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Using Regression Models to Predict Electrical Conductivity of Soil Through ALOS PALSAR Satellite

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Abstract: The electrical conductivity is dielectric properties and able to identify normal soil and soil salinity. EC values is the method able to classify soil salinity levels quickly. To determine soil salinity from the field experience is very complicated and difficult. ALOS PALSAR is known as penetrated satellite data. They have been proved as a powerful tool to indicate the accuracy of salinity value in saline conditions. This reserce to study the sufficiency of EC as derived from ALOS PALSAR satellite data to predict EC values associated with soil salinity. A regression model was used to create an EC estimation model. This research developed an estimation model that could explain the EC of saline soil. This research illustrated that a relationship between two different data sources, ALOS PALSAR and ground data, the statistical model could be developed to accurately estimate the value of EC soil using ALOS satellite

Key words: Electrical conductivity, soil salinity, ALOS, regression model, sufficiency, relationship

INTRODUCTION

Electrical Conductivity (EC) is the ability of a material to conduct electrical current. The apparent EC of soil is influenced by many factors such as water content, soil porosity, texture and organic matter. The availability of satellite microwave data facilitates the detection, assessment and mapping of wetlands, forests. The use of microwave data for an indirect measurement to detect salt-affected soils has been studied since, 1996 (Aly *et al*., 2004). Nevertheless, the arid and semi-arid regions researched in those studies were comparably simple to study since these were not affected by humidity limiting satellite image data application. Apart from that, little research has been done on using ALOS data to study soil salinity. The developments in L-band microwave sensing have enabled new advanced techniques with predictive mapping capability. The BC recorded in a Synthetic Aperture Radar (SAR) image has a significant correlation to soil salinity based on laboratory measurements (Shao *et al*., 2003). Relatively few studies have investigated the possibility of matching SAR data to BC values from field research. Most preceding studies have overlooked possibilities to investigate salinity including the other parameters of the backscattering coefficient or establishing BC using several backscattering models, the Small Perturbation Model or the Physical Optic Model (Aly *et al*., 2004) for instance which face constraints in their respective systems as they involve a huge amount of parameters. In order to diminish such complications through large numbers of parameters, the present model was designed to learn directly to enhance the relationship between BC value and soil salinity.

The aim of research: This study conducted research to estimate EC values of soil through the correlation between the EC values established during field research and BC values retrieved from ALOS PALSAR images. Images data polarizations were compared to assess which polarization was the best for estimating the EC of soils.

MATERIALS AND METHODS

Method of research: The basic materials for this study were soil samples for laboratory measurement and BC values from ALOS imagery.

Ground measurement data: Soil samples were collected from bare land within the salinity affected areas. The soil sampling was scheduled at a date close to that of ALOS microwave data recording to best match EC values from soil samples with BC values from microwave data. The locations of the soil sampling points across all salinity levels were randomized. GPS was used to determine the exact coordinates of each point during field measurement. From each point, soil samples were gathered in 5-10 cm. depth below the surface. The soil samples were analysed for EC, pH and soil texture.

Microwave data from PALSAR-ALOS: BC was extracted from microwave imagery of ALOS-PALSAR. The selected scene was a resolution of 12.5 m. The centre of the image scene is between 15.943° latitude and 103 °longitude. Image correction of the satellite image was necessary to allow geometric overlays of the image data and to remove effects of side looking geometry of SAR images because the ALOS image was geometrically terrain corrected. The relationship between DN and BC can be written as:

$$DN^2 = \text{const (BC)} \quad (1)$$

The following equation is used in this research to obtain the BC in dB unit:

$$BC = 20\log 10\ (DN)+K\ (dB) \quad (2)$$

Where:
DN = The pixel intensity value of the image
BC = The backscattering coefficient or sigma naught on image
K = A constant of -83 dB, determined as a constant compatible with ALOS image data

Stepwise Multiple Linear Regression (SMLR): An SMLR model was developed to estimate the EC of soil from the BC data. Estimate models were calculated based on four polarizations (HH, HV, VH and VV) of BC variables. SPSS, statistical software was used for developing the model. The equation of regression model represented the quantitative relationship between dependent variables and independent variables. The correlation analysis could interpret in causal terms the relation of BC and EC of saline soil. The regression was run with the entire dataset to find EC values to be included in a linear predicting model. The square value of the correlation coefficient (R^2) can be interpreted as indicating the percentage of variation in one variable that is associated with another variable.

Model validation: The regression model was built to estimate EC from BC. The remainder of the measured EC data from field survey was used to validate the model. The performances of predicting models were reported in terms of coefficient of determination (R^2) and Root Mean Square Error (RMSE). The coefficient of determination (R^2) indicates the correlation of EC estimated from BC and EC measured in the field. The accuracy of predicting models was significantly improved using higher R^2 and lower RMSE.

RESULTS AND DISCUSSION

Relationship between EC and BC by regression model: The relationship of EC and BC as of the regression model estimates and in regression equation terms. The coefficient of determination (R^2) is presented as the result of the relationship between EC and BC values. The statistical significance level was a p-value of 0.01 (two-tailed test) at a 99% confidence level. It was noted that the correlation between EC and BC from co-polarization (HH and VV) was higher than that from cross polarization (VH or VV). The R^2 is a significant indicator of the relationship that proves the capability of the regression model used to predict EC from BC. This study, the highest R^2 was 0.743 for dry season and 0.707 for wet season. These results are consistent with those of previous studies (Aly *et al*., 2004) that looked into the BC-EC relationship in salt-affected areas from RADASAT image data using a C band frequency and found an R^2 = 0.83, however, the relationship was learned through semi-empirical backscattering models which suffer from the constraint of requiring a huge amount of parameters. Concerning the results of predicting EC from BC by regression model, it was found that the data obtained during dry season generated a better prediction of EC values than those during wet season as BC values were slightly influenced by humidity in wet season which conformed with the theory of the relationship between BC and soil moisture values (Rombach and Mauser, 1997; Shi *et al*., 1997; Jackson *et al*., 2012). Although, the coefficient of determination was not quite high, it is acceptable as a guideline in developing a statistical model for satellite data. By the way, this is the most comfortable way to get EC values without wasting time and resources by traveling to the real site. This development will be an effective tool for the most accurate result in the future.

Model validation: The equation derived from the calibration model to estimate EC from BC for each polarization was subjected to validation by the residual data that had not been utilized in the model calibration. The values of the measured EC from field research and the estimated EC from the equation were compared using coefficient of determination and root mean square error. The R^2 between estimated EC from BC and measured EC from field and the Root Mean Square Error (RMSE) are show in Table 1. BCHH showed the highest R^2 at all polarizations for both seasons with a lower RMSE of 1.41 for dry season and 2.25 for wet season. For dry season, the highest coefficient of determination was achieved by BCHH (R^2 = 0.64). For wet season, the highest coefficient of determination was from BCHH (R^2 = 0.58) again. The results conformed with preceding researches (Shao *et al*., 2003) finding that the HH backscattering gives a better result in relationship values than VV scattering, resolved by the scattering properties of soil surface in microwave imagery. However, EC values predicted from BC by linear regression mean could only produce an R^2 value of 0.64

Table 1: The coefficient of determination (R^2) of EC and BC and regression equations

	Calibration (N = 150)		Validation (N = 100)		
Polarized	R^2_c	$RMSE_1$	R^2_v	$RMSE_2$	Regression equation
Dry season					
BC-HH	0.743	1.04	0.641	1.41	EC = -0.435BCHH -1.597
BC-HV	0.722	2.14	0.573	2.32	EC = -0.369BCHV –0.111
BC-VH	0.644	2.27	0.594	2.34	EC = -0.033BCVH –0.364
BC-VV	0.727	2.18	0.632	2.22	EC = -0.390BCVV –0.584
Wet season					
BC-HH	0.707	3.38	0.584	2.25	EC = - 0.445BCHH -1.208
BC-HV	0.643	3.23	0.521	3.04	EC = -0.395BCHV –0.171
BC-VH	0.593	4.06	0.556	2.68	EC = -0.372BCVH -0.309
BC-VV	0.705	2.61	0.636	3.29	EC = -0.425BCVV –0.724

$RMSE_1$, $RMSE_2$: Root Mean Square Error of calibration and validation in unit of EC; R^2_c, R^2_v: coefficient of determination; High significance at a p-value of 0.01 for the fit between estimated and observed values

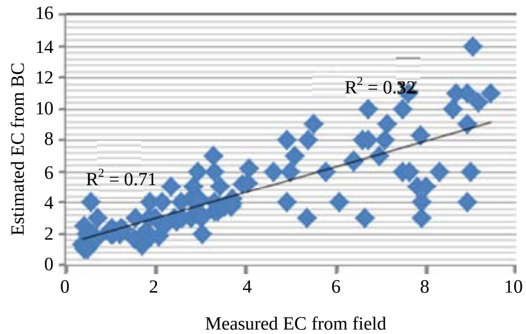

Fig. 1: The R^2 between estimated EC from BCHH and EC measured in the field (*R^2: all EC data); R^2 = 0.641 EC (Unit: dS/m)

which was not quite high. It was also found that with EC lower than 4 dS/m, R^2 was at 0.71 which was in a higher range than that of EC values of >4 dS/m with an R^2 of 0.32 (Fig. 1). Concerning surface roughness of the study area in the EC range from 0 to 4, roughness characteristics appeared more distinctive than in areas with EC values above 4, whereby the EC range of 0 to 4 included the classes of normal soil (0-2 dS/m) and slightly saline soil (EC>2 dS/m) which have clearly different surface roughness characteristics. This conformed with the finding that the relationship of salinity and the reflection of BC was influenced by surface roughness (Ulaby *et al*., 1986; Santanello *et al*., 2007).

The accuracy of predicting models was significantly improved using higher R^2 and lower Root Mean Square Error (RMSE) values. RMSE was computed to check the reliability of the prediction. Date were divided into two datasets, a calibration dataset (N = 150) and a validation dataset (N = 100) for two seasons (wet and dry season. RSME values for predicting EC by regression model for the dry season were found to be lower than those for the wet season, yet they are only slightly unequal. R^2 and RMSE results are also only slightly different between the seasons which indicate that the regression model equation with a single variable is well able to predict EC from BC for both seasons.

Multiple regressions: Multiple regression analysis is a technique for predicting the relationships among variables. Here, it was used to determine the relationship between EC and BC combining four polarizations (HH, HV, VH and VV). Multiple regressions of data from dry season determined an R^2 of 0.889 with an estimated standard error of 1.09 while that of wet season data established an R^2 of 0.844 with an estimated standard error of 1.14. The regression equations to predict EC from BC are:

$$EC = -0.208(BCHH) -0.145(BCHV) 0.026(BCVH)-0.109(BCVV) 2.194 \text{ (Dry season)}$$

$$EC = -0.218(BCHH) -0.065(BCHV) 0.109(BCVH)-0.131(BCVV) 2.279 \text{ (Wet season)}$$

Combining all four variables of BC to determine their linear correlations with EC values increased the R^2 result which indicates that employing BC to predict EC.

CONCLUSION

This study focused on the relationships between four BC polarizations and the EC of soil in saline areas. The main objective was to study the sufficiency of EC as derived from satellite data to predict EC values associated with soil salinity. A regression model was used to create an EC estimation model clarifying the variations of BC. EC measurement of soil surface samples (0-5 cm depth) is a common practice to define and assess soil salinity. BC from microwave data was also found to be a suitable indicator of soil salinity as this study revealed its significant relation with the observed EC. The highest R^2 was 0.743 and root mean square error value was 1.04. The examination by multiple regressions produced an increased R^2 value of 0.889. In conclusion, by creating a relationship between two different data sources, satellite data and ground data, the statistical model could be developed to accurately estimate the value of EC soil salinity using BC from satellite. The advantage of this study was that the proposed evaluated statistic model can well give an accurate relationship between EC and BC and it can be applied to estimate EC from other statistic models.

RECOMMENDATIONS

In future studies, relational characteristics between these two data sources should be analysed by a non-linear model as this chapter of the study exposed that both sources of data inclined to have a more well-correlated relationship when applying a polynomial fitting model and the BC data should be considered in their combination, since multiple variables demonstrated more effective results than single variables.

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