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Backscattering of Saline Soils in view of Active Microwave Remote Sensing

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Abstract: In view of the active and microwave remote sensing, radar backscattering coefficient (${}_0\sigma$)of artificially salinized and moistened soil surface have been estimated by Small Perturbation Model (SPM using experimentally determined complex permittivity of soil and at a fix view angle 30^0 as input parameters. Further, the of salinized and moistened soil surface exhibit a little positive correlation with salinity. In case of dry soil salinity produces hardly any effect on the scattering behaviour of soil.

Key words: Saline soils, microwave remote sensing, radar backscattering coefficient and soil moisture content.

1. Introduction

Active microwave remote sensing for the study of salt affect soils is important emerging field of research because, radar backscattering of soil dependent on dielectric properties which are affected by salinity. Microwave remote sensing has a great potential for monitoring dynamical process like salinization of soils. Robbins and Wiegand[1] emphasised that the ability to accurate prediction of soil salinity from remote sensing is very important because, it saves labour, time, cost and effort when compared to field work. According to Metternicht[2] the various sensors and approaches of the optical and microwave remote sensing (aerial photographs, satellites and airborne multi-spectral sensors, microwave sensors, video imagery, hyper spectral sensors and electromagnetic induction meters) significantly contribute to detect temporal and spatial changes of salt-affected soil surface features. Hence, proper utilization, reclamation and land water management of saline soil the microwave remote sensing is very suitable tool.

2. Dielectric properties and active microwave remote sensing of saline soil

Qingrong *et al*[3] described Synthetic aperture radar (SAR) image can be a useful tool for monitoring soil salinity. Further Calla *et al*[4] estimated that at microwave frequencies the ${}_0\sigma$decreases with increase in salinity for slightly rough and undulating surface. Ziad Aly[5] observed that the high values of dielectric constant are due to the extensive presence of salts that leads to significant effect on the backscattering values for the RADARSAT-1 satellite images of salt-affected soils.

Using the Advanced Integral Equation Model (AIEM) and modified Dobson dielectric mixing model Wu and Wang[6] simulated the effect of salinity on the depends on the polarization of microwaves. Moreover, the simulation results also suggest that VV or HH polarization can be used to retrieve soil salinity at low volumetric soil moisture content .

Many backscattering coefficient models use the real part ‘ε of the dielectric constant because of the fact that the moisture affects the real part significantly. But the effect of salt mainly appears on “ε so that, ignoring the effect of salt in the calculation of backscattering coefficient by existing models causes a considerable amount of error. Therefore, the integration of on new emission and backscattering models is imperative.

3. Materials and method

The soil from superficial horizon of local profile of Alwar region with textural composition sand=79.0%, silt=14.6% and clay=6.4% has been selected for preparation of samples. Texture of soil is determined using sieving and sedimentation methods. Firstly salt free soil is obtained by leaching of salts from the soil through repeatedly flushing with conductivity water until the residual d.c. conductivity of soil extract remains negligible. 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 respectively.

The eight different solutions of NaCl soluble in conductivity water with different concentrations in part per million (ppm) corresponding to 0 ppm, 5000 ppm, 10000 ppm, 15000 ppm, 20000 ppm, 25000 ppm, 30000 ppm and 35000 ppm are prepared. Then each NaCl solution is mixed with dry soil such that each soil group (A to H) posses eight different desired level of saline water concentrations (0.0%, 2.0%, 4.0%, 6.0%, 8.0%, 10.0%, 12.0%, and 14.0%).

Total sixty four 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 saline water within the entire volume of soil.

4. Experimental Determination of Dielectric Constant

The real and imaginary part of dielectric constant (and "ε) artificially salinized and moistened soil samples prepared in the laboratory as a function of salinity and water content are evaluated. The and of 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 the wave guide cell method developed by Yadav and Gandhi[7]. The and 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. The experimental set up, theory and procedure for the present work is the same as used earlier by other researchers[8]

5. Estimation of microwave remote sensing parameters

Radar backscattering coefficient is the basic observational parameters of active microwave remote sensing. Small Perturbation Model (SPM) proposed by Ulaby *et al*[9] is suitable for estimation of radar backscattering of slightly rough surfaces given by equation (1):

$$\sigma^0_{pp} = 4k^4\sigma^2\cos^4\theta\left|\alpha_{pp}\right|^2\left[W(2k_0\sin\theta)\right] \qquad (1)$$

Where, σ^0_{pp} is co- polarized backscattering coefficient, σ is the RMS surface height, θ is the angle of incidence or scattered for back scattering. $\left|\alpha_{pp}\right|$ is the polarized Fresnel reflectivity of smooth soil surfaces either for horizontal-horizontal or vertical-vertical polarizations. k_0 is free space wave number of microwaves. $W(2k_0\sin\theta)$ is the normalized roughness spectrum which is evaluated at wave number $2k_0\sin\theta$ for isotropic Exponential surfaces.

SPM is employed with the values for $\sigma = 0.14$ cm and correlation length, $l = 2.0$ cm which are in accordance of validity conditions $h < 0.3$ and $k_0\sigma < 0.3$ Where h is the surface RMS slope given by $h = \sigma / l$.

For horizontal-horizontal and vertical-vertical polarizations Fresnel reflection coefficients ($_{hh}$αand$_{vv}$α) are given by the equations (2) and (3) respectively.

$$\alpha_{hh} = \frac{\cos\theta - \sqrt{\varepsilon - \sin^2\theta}}{\cos\theta + \sqrt{\varepsilon - \sin^2\theta}} \qquad (2)$$

$$\alpha_{vv} = (\varepsilon - 1).\frac{\sin^2\theta - \varepsilon(1+\sin^2\theta)}{\left[\varepsilon\cos\theta + \sqrt{\varepsilon - \sin^2\theta}\right]^2} \qquad (3)$$

Where εthe complex permittivity of saline soil andθ is the observation angle.

The values used for standard deviation height (cm14.0=σ) and roughness correlation length (cml0.2=) are in accordance with the agricultural field roughness[10] and Exponential correlation function[11] is well approximated for agricultural soils and describes the smooth natural surfaces.

6 Results and Discussion

The variations of co-polarized radar backscattering coefficient, horizontally incident-horizontally scattered (σ^0_{hh}),vertical incident - vertical scattered (σ^0_{vv}), of saline soil, mixed with different concentrations of saline water (0.0% to 14.0%) with different salinity of NaCl (0-35000 ppm), estimated at 30^{0}observation angle are shown in figures-1,2.

(i) An examination of figures-1 and 2 reveals that and increases weakly with the salinity in the comparison of moisture. These variations may be explained as the increase in salinity or moisture leads to an increase in the magnitude of complex permittivity, resulting into an increase in the soil reflectivity (from the Fresnel equations), which eventually leads to an increase in radar backscattering coefficient.

(ii) Effect of salinity on radar backscattering coefficient becomes significant only at higher levels of moistness of the soil. The salinity produces no effect on radar backscattering coefficient of dry soils. This is because of the fact that effective role of salinity come into play only at higher SMC levels where the free water dominates over bound water and salt is dissolve in free water.

7. Conclusions

Dielectric study of salt affected soils and associated active microwave remote sensing parameters, is very important regarding mapping, monitoring and management of salt effected soils. Because of the differential behaviour of the real and imaginary parts of the complex permittivity, microwave remote sensing appear to be efficient in detecting soil salinity (the real part is independent and imaginary part is highly sensitive to variations in salinity). This allows separating saline soils from non-saline soil. Further, for active microwave remote sensing the scattering coefficient data for saline soil for different moisture contents and for different types of surfaces are useful for image analysis and its applications. The results of present investigations provide a basis for using active microwave sensors in the detection of soil salinity. Also precise microwave dielectric measurements of saline soils and recognition of their dependence on salinity is interesting and can be used in support of radar investigations of the salt deposition on land or Earth's geology.

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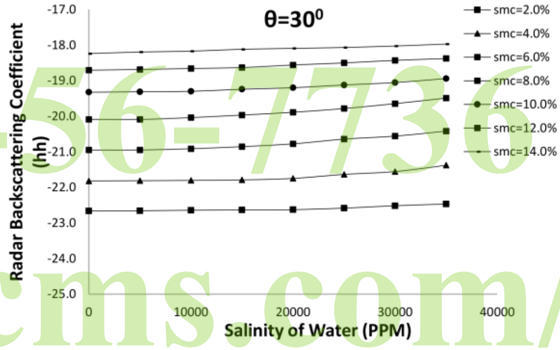

Fig-1: Variations of σ^0_{hh} of soil w.r.t salinity of NaCl at different levels of SMC at 30⁰ observation angle

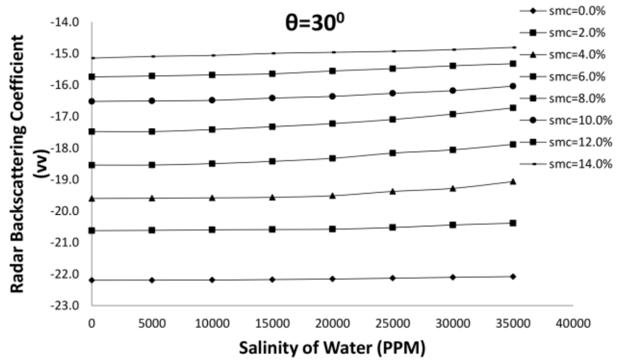

Fig-2: Variations of σ^0_{vv} of soil w.r.t salinity of NaCl at different levels of SMC at 30⁰ observation angle