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Research Article

Passive Microwave Study of Salt Affected Agricultural Soil

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Abstract

Salt affected agricultural soil from superficial horizon of local profile of Alwar region with textural composition sand=30.2%, silt=59.7% and clay=10.1% has been selected for an estimation of observable parameter of passive microwave remote sensing. Artificially salinized and moistened soil samples with different concentrations in part per million (ppm) of Sodium Chloride corresponding to 0 ppm to 35000 ppm soluble in conductivity water are prepared.The real and imaginary parts of dielectric constant ε' and ε" for artificially moistened and salinized soil with Sodium Chloride are determined at different levels of salinization. Real and imaginary part of dielectric constant is measured by wave-guide cell method at a single microwave frequency 9.78 GHz and at constant temperature 33^{0}C. The Fresnel reflectivity of salinized and moistened soil is determined for different observation angles. Further, Microwave emissivity of salinized soil is also calculated with suitable model calculations in view of passive microwave remote sensing. Microwave emissivity decreases with both salinity and moistness. Effect of salinity on emissivity is very small and considerable only at higher wetness of soil. In dry soils no impact of salinity observed on emission behaviour. High dielectric contrast between emitting layer of soil and air causes more energy to reflect back within the soil media than that of transmitted out in air. Hence, emissivity of soil decreases as salinity increases.

Keywords: Dielectric constant, Microwave emissivity, Salinization

Introduction

The increasing percentage concentration of salts in agricultural soil is a crucial environmental hazard and this may be one of the causes for the decline and disappearance of a civilization [1]. In so many regions of the world, presence of salt is one of the principal causes of soil degradation. An important mapping study of salt affected soils located in the south-eastern tract of arid Rajasthan performed by Kolarkar et al [2] concluded that natural salt affected soils are mostly due to sodium chloride followed by calcium chloride and sodium sulphate.

Generally, there are three types of salt-affected soils namely saline, alkaline and saline-sodic soils found at different agricultural locations. (i) In saline soil excessive water-soluble salts in the soil accumulate and salts include chlorides and sulphates of sodium, potassium, magnesium and calcium. Saline soils contain excessive concentration of soluble chloride and sulphate salts that cause electrical conductivity (EC) level of soil to exceed 4.0 desiemens per meter (dS.m^{-1}). Soil salinity can be determined by measuring the EC of a solution extracted from a water saturated soil paste. Crop yields are not significantly affected where the salt level is corresponding to conductivity values from 0 to 2.0 dS.m^{-1}. The conductivity level of soil from, 2.0 to 4 .0 dS.m^{-1} restricts the cultivation of some crops, 4.0 to 5.0 dS.m^{-1} restrict farming of many crops and above 8.0 dS.m^{-1} restrict all except of very tolerant crops.**(ii) Alkaline:** Alkaline soils are characterized by high pH (> 9.0) and have poor soil structure and a low infiltration capacity. Soil alkalinity is associated with the presence of relatively high proportion of sodium bicarbonates ($NaHCO_3$) or sodium carbonates (Na_2CO_3) in the soil. Alkaline soils contain high exchangeable sodium percentage (ESP). The clay particles of the soils attract and adsorb cations (positively charged atoms); desirable (useful) cations in the soil include calcium, magnesium, potassium and ammonium. These cations readily interchange with one another. Alkaline soils are high in exchangeable sodium so that it replaces desirable

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cations with sodium. The amount of exchangeable sodium in soil is reported as the Sodium Adsorption Ratio (SAR). This is the ratio of the amount of positive charge contributed to a soil by sodium to that of contributed by calcium plus magnesium. An SAR value below 13.0 is desirable for cultivation. Higher values of exchangeable sodium can deteriorate soil structure and restrict water infiltration. Alkaline soils are hard and cloddy when becomes dry and tend to crust. Water intake usually is poor, especially in soils high in silt and clay. (iii) Saline-Sodic soils: Saline-Sodic soils contain large amounts of salts as well as high exchangeable sodium. If excessive salts are present as well as excessive sodium, the physical condition of the soil and water intake may be satisfactory, but plant growth may be restricted.

Reasons of Salinization and Alkalization of Soil

Large numbers of reasons are associated with salt accumulation of agricultural soils. The few important of them are as: The salts are readily present in the parent materials of soil, salts can be formed during weathering of the parent rocks, salts can be air or water borne, saline ground water comes out through capillary action and evaporates , leaving behind the salts at surface and The salts can be brought by irrigation water.

Identification and detection of salt affected areas are very important due to environmental and agricultural salinization of soil [3]. The ability to monitor soil salinity accurately from microwave remote sensing is very important because it saves labour, time, cost and effort when compared to in-situ field work. The basic observable parameter of at the sensor in passive microwave remote sensing is Microwave Emissivity. Microwave emissivity primarily depends on the dielectric constant of soil. Thus, in case of salinization of soil due to presence of salt there must be a contrast in dielectric properties of soil with respect to salt free soil [4]. The emissivity of soil at microwave frequencies depends upon the percentage of contaminants in the soil.

Experimental procedure and theory

The effect of soil moisture on dielectric properties of soil has been widely investigated and variety of models is devised. But a little work has reported regarding the influence of salts on dielectric properties of soils. However, the concentration of salts in water affects its dielectric properties in a well-known manner. When saline water is mixed with soil, the dielectric properties of this mixture will exhibit a different manner. Salts may affect the real and imaginary parts of dielectric constant, the real part ε' which is related to the polarization of medium that governs the velocity of propagation of microwaves through the material and imaginary part ε'' which is related to the conductivity of the medium and represents the microwave attenuation by energy absorption (ohmic losses).

The soil from superficial horizon of local profile of Alwar region with textural composition sand=30.2%, silt=59.7% and clay=10.1% has been selected for preparation of artificially salinized and moistened soil samples. Firstly salt free soil is prepared by leaching of salts from the soil through repeatedly flushing with conductivity water until the residual conductivity of soil extract. Salt free soil was oven dried for twenty-four hours at 110 ^{0}C and divided in eight different Groups namely A, B, C, D, E, F, G and H. Desired gravimetric percentage (0.0%, 2.0%, 4.0%, 6.0%, 8.0%, 10.0%, 12.0%, and 14.0%) of saline water having eight different concentrations of salinity, have been mixed with eight sub-groups of each Group (A to H) of salt free soil samples. The eight different solutions of saline water with different concentrations in part per million (ppm) of Sodium Chloride corresponding to 0 ppm, 5000 ppm, 10000 ppm, 15000 ppm, 20000 ppm, 25000 ppm, 30000 ppm and 35000 ppm soluble in conductivity water are prepared. Total sixty four prepared samples of saline soil at different levels of salinity (0 ppm to 35000 ppm) and moistness (0.0%, to 14.0%) are prepared. The saline water properly mixed with salt free soil and these artificially salinized and moistened soil samples are kept in air tight plastic container for uniform mixing and to avoid any evaporation from soil. Time of setting was twenty-four hours for homogeneous distribution of salty water within the entire volume of soil.

Determination of Dielectric Constant

The values of real and imaginary part of dielectric constant ε' and ε'' of these artificially salinized and moistened soil samples are determined at a single microwave frequency 9.78 GHz and at a single temperature 35.0 ^{0}C using a wave guide cell method developed by Yadav and Gandhi [5]. The ε′ and ε″ of the soil samples are measured using shift in minima of the standing wave pattern inside the slotted section of a X-band rectangular wave guide excited in TE_{10} mode. Magnitude of the complex dielectric constant of soil is given by the equation (1).

$$\varepsilon = \left|\varepsilon^*\right| = \left|\varepsilon' - j\varepsilon''\right| \quad (1)$$

Estimation of Microwave Emissivity of Saline Soil

The emissivity of saline soil is estimated using the emissivity model proposed by Peak [6] treating soil as a single layer of homogeneous media. The emissivity (e) of the soil is the ratio of brightness temperature T_B to the physical temperature T of soil followed by the equation (2).

$$T_B = e.T \quad (2)$$

The brightness temperature T_B at radiometer can be computed by equation (3).

$$T_B = (1 - W)\, T + T_{sky} \quad (3)$$

Where, W is the scattering albedo and T_{sky} is the sky temperature. For smooth and bare soil surfaces W can be replaced by Fresnel reflectivity R and contribution of T_{sky} is very small of the order of 4.0 K. So we may neglect T_{sky} and using equations (2) and (3) the emissivity e can be written as:

$e = 1 - \Gamma$ (4)

The horizontal component of microwave emissivity (e_h) is the functions of view angle (θ) which can be written as:

$e_h(\theta) = 1 - R_h(\theta)$ (5)

Where $R_h(\theta)$ is the Fresnel reflectivity for horizontally polarized components of microwaves and derived from electromagnetic theory [7] and given by the equations (6).

$$R_h(\theta) = \left[\frac{\cos\theta - \sqrt{\varepsilon - \sin^2\theta}}{\cos\theta + \sqrt{\varepsilon - \sin^2\theta}}\right]^2 \quad (6)$$

Results and Discussion

The variations of horizontal component of emissivity (e_h) of soil mixed with different percentage concentration of saline water (0.0% to 14.0%) having different salinity of NaCl (0-35000ppm), calculated at three different observation angles (0^0, 30^0, 60^0) shown in figures-1.1 to 1.3. An inspection of these figures infers that e_h decreases with both salinity and moistness. Effect of salinity on emissivity is very small and considerable only at higher wetness of soil. In dry soils no impact of salinity observed on emission behaviour. The decrease in emissivity of soil with increasing salinity and moisture can be attributed to the increased dialectic contrast between emitting layer of soil and overlapping air media. Thermal microwave emission from soils is generated within the soil volume and the amount of energy generated at any point within the volume depends on the soil dielectric properties. As this energy moves upward and crosses the surface, it is reduced by the effective transmission coefficient (emissivity) of the surface, which is determined by the average dielectric characteristics of the soil in a transition layer. High dielectric contrast between emitting layer of soil and air causes more energy to reflect back within the soil media than that of transmitted out in air. Hence, emissivity of soil decreases as salinity increases.

The comparison of figures-1.1, 1.2 and 1.3 reveal that the value of e_h for any particular value of salinity and moistness of soil decreases as the angle of observation (ϑ) increases. The e_h is maximum at normal incident angle ($\vartheta = 0^0$) and decreases towards grazing direction. This is because of the boundary value conditions of Fresnel relations. According to Fresnel relations, horizontal reflectivity is lowest in normal direction and increases as obliquity increases. Hence, e_h decreases as the angle of observation increases.

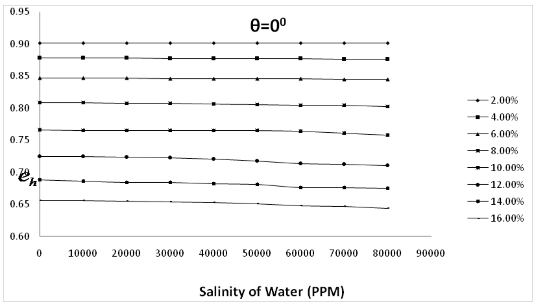

Figure 1.(1)Variations of e_h of soil w.r.t salinity of NaCl at different levels of SMC at 0^0 observation angle

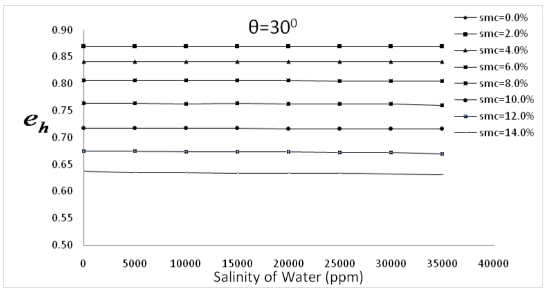

Figure 1.(2)Variations of e_h of soil w.r.t salinity of NaCl at different levels of SMC at 30^0 observation angle

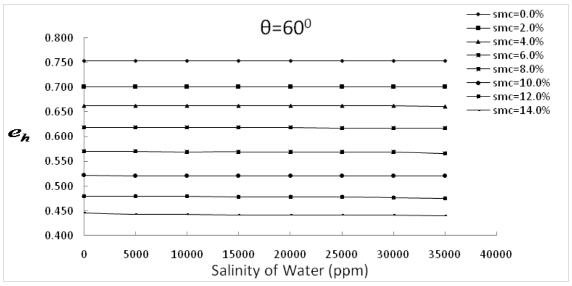

Figure 1.(3)Variations of e_h of soil w.r.t salinity of NaCl at different levels of SMC at 60^0 observation angle

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