POTENTIAL OF PALSAR DATA IN RETRIEVING SPATIAL VARIABILITY OF SOIL MOISTURE IN TROPICAL CATCHMENT

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KEY WORDS: Remote Sensing, PALSAR data, soil moisture, Land use

Abstract: The potential of PALSAR data for soil moisture retrieval over four land use type of tropical area in Malaysia was evaluated using backscattering regression model. The catchment is divided into four land use types which are rubber, shrub, oil palm and grass land area. Without having any knowledge on surface roughness, the regression model was inversed and applied to the data. The regression coefficient of the model is analyzed to overall catchment and each type of the land use. The final output showed the calibration between backscattering coefficient and measured soil moisture is R = 0.52. The validation result between derived and measured soil moisture is found to decrease in R = 0.47. However, the division of each land uses are found to give a different result with one to another due to the type of land used based on the observation during the fields. The higher coefficient is found in rubber area and followed by oil palm, grassland and shrub area with R = 0.89, 0.79, 0.38 and 0.13 respectively. The result showed the potential of PALSAR data is reliable to be used in tropical catchment.

INTRODUCTION

Malaysia is one of the tropical countries blessed with high intensity of rainfall. As a tropical country, the climate and weather in Malaysia is hot and humid through the year. Approximately Malaysia receives an annual average of 2500 mm rainfall per year (Shafie, 2009). With this kind of climate, the soil condition in Malaysia is very reach with moisture content. Soil moisture measurement plays an important role in environmental processes over a large spatial and temporal scale. Due to the fact that soil moisture is difficult to handle and costly, the estimation is much crucial in modeling various large scale ecological processes (Sikdar and Cumming, 2004; Barret *et al.*, 2009).

Previous studies have shown that soil moisture can be retrieved by variety of remote sensing technique (Gupta, 2011). However, only microwave sensors give the promising technique and capability to measure the soil moisture in the variety of topographic and vegetation cover conditions (Baup *et al.*, 2007). With the use of Synthetic Aperture Radar (SAR) sensor on remote sensing space borne, the soil moisture condition can be retrieved from the backscattering coefficient received by the sensor (Coppo *et al.*, 1990; Dubois *et al.*, 1995; Ji *et al.*, 1996; Sikdar and Cumming, 2004).). The fact is except soil moisture, microwave signal is much influenced by vegetation cover and surface roughness (Ulaby *et al.*, 1978; Ulaby *et al.*, 1979; Jackson and Schmugge, 1991; Ferrazzoli *et al.*, 1992; Narayan *et al.*, 2004). Due to the fact, this study has been conducted using low frequency and longer wavelength to minimize those influencing factors.

Low frequency with longer wavelength band gives advantages in term of soil moisture retrieval since the longer wavelength can penetrate deeper through the soil in sparse vegetated area which approximately about 1-5 cm for L band (Ulaby *et al.*, 1996 ; Oh, 2000; Sanobe *et al.*, 2008). The deeper penetrations give less sensitivity to the dense vegetated tropical cover and surface roughness (Jackson and Schmugge, 1991; Jensen, 2007). Thus this study is focus on the microwave L band since the band give much advantages comparing to other bands in term of signal penetration.

PALSAR data is the most suitable data to be used as a main data to retrieved soil moisture in this study. PALSAR sensor which defines as Phased Array L-band Synthetic Aperture Radar is one of the remote sensing instrument carried by ALOS satellite. ALOS satellite is the largest satellite developed in Japan and was launched from the Japanese Space Exploration Agency's (JAXA) Tanegashima Space Center on January 24, 2006. The characteristics of PALSAR sensor use in the study is shown in the table 1.

Table 1: PALSAR sensor characteristic

Details information of ALOS/PALSAR	
Sensor	PALSAR
Image mode	Quad-pol (HH)
Scene ID	ALPSRP275780030
Beginning date of observation	2011/03/29 15:37:57
End date of observation	2011/03/29 15:58:57
Orbit direction	Ascending
Off-nadir angle	21.5°
No of pixels	400
Line number	700
Resolution	12.5m/pixel

The spatial variability of soil moisture is focused on the Bekok catchment. The area covers about 223 km^2 of Batu Pahat catchment and surrounded by four types of land uses which are oil palm, rubber, shrub and grass land. The soil moisture retrieved in the area were calibrated and validated with the field measurement. Hence, the objective of this study was to determine the potential of PALSAR data in determine soil moisture using simple regression model. The model applied to the whole catchment and each land use in the catchment. The overall result and the result from each land use also discussed.

METHODOLOGY

The main satellite data used for this study are ALOS/PALSAR data which acquire on Mac 29, 2011. Since the data is geocoded product, the preprocessing only involved speckle filtering and backscatter coefficient conversion. The overall methodology of the study is showed in the figure 1.

The main processing involved the backscattering regression model which showed the relationship between measured surface soil moisture and radar backscattering signal in equation 1.1 (Zribi and Dechambre, 2002; Weimann *et al*., 1998).

$$\sigma^{\circ}_{dB} = \alpha m_v + \beta \quad (1.1)$$

Where σ^{o}_{dB} is the radar cross-section in dB, m_v is the volumetric surface soil moisture and the constant unknown which are α and β According to Holah *et al.*, (2004), the unknown α and β is dependent on radar incident angle and polarization respectively. Based on this linear model, the inversion of it was applied to the data to retrieve volumetric soil moisture. The surface soil moisture retrieval from PALSAR imagery is calibrates and validates from soil moisture field measurement data.

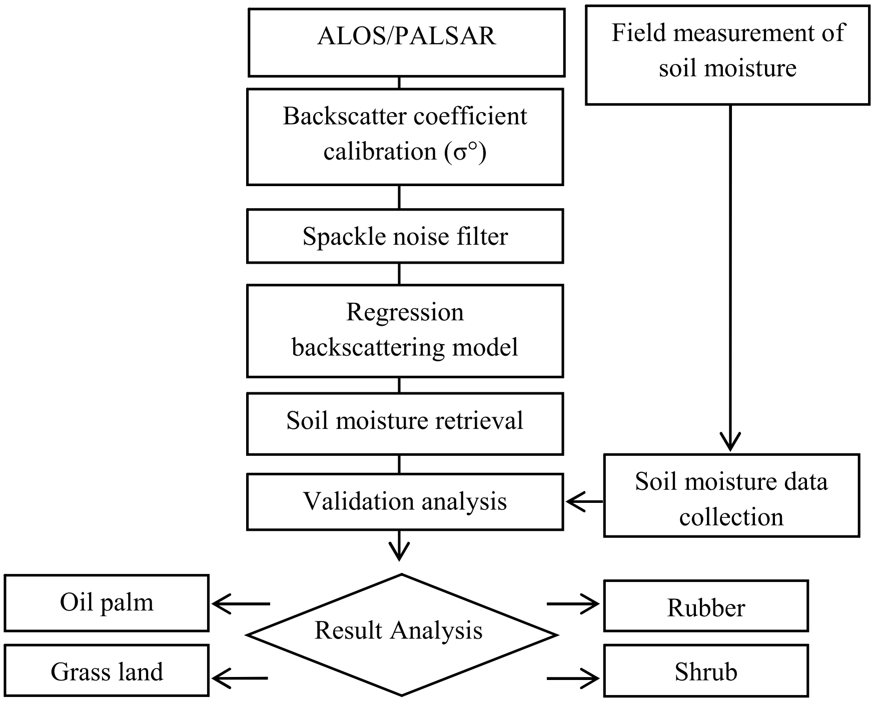

Figure 1: Flowchart of methodology

Field measurement was conducted in the study to obtained volumetric soil moisture directly from the soil using soil moisture meter instrument with sensor type of 5TE. The sensor measures the soil moisture in volume percentage (%) unit from 5 cm above the soil. About 72 points of soil moisture measurement were taken randomly around the study area which covers four major land use type which are shrub, oil palm, rubber and grassland. From 72 point data collected from the field, half of the data (36 point) was used for calibration and another half was used for validation analysis. To be equal, the data was randomly divided into two parts which each part comprise all land use type.

RESULTS AND DISCUSSIONS

In order to analyze the behavior of the PALSAR signal as a function of soil moisture, the linear regression model was perform from backscattering coefficient (σ°) data and field measurement data. For calibration path, the correlation coefficient show *R* value between backscattering coefficient and soil moisture measured was equal to 0.52. These result demonstrate that the backscatter value derive from PALSAR image and field measurement are moderately correlated in the tropical catchment with densely vegetated area without taking into account any surface roughness (Figure 2).

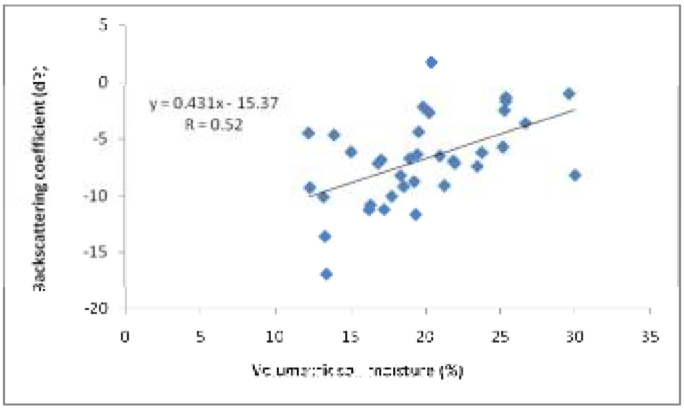

Figure 2: Calibration of soil moisture

The result of calibration indicates that the HH polarization with low incidence angle (20° - 24°) is more sensitive to soil moisture as many studies reported similar result (Holah *et al.*, 2005; Baghdadi *et al.*, 2006; Li *et al.*, 2004). In fact, L band give a better penetration through the canopy cover without considered any surface roughness data when comparing to ASAR C band data as reported by Holah *et al.*, (2005). Nonetheless, some researcher has suggests the use of low incidence angle (7°-22°) to obtain the optimal soil moisture retrieval (Ulaby *et al.*, 1986). The graph shows the positive correlation where soil moisture increases with backscattering coefficient.

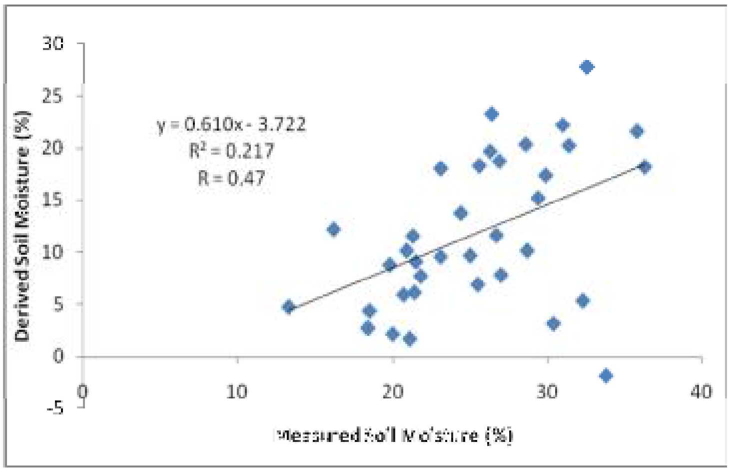

Figure 3: Correlation coefficient between retrieved and measured soil moisture

The result of derived and measured soil moisture in figure 3 shows there is no strong correlation between both data in the study area with taking into account all the land use type. However, when the data is separated into four land use type, the correlation between derived and measured data are highly strong in the rubber and oil palm land use followed by two others land uses which are grassland and shrub where the correlation is not agreed well (Figure 4).

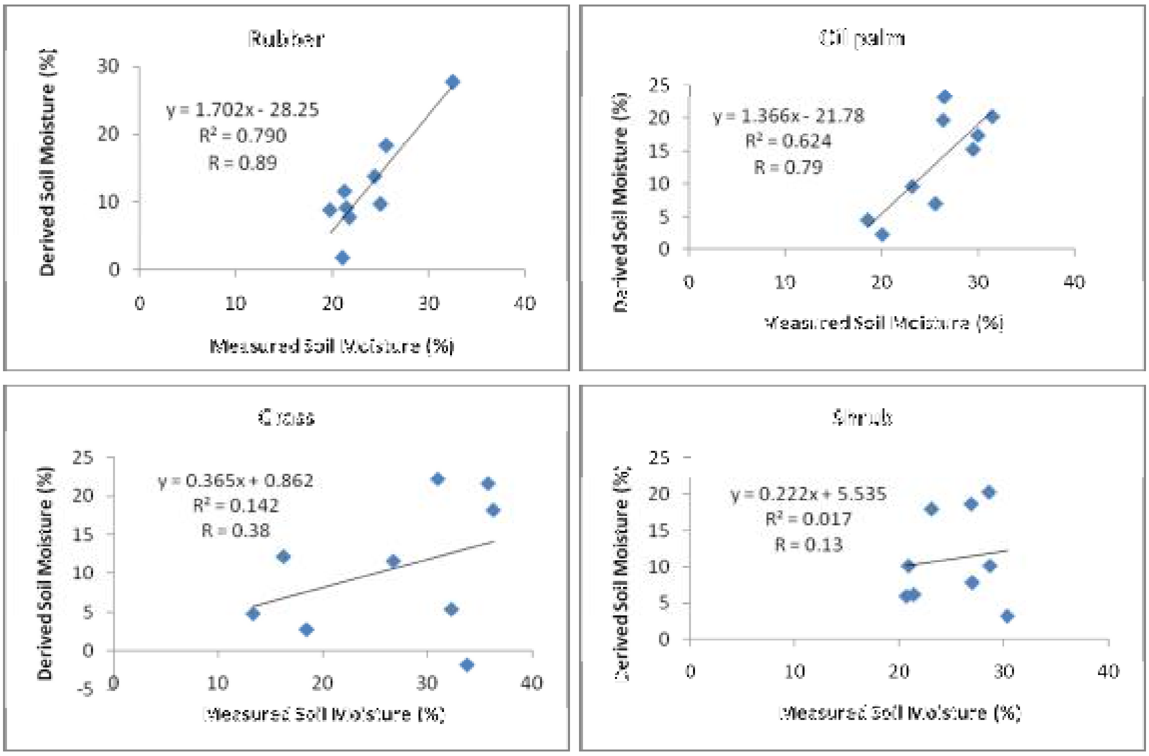

Figure 4: Correlation coefficient for four land use type

The graphs of figure 4 showed the soil moisture derived in the rubber and oil palm land use type fit well with the field measurement. With no scientific evidence and research of canopy structure, from the observation in the study area the canopy structure of both land use type provide some space for backscatter signal penetrate through the soil since both land use are well arranged and managed.

On the other hand, for grass land and shrub area the soil are covered by thick of grass and undergrowth. This can considered as the influences of surface roughness on the backscatter signal since it is one of the most influencing parameter and limiting factor that could not easily differentiated from the signal (Barret *et al.*, 2009).

CONCLUSIONS & RECOMMENDATIONS

From the result and analysis, the study can be concluded that ALOS/PALSAR satellite with HH polarization has a potentiality to be use to retrieved surface soil moisture data. The correlation coefficient between backscattering coefficient (dB) and volumetric surface soil moisture has showed the relationship between both data. Some recommendations were indicate from this study where the PALSAR imagery should be real time data to maximize the correlation of the result. Furthermore, add on of surface roughness data into the regression model was better to minimize the error.

REFERENCES

Baghdadi N., Holah N. and Zribi M. 2006. Soil Moisture Estimation Using Multi-Incidence and Multi-Polarization ASAR Data. International Journal of Remote Sensing. 27 (10), 1907–1920.

Barrett B. W., Dwyer E. and Whelan P. 2009. Soil Moisture Retrieval from Active Spaceborne Microwave Observations: An Evaluation of Current Techniques. Remote Sensing. 1, 210-242.

Baup F., Mougin E., Rosnay P. D., Timouk F., and Chênerie I. 2007. Surface Soil Moisture Estimation Over The AMMA Sahelian Site In Mali Using ENVISAT/ASAR Data. Remote Sensing of Environment. 109 (4), 473–48.

Coppo P., Ferrazzoli P., Paloscia S., Pampaloni P., Schiavon G., and Solimiui D. (1990). Sensitivity Of Active And Passive Microwave Sensors To Soil Moisture Of Vegetated Fields. Geoscience and Remote Sensing

Symposium, 1990. IGARSS '90. 'Remote Sensing Science for the Nineties'., 10th Annual International.1851-1854.

Dubois P.C., Zyl J.V. and Engman T. 1995. Measuring Soil Moisture with Imaging Radars.IEEE Transactions on Geoscience and Remote Sensing. 33 (4), 915-926.

Ferrazzoli P., Paloscia S., Pampaloni P., Schiavon G., Solimini D. and Coppo P. 1992. Sensitivity of Microwave Measurements to Vegetation Biomass and Soil Moisture Content: A Case Study. IEEE Transactions on Geoscience and Remote Sensing.30 (4).750-756.

Holah, N., Baghdadi, N., Zribi, M., Bruand, A. and King, C. 2005. Potential of Asar/Envisat for the Characterisation of Soil Surface Parameters over Bare Agricultural Fields. Remote Sensing of Environment.96, 78–86.

Jackson T.J. and Schmugge T.J. 1991. Vegetation Effects on the Microwave Emission of Soils. Remote Sensing of Environment. 36, 203-212.

Jensen J. R. 2007. Remote sensing of the environment: An Earth Resources Perspective. New Jersey: Pearson Prentice-Hall Inc.

Ji J., Keur P. V. D., Thomsen A. and Skriver H. 1996. Soil Moisture Retrieval Using the Danish L- & C-Band Polarimetric SAR. IEEE International Geoscience and Remote Sensing Symposium. 2. 1300-1302.

Li Z., Ren X., Li X. and Wang L. (2004). Soil Moisture Measurement and Retrieval Using Envisat ASAR Imagery. Geoscience and Remote Sensing Symposium, 2004. IGARSS'04. Proceedings IEEE International. 5, 3539-3542.

Narayan U., Lakshmi V., and Njoku E. G. 2004. Retrieval of Soil Moisture From Passive And Active L/S Band Sensor (PALS) Observations during the Soil Moisture Experiment In 2002 (SMEX02). Remote Sensing of Environment. 92. 483–496.

Oh Y. (2000). Retrieval of the Effective Soil Moisture Contents as a Ground Truth from Naitural Soil Surfaces. Geoscience and Remote Sensing Symposium, 2000. Proceedings. IGARSS 2000. IEEE 2000 International. 4, 1702-1704.

Shafie A. (2009). Technical Report Extreme Flood Event: A Case Study on Floods of 2006 and 2007 in Johor, Malaysia. Master Thesis. Colorado State University, Colorado.

Sikdar M. and Cumming I. (2004). A Modified Empirical Model for Soil Moisture Estimation in Vegetated Areas Using SAR Data.Geoscience and Remote Sensing Symposium, IGARSS '04. Proceedings, IEEE International. 803-806.

Ulaby F. T., P. P. Batlivala, and Dobson M. C. 1978. Microwave Backscatter Dependence on Surface Roughness, Soil Moisture, and Soil Texture: Part 1I-Bare Soil. IEEE Transactions on Geoscience Electronics. Ge-16 (4), 286-295.

Ulaby F. T., Bradley G. A., and Dobson M. C. 1979. Microwave Backscatter Dependence on Surface Roughness, Soil Moisture, And Soil Texture: Part 11-Vegetation-Covered Soil. IEEE Transactions on Geoscience Electronics. Ge-17 (2), 33-40.

Ulaby F.T., P.C. Dubois, and J.J. van Zyl. 1996. Radar Mapping Of Surface Soil Moisture.Journal of Hydrology. 184(1-2), 57-84.

Weimann A., Von Schonermark, M., Schumann A., Jorn, P. and Gunther, R. 1998. Soil moisture estimation with ERS-1 SAR data in the East-German loess soil area. International Journal of Remote Sensing. 19 (2), 237-243.

Zribi M. and Dechambre M. 2003. A New Empirical Model To Retrieve Soil Moisture and Roughness From C-Band Radar Data. Remote Sensing of Environment. 84 (1), 42-52.

Ulaby F. T., Moore R. K. and Fung A. K. 1986. Microwave Remote Sensing Active and Passive Volume III: From Theory to Applications. North Bergen, New Jersey: Book-Mart Press, Inc