THE DETERMINATION OF SOIL WATER CONTENT IN VARIOUS DEPTH LEVELS IN CASSAVA FIELDS USING ALOS-2 PALSAR IMAGERIES

Navavit Ponganan1, Patchara Praseartkul1, Piyanan Pipatsitee1, Kanyarat Taota1, Sumaid Kongpugdee1, Kampol Sakulleerungroj1 and Apisit Eiumnoh1

1 National Center for Genetic Engineering and Biotechnology (BIOTEC),
113 Thailand Science Park, Phahonyothin Road, Khlong Nueng, Klong Luang, Pathum Thani, 12120, Thailand,
Email: navavit.pon@biotec.or.th

KEYWORDS: Soil Water Content, SWC, ALOS-2 PALSAR, Backscattering coefficient

ABSTRACT: It's well known that Polarization of L-band have capability to detect soil water content (SWC). However, there is no conclusion to explain the depth of SWC sensing. This research attempted to find relation between L-band polarization and ground SWC in different depth levels. The ground SWC measurement, carried out over 35 points on harvested cassava area in Thai Tapioca of Development Institute (TTDI), Huai Bong sub-district, Dan Khun Thot district, Nakhon Ratchasiwema province. The gravimetric method was used to gathering SWC at 5 depths between 0-50 cm (10 cm interval). The ground SWC value has an average into 0-10, 0-20, 0-30, 0-40 and 0-50 cm depth levels, respectively. There are ALOS-2 PALSAR image in fine mode (6.25m x 6.25m) with dual polarizations (HH and HV). Backscattering coefficient has used to predict SWC by using regression analysis. An experimental result demonstrated that HH polarization were related to determine ground SWC within 0-10, 0-20 and 0-30 cm depth levels ($R2$ = 0.61, 0.60 and 0.53 respectively) while HV polarization were relate to determine ground SWC 0-10 cm depth level ($R2$ = 0.50).

INTRODUCTION

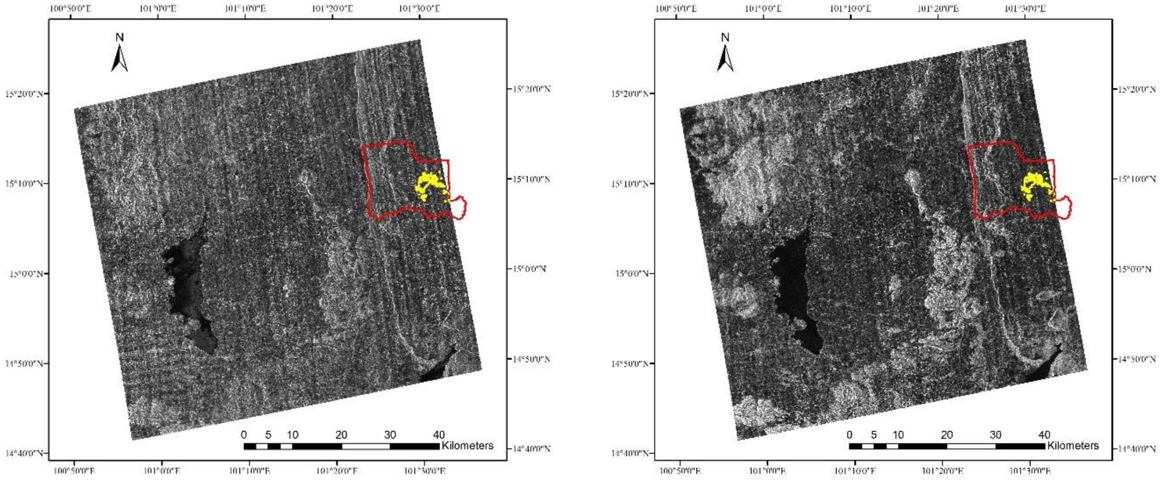
The relation between the radar backscattering coefficient in low frequency (P and L-Band) and soil water content (SWC) are well described in many literatures. (G. Macelloni, et al. 2003; M. J. Escorihuela. Et al, 2010; Woranut C. Et al, 2013; M. Bittelli, 2011) Radar beam's penetration properties should be consider to measuring the depth level of SWC. In General, the penetration depth of the radar beam depends on frequency, soil characteristics and water content. Nonetheless, there are some argument on penetration ability of radar beam. Ulaby said that the penetration ability can measured the depth up to half a wavelength (~10 cm for L-band). (Ulaby, et al., 1981) T. G. Farr use Shutter Image Radar (SIR) to measuring L-band penetration depths in Nevada desert area. He found that L-band can penetrate into soil surface which the depth can be up to 85 cm in very dry soil. (Farr, et al., 1986) M. J. Escorihuela studied the effective soil moisture sampling depth of L-band radiometry. He recommended to use mechanistic model to estimate soil water content over a shallower layer (2 cm for L-band). (G. Macelloni, et al. 2003).

The cassava planting emphasizes on SWC about 50 cm depth (Cassava's storage rooting depth ~ 40 cm). (R.j. Hillocks, 2001) Therefore, this research objective is to estimate the SWC within 50 cm by radar backscattering coefficient from ALOS 2 – PALSAR.

STUDY AREA AND DATA

The selective sites of this study are located in Thai Tapioca of Development Institute (TTDI), Huai Bong sub district, Dan Khun Thot district, Nakhon Ratchasima province, totaling of 6.62 sq.km.. The topography is homogeneous erosional plain surface. The main activity of this is field crop plantation e.g. cassava, sugarcane and corn.

ALOS 2 – PALSAR data used in this study was acquired on Feb 9, 2015 with Ascending pass, Incidence angle 28.6°, 6.25 m pixel sizes (high sensitive mode), Dual Polarizations (HH and HV), Process Level 1.5 and resampling with Nearest Neighbor (NN) algorithm. Figure 1 shows full scene of ALOS 2 – PALSAR data (Red line: Huai Bong sub district boundary and yellow line: Thai Tapioca of Development Institute (TTDI) boundary).



(a) HH- Polarization (b) HV- Polarization

Figure 1 ALOS 2 – PALSAR data used in this study.

METHODOLOGY

Flowchart of methodology for SWC mapping as shown in Figure 2.

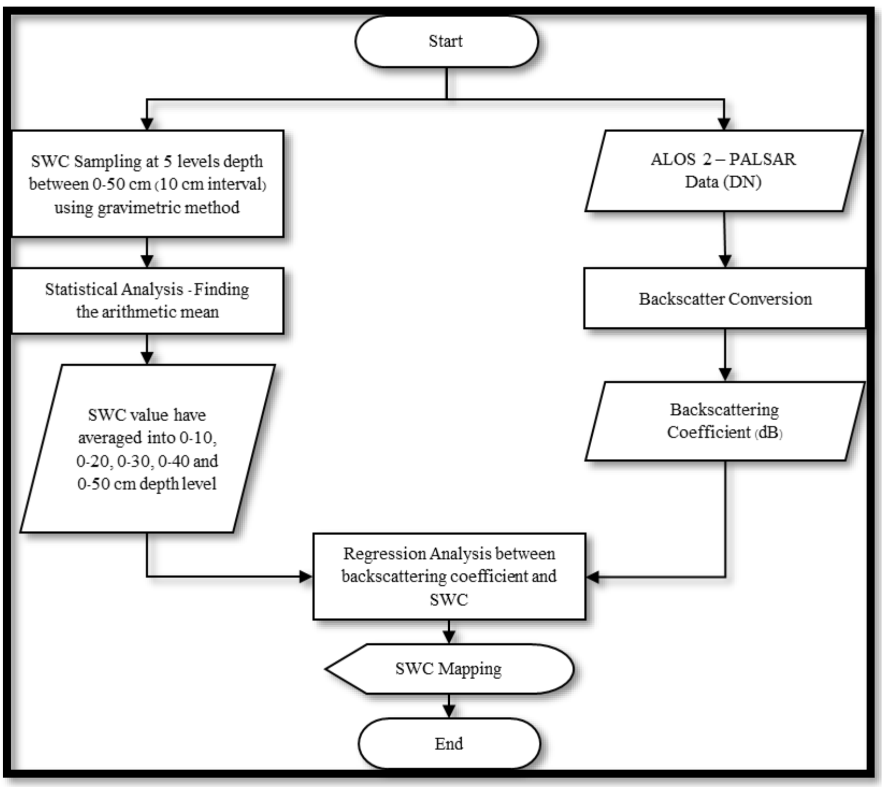


Figure 2 Methodology of this study

1) SWC Sampling; Soil water content (SWC) was measured by using gravimetric method. The gathering samples of soil at the depth between 0 to 50 cm with soil core (10 cm interval). Figure 3 shows instrument tools (Soil Core) and SWC sample gathering.

(a) Instrument tool (Soil Core) (b) SWC sample gathering

Figure 3 Soil water content (SWC) Sampling

The moist samples were weighed and dried in microwave oven. Soil water content can be calculated by following equation.

$$SWC = [(W_{wet} - W_{dry}) / W_{dry}] * 100$$

Where SWC is soil water content; W_{wet} and W_{dry} are soil weight in wet and dry condition.

We carried out 34 sampling points in early summer season (< 50 mm cumulative rainfall in the last 3 month). Figure 4 shows SWC sampling sites (Red dot: Sampling point and yellow line: Thai Tapioca of Development Institute (TTDI) boundary).

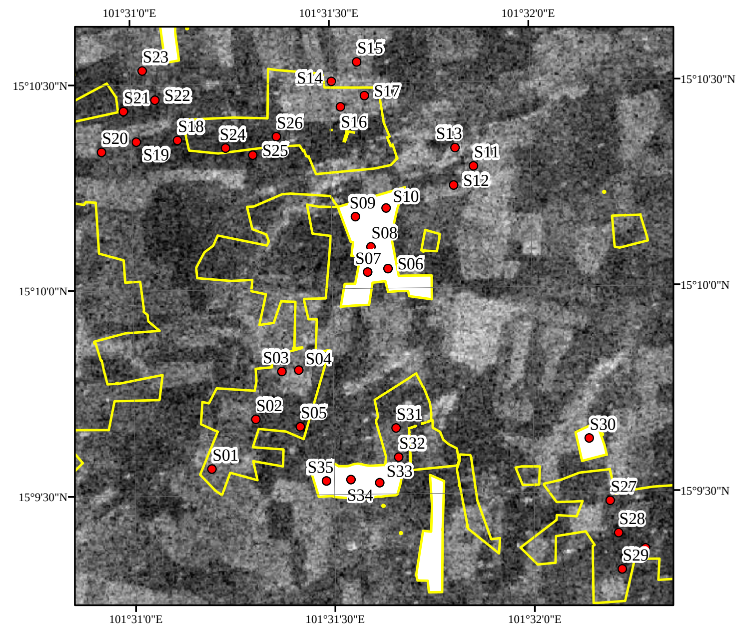


Figure 4 SWC Sampling sites in Thai Tapioca of Development Institute (TTDI), Huai Bong sub district, Dan Khun Thot district, Nakhon Ratchasima province.

2) Statistical Analysis; The Soil Core (h = 5 cm) was used for SWC sampling (Figure 3). The SWC value was expanded into 0-10, 11-20, 21-30, 31-40 and 41-50 cm depth levels. Whereat, to finding the arithmetic mean from SWC value into 0-10, 0-20, 0-30, 0-40, 0-50 cm depth levels. The statistical analysis steps were shown in Figure 5.

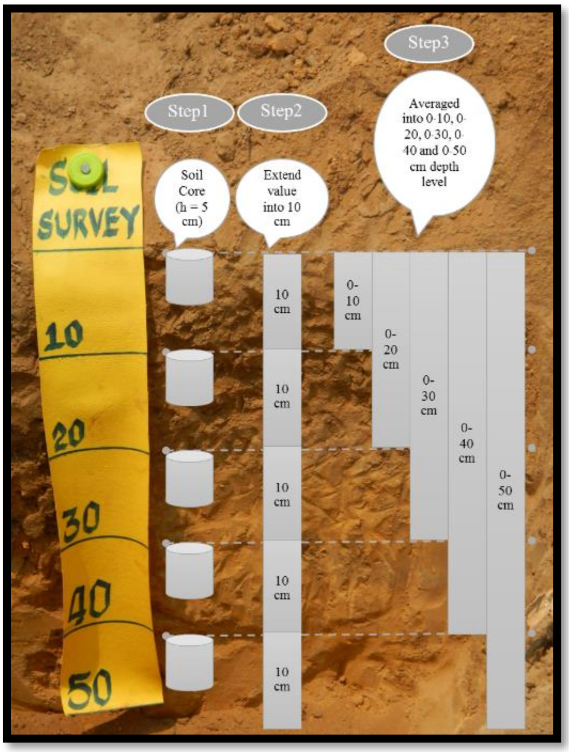


Figure 5 The statistical analysis steps for SWC

3) Backscattering Conversion; Conversion from Digital Number (DN) to Backscattering Coefficient (sigma-naught) (dB) can be calculated by the following equation (JAXA, 2015).

$$\sigma^0{}_{Q16} = 10.log_{10}(DN^2) - 83$$

Where σ = Backscattering Coefficient (dB), DN = Digital Number

4) Regression Analysis; Using regression analysis for estimating the relationships between ALOS-2 PALSAR Backscattering Coefficient (dB) including both HH Polarization and HV Polarization and averaged of SWC value in depth levels range 0-10, 0-20, 0-30, 0-40 and 0-50 cm. The coefficient of determination (R^2) was calculate by the following equation.

$$R^2 = \left(\frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 + \sum_{i=1}^{n}(y_i - \bar{y})^2}}\right)^2$$

R^2 values indicates the strength of the statistical linear relation between ALOS2-PALSAR Backscattering Coefficient (dB) and SWC values.

5) Generated SWC Map; Using linear equation from regression analysis. The backscattering coefficient (dB) level is direct variation with SWC level. Thus the low backscatter represents low SWC and high backscatter represents high SWC.

RESULT AND DISCUSSION

1) SWC Samples

The descriptive statistics of SWC value was shown in Table 1. It found that the SWC will likely increase with more depth levels. SWC at various depth levels of 35 point samples are shown in Figure 6.

Table 1. Descriptive statistics of SWC value

Depth Level (cm)	*Min*	*Max*	*AVG*	*SD*
0-10	2.39	10.58	5.27	1.74
11-20	3.91	17.11	8.72	2.96
21-30	4.76	18.16	10.65	3.40
31-40	6.57	21.44	12.35	3.51
41-50	7.71	23.66	14.49	3.82

Min: minimum; Max: maximum; AVG; average SD: standard deviation

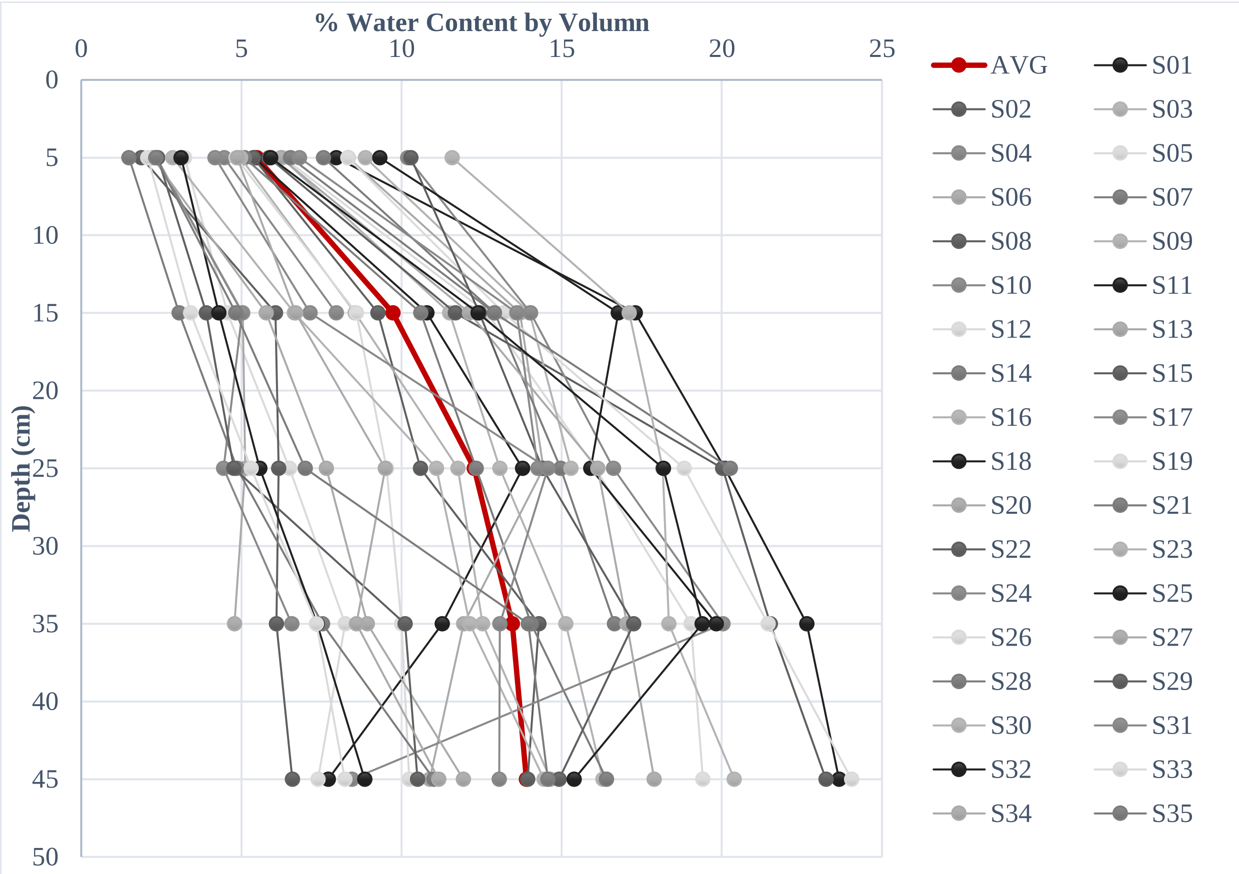


Figure 6 SWC at various depth levels (The grey tone lines show SWC of 35 sampling point, red line shows an average of SWC value.)

2) Averaged of SWC value in the various depths.

SWC value in 0-10 (green), 0-20 (blue), 0-30 (orange), 0-40 (grey) and 0-50 cm (yellow) depth ranges were shown in Figure 7. SWC will likely increase with averaged of more depth levels.

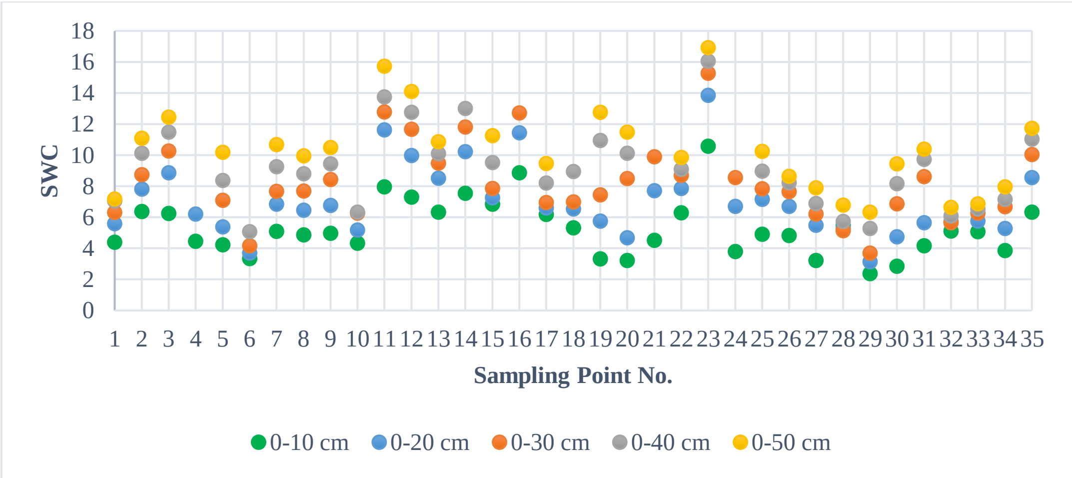
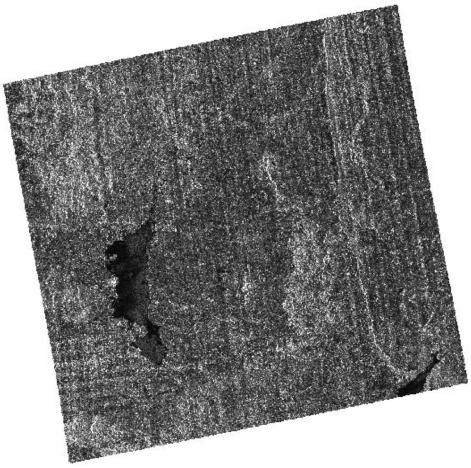


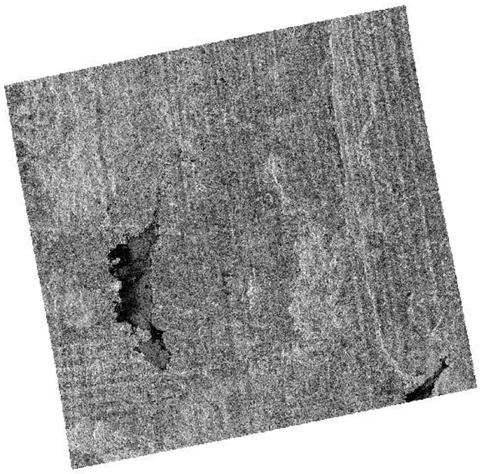
Figure 7 Averaged of SWC value in the various depths

3) ALOS-2 PALSAR Backscattering images

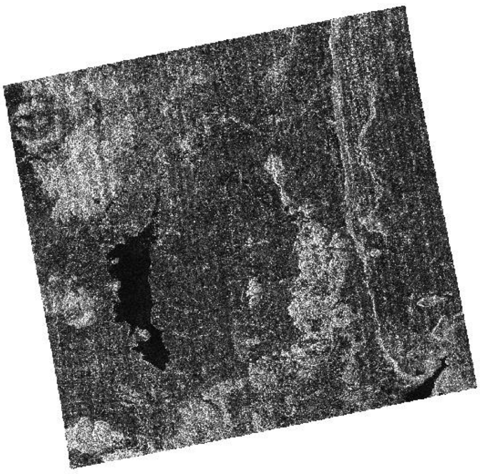
ALOS-2 PALSAR imageries were converted from Digital Number (DN) to Backscattering Coefficient (dB). The conversion result was shown in Figure 8. The result show brightness, sharpness and smoothness so it can clearly separate the land parcel.



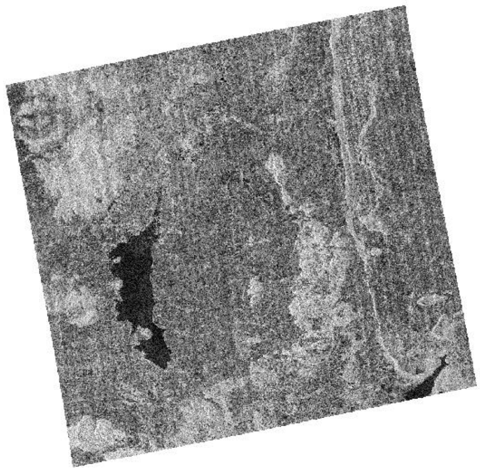
(a) HH Polarization (DN)



(b) HH Polarization (dB)



(c) HV Polarization (DN)

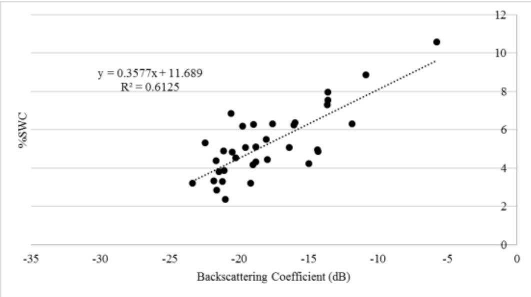


(d) HV Polarization (dB)

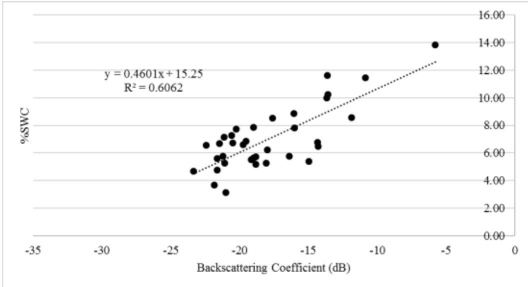
Figure 8 Backscatter conversion from Digital Number (DN) to Backscattering Coefficient (sigma-naught) (dB)

4) Relationships between ALOS2-PALSAR Backscattering Coefficient (dB) and averaged of SWC value.

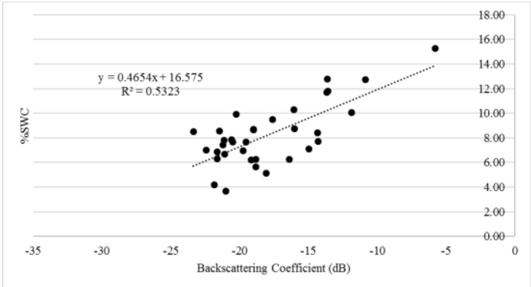
The linear regression equation and coefficient of determination (R2) are shown on Figure 9 and summarize on Table 2. R2 of HH polarization in every depth level is higher than HV polarization. Moreover, R2 is the highest at 0-10 cm depth level and will decrease with more depth level.



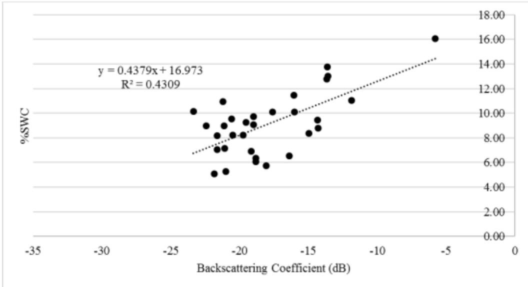
(a) HH Polarization and SWC in 0-10 cm depth



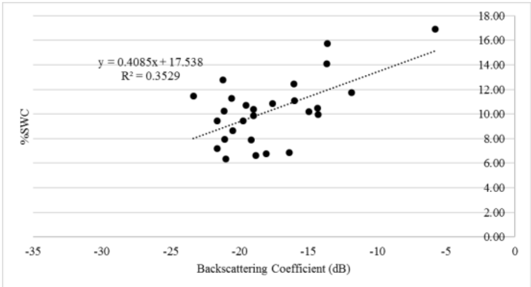
(b) HH Polarization and SWC in 0-20 cm depth



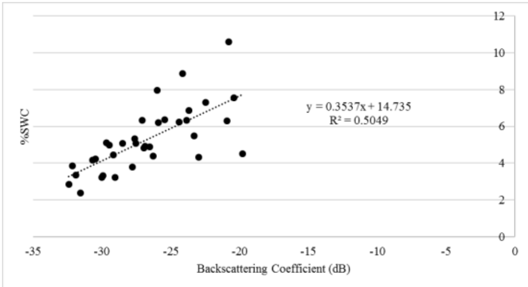
(c) HH Polarization and SWC in 0-30 cm depth



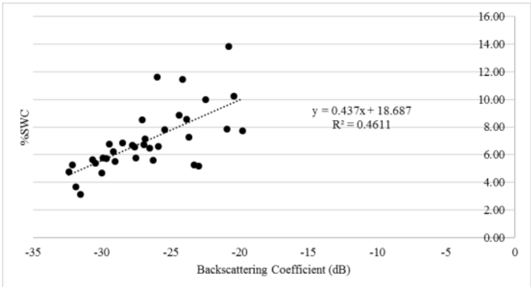
(d) HH Polarization and SWC in 0-40 cm depth



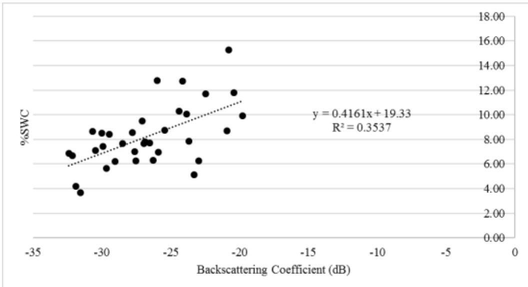
(e) HH Polarization and SWC in 0-50 cm depth



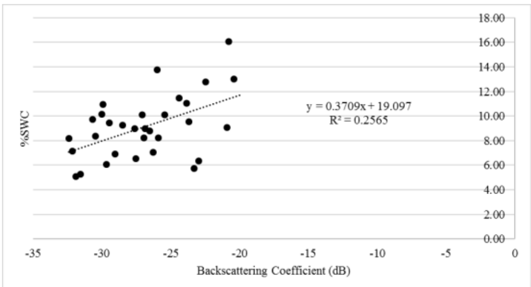
(f) HV Polarization and SWC in 0-10 cm depth



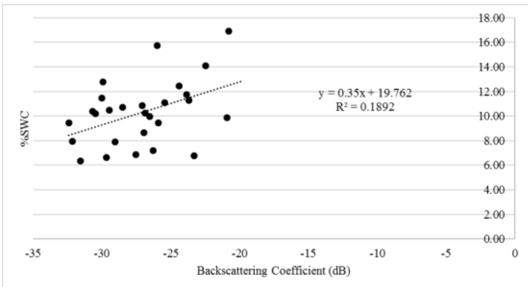
(g) HV Polarization and SWC in 0-20 cm depth



(h) HV Polarization and SWC in 0-30 cm depth



(i) HV Polarization and SWC in 0-40 cm depth



(j) HV Polarization and SWC in 0-50 cm depth

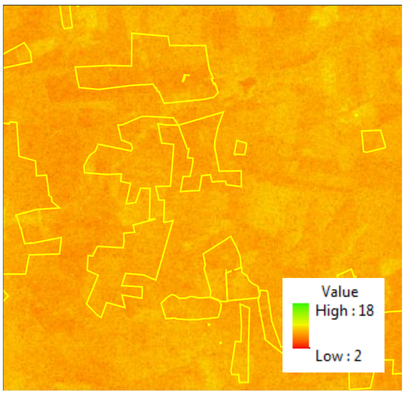
Figure 9 Simulate backscattering of HH and HV Polarization compared to SWC in the various depths.

Table 2. Linear regression equation between HH, HV Polarization and SWC in the various depths.

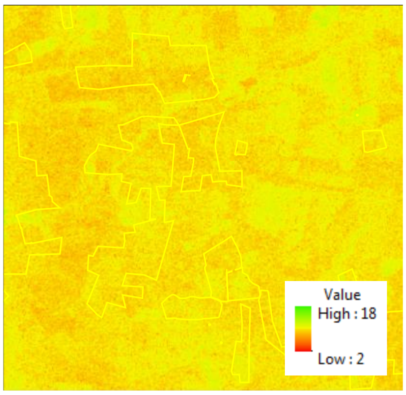
SWC Sample Depth Range (cm)	*HH Polarization*		*HV Polarization*	
	Equation	*R2*	*Equation*	*R2*
0-10	y = 0.3577x + 11.689	0.6125	y = 0.3537x + 14.735	0.5049
0-20	y = 0.4601x + 15.25	0.6062	y = 0.437x + 18.687	0.4611
0-30	y = 0.4654x + 16.575	0.5323	y = 0.4161x + 19.33	0.3537
0-40	y = 0.4379x + 16.973	0.4329	y = 0.3709x + 19.097	0.2565
0-50	y = 0.4085x + 17.538	0.3529	y = 0.35x + 19.762	0.1892

5) Generated SWC Map

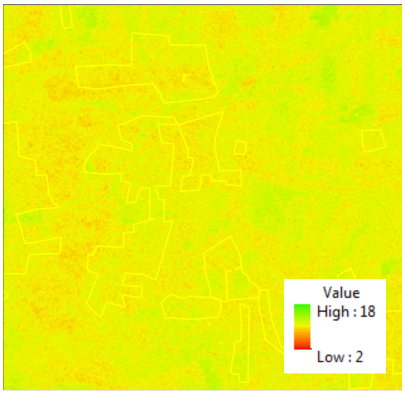
Referring to the regression equation in table 2. The regression analysis led to this model which can used to generate SWC Map in the various depths. SWC must be used to consideration in making rescale range of the map. The generate SWC were shown in Figure 10. The low backscatter (red) refers to low of water content and high backscatter (green) refers to high of water content.



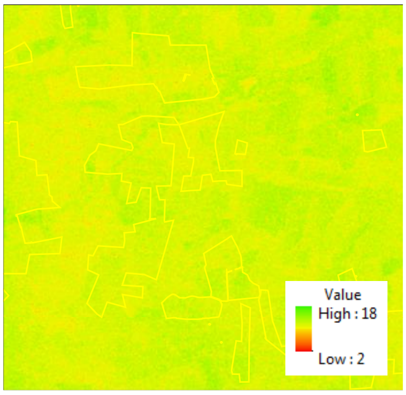
(a) SWC 0-10 cm depth



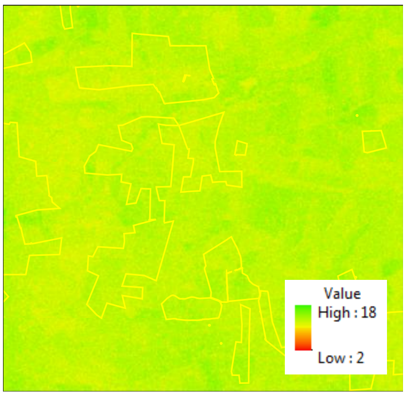
(b) SWC 0-20 cm depth



(c) SWC 0-30 cm depth



(d) SWC 0-40 cm depth



(e) SWC 0-50 cm depth

Figure 10 SWC Map in the various depths. (Yellow line is of TTDI boundary)

CONCLUSION

Polarization of L-band has capability to detect SWC in various depths. According to the property of the SWC in this study area is systematically increase with depth. Caused the relationship between ALOS2 PALSAR backscattering coefficient (dB) and SWC in various depth levels are significant. The generated SWC map in 0-10, 0-20, 0-30, 0-40 and 0-50 cm can be utilized in an agricultural management.

ACKNOWLEDGMENT

We would like to thank BIOTEC (National Center for Genetic Engineering and Biotechnology) and Thai Tapioca of Development Institute (TTDI) for supporting our project.

REFERENCE

G. Macelloni, S. Paloscia, P. Pampaloni, E. Santi and M. Tedesco., 2003. Microwave radiometric measurement of soil moisture in Italy. Hydrology and Earth System Sciences, 7 (6), pp. 937-948.

JAXA, 2015. ALOS-2 / Calibration Result of JAXA standard products, Retrieved September 15, 2015, from Japan Aerospace Exploration Agency Web site: http://www.eorc.jaxa.jp/ALOS-2/en/calval/calval_index.htm

M. J. Escorihuela, A. Chanzy, J.P. Wigneron and Y.H. Kerr, 2010. Effective soil moisture sampling depth of L-band radiometry: A case study. Remote Sensing of Environment, Elsevier, pp. 7.

M. Bittelli, 2011. Measuring soil water content: A Review. HortTechnology, pp. 293-300

R.j. Hillocks, J.M. Thresh and A.C. Bellotti., 2001, Cassava: Biology, Production and Utilization, CABI Publishing, London, pp. 69

T. G. Farr, C. Elachi, P. Hartl, and K. Chowdhury., 1986. Microwave Penetration and Attenuation in Desert Soil A Field Experiment with the Shuttle Imaging Radar, IEEE Transactions on Geoscience and Remote Sensing, Vol. ge-24, no. 4, pp. 590-593

Ulaby, F. T., M. C. Dobson, and G. A. Bradley, 1981. Radar reflectivity of bare and vegetation covered soil. Advances in Space Research, Vol. 1, no. 10, pp. 91-104.

Woranut C, Phattaraporn Sangrawee, Yotthaphom Pothiracha, Thitawadee Suvachananon and Wanapong Kaenwsing, 2013. The estimate of soil moisture in agricultural fields Nakhon Ratchasima province Thailand, Proceedings of the 34th Asian Conference on Remote Sensing 2013, Bali – Indonesia, Oct 20 -24, 2013, pp. 458 – 464