18 | 1.16 | 1.45 | 0.1 | 0.26 | 6.88 | 8.34 | 1.25 | 2.00 |
| Coimbatore (Tamilnadu) | 67 | 90 | 3 | 17 | 5 | 27 | 1.25 | 1.57 | 0.03 | 0.18 | 5.39 | 8.85 | 1.00 | 1.85 |
| Indore (Madhya Pradesh) | 19.50 | 57.25 | 18.50 | 40.25 | 12.50 | 40.00 | 1.33 | 1.42 | 0.08 | 0.13 | 7.8 | 8.00 | 1.2 | 18.00 |
| Bangalore (Karnataka) | 42.25 | 57.75 | 22.5 | 36.5 | 17.5 | 24.25 | 1.19 | 1.55 | 0.032 | 0.1 | 6.01 | 7.89 | 0.25 | 4.75 |

**Table II : Correlation Coefficients**

| Soil Parameters Related with BD | Correlation Coefficient (r) | Level of Significance | Regression Equations |
|---|---|---|---|
| B D(x) - Sand%(y) | 0.6656 | Significant Positive | $y = 7E\text{-}06x^3 - 0.001x^2 + 0.052x + 0.679$ |
| B D(x) - Silt%(y) | -0.5788 | Significant Negative | $y = -3E\text{-}05x^3 + 0.002x^2 - 0.048x + 1.588$ |
| B D(x) - Clay%(y) | -0.4722 | Significant Negative | $y = 6E\text{-}07x^5 - 6E\text{-}05x^4 + 0.002x^3 - 0.036x^2 + 0.224x + 1.035$ |
| B D(x) - Porosity(y) | -0.8967 | Strong Negative | $y = -38.06x + 99.25$ |
| **Soil Parameters Related with EC** | **Correlation Coefficient (r)** | **Level of Significance** | **Regression Equations** |
| EC(x) - Sand%(y) | -0.4472 | Significant Negative | $y = -3620.x^3 + 2790.x^2 - 619.9x + 103.2$ |
| EC(x) - Silt% (y) | 0.5186 | Significant Positive | $y = -7410.x^4 + 10374x^3 - 4600.x^2 + 757.7x – 19.95$ |
| EC(x) - Clay%(y) | 0.3131 | Positive but no Significant | $y = 4E+06x^6 - 4E+06x^5 + 2E+06x^4 - 32048x^3 + 28047x^2 - 1143.x + 35.04$ |
| EC(x) - Porosity(y) | 0.4743 | Significant Positive | $y = 6808x^5 + 94326x^4 - 56972x^3 + 11183x^2 – 794.7x + 61.64$ |
| EC(x) - BD(y) | -0.5514 | Significant Negative | $y = 34232x^5 - 24368x^4 + 6521.x^3 - 809.8x^2 + 44.22x + 0.627$ |
| EC(x) - CaCO3(y) | 0.3701 | Positive but no Significant | $y = -4170.x^4 + 4794.x^3 - 1782.x^2 + 238.6x - 5.826$ |

### *B. Relationship of Electrical Conductivity with texture and bulk density of soil samples*

Soil texture can be expressed significantly by its electrical conductivity. Correlation studies showed positive sixth order polynomial but not significant relationship between electrical conductivity and clay content (r = 0.3131) of soil samples. While third order polynomial significant negative and fourth order polynomial significant positive correlation of electrical conductivity was observed with sand content (r = -0.4472) and silt content (r = 0.5186) of soil samples respectively. Marx et al.[9] reported that the clay-textured soil is highly conductive while sandy soils are poor conductors. H. J. Farahani et al. [10] and Dan Mummey and Lauren Stoffel [11] found that Electrical conductivity of soil correlated negatively with sand content, and positively with silt and clay. 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 fifth order polynomial negative significant correlation (r = -0.5514) was observed between electrical conductivity and bulk density of soil samples. Similar result was reported by Jung et al. [12]. They found that bulk density at depths from 15-30 cm electrical conductivity was negatively correlated with bulk density.

## V. CONCLUSIONS

1. Higher order correlations were observed between bulk density and texture of Indian soils.
2. Higher order correlations were observed between Electrical Conductivity and Physical Parameters of Indian soils.
3. There was inverse correlation between Electrical Conductivity and Bulk Density of Indian Soils.
4. Higher order positive but no significant correlation was observed between Electrical Conductivity and Calcareous nature of Indian Soils.
5. Regression equations between Electrical Conductivity and Physical Parameters may be used to determine the significant level of Physical Constituents of Indian Soils.

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## AUTHORS

**First Author –** Pravin R. Chaudhari, Microwave Research Laboratory, Z. B. Patil College, Dhule - 424002, India
**Second Author –** Dodha V. Ahire, Microwave Research Laboratory, Z. B. Patil College, Dhule - 424002, India
**Third Author –** Manab Chkravarty, Space Application Centre, ISRO, Ahmedabad – 380015, India
**Fourth Author –** Saroj Maity, Space Application Centre, ISRO, Ahmedabad – 380015, India

**Correspondence Author –** Dr. Pravin R. Chaudhari , Microwave Research Laboratory, Department of Physics, Z. B. Patil College, Dhule-424002 (India), E-mail: prc_61@rediffmail.com , Contact No. : 09422757654