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REMOTE SENSING BASED VEGETATION INDICES FOR ESTIMATING ABOVE GROUND CARBON SEQUESTRATION IN ORCHARDS

SUMMARY

This study aims to apply remote sensing technology to estimate above ground carbon sequestration of orchards with vegetation indices into two forms: 1) Normalized Difference Vegetation Index (NDVI) and 2) Transformed Normalized Difference Vegetation Index (TNDVI). It also aims to explore field data by using the data from a satellite called Landsat 7 ETM+ Path 127 Row 48 that was recorded on 30 January 2015 to adjust the Top of Atmosphere (ToA) reflectance and then determine the percentage of fractional cover, and build the relationship equation between satellite data from Landsat 7 ETM+ and field data collection. The results from NDVI showed the equation $y = 0.2836e^{0.0373x}$ with coefficient of $R^2 = 0.872$. As a result, the calculated amount of above ground carbon was 255.712 tCO₂/rai. Meanwhile, the results from TNDVI showed relationship equation $y = 0.2261e^{0.0388x}$ with the coefficient of $R^2 = 0.877$. As a result, the calculated amount of $R^2 = 0.877$. As a result, the calculated amount of $R^2 = 0.877$. As a result, the calculated amount of $R^2 = 0.877$. As a result, the calculated amount of $R^2 = 0.877$. As a result, the calculated amount of $R^2 = 0.877$. As a result, the calculated amount of $R^2 = 0.877$. As a result, the calculated amount of $R^2 = 0.877$. As a

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INTRODUCTION

Nowadays, the current development of the economy and industry consumes too much natural resources beyond the natural balance, which is a major factor that causes climate change. As a result, the world has faced more natural disasters, which threaten the lives and well-being of mankind. The dramatic increase in the average temperature of the earth's surface is also called "global warming", which is a part of the world's climate change caused by various human activities that release greenhouse gases, particularly carbon dioxide, the highest amount of greenhouse gas in the atmosphere. Burning fossil fuels and forestry activities are another activity that has a major role to the change of carbon amount in the atmosphere (Wasun et al., 2010). One of the major reasons that cause climate change is the change of land usage, especially the deforestation. The study found that there is 20 percent of the issue caused by

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losing carbon that is stored in the wood (Usa et al., 2011). The reason is that forests can absorb and store CO_2 by sequestrating carbon as biomass in various parts of plants, including stem, branches, leaves, and roots. The potential for CO_2 sequestration would depend on the ecological factors including type of forest, forest density, topography and environmental factors. In the assessment, the above ground carbon sequestration of forests is extremely important (Ogawa et al., 1965; Senpaseuth et al., 2009).

Remote sensing with the use of satellite data is considered as a modern technology. It has been used as data to monitor the changes of natural and manmade events in time. Furthermore, it can also be used together with the Geographic Information System effectively (Gomasathit et al., 2011; Laosuwan, et al., 2011; Odindi, et al., 2015). Currently, the remote sensing technology has been developed to help sequestrating above ground carbon because the satellite data can record the reflection of multi-spectral electromagnetic waves, resulting in the ability to estimate the amount of above ground carbon sequestration in the forests quickly and easily through the features of the recorded electromagnetic waves (Lu, et al., 2002; Laosuwan, et al., 2011; Patel, et al., 2007; Schlerf and Alzberger, 2005; Samaniego and Schulz, 2009; Senpaseuth, et al., 2009; Teerawong and Pornchai, 2014). For this study, the purpose is to apply the remote sensing to estimate above ground carbon sequestration of the orchards in Sang Kho sub district, Phu Phan district, Sakon Nakhon Province in northeast Thailand.

MATERIAL AND METHODS

A total orchard areas of 14 local orchard farmers which is 70.10 rai (6.25 rai = 1 hectare) Sang Kho sub district, Phu Phan district, Sakon Nakhon Province in northeast Thailand (Figure 1) has been chosen as the study area for this research.



Figure 1. The study area

This study used data from the satellite named Landsat 7 ETM+ (Table 1) Path 127 Row 48 with recorded data on 30 January 2015 by the satellite data can be downloaded from The US Geological Survey (USGS) through the website http://glovis.usgs.gov/.

Band	Wavelength	Characteristics
Band 1	0.450-0.515 µm (Blue-Green)	Ground/plant different, coastal zones
Band 2	0.525-0.605 µm (Green)	Vegetation
Band 3	0.630-0.690 µm (Red)	Differentiate plant species
Band 4	0.775-0.900 µm (Near infrared)	Biomass
Band 5	1.550 - 1.750 µm (Shortwave IR)	Snow/cloud differentiation
Band 6	10.40 - 12.50 µm (Thermal IR)	Thermal
Band 7	2.090 - 2.350 µm (Reflective IR)	Lithology
Band 8	0.520-0.900 µm (Far IR)	Panchromatic

Table 1. Landsat 7 ETM+

The data preparation before analysis was done by adjusting the Top of Atmosphere (ToA) Reflectance of the satellite data from Landsat 7 ETM+. To ensure the accuracy of information, the preparation was done in two processes, including 1) The process of making convert digital number to radiance values and 2) The process of making convert radiance to ToA reflectance. Also, for the implementation of the two processes, the researchers adopted equation 1 and equation 2 as follows (Senpaseuth, et al., 2009; Usa et al., 2011; Teerawong and Pornchai, 2014).

$$L_{\lambda} = Grescale * Qcal + Brescale \tag{1}$$

Where;

$$Grescale = \frac{LMAX_{\lambda} - LMIN_{\lambda}}{Qcalmax - Qcalmin}$$

Brescale = $LMIN_{\lambda} - [LMAX_{\lambda} - LMIN_{\lambda} / Qcalmax - Qcalmin] \times Qcalmin$ Where;

 L_{λ} = Spectral radiance at the sensor's aperture [W/(m² sr µm)]

Qcal = Quantized calibrated pixel value [DN]

Qcalmin = Minimum quantized calibrated pixel value corresponding LMIN_{λ}

Qcalmax = Maximum quantized calibrated pixel value corresponding LMAX_{λ}

 $LMIN_{\lambda}$ = Spectral at sensor radiance that is scaled to Qcalmin [W/(m²sr µm)]

 $LMAX_{\lambda} =$ Spectral at sensor radiance that is scaled to $Qcalmax [W/(m^2 sr \mu m)]$

Grescale = Band specific rescaling gain factor [($W/(m^2 \text{ sr } \mu m)$)/DN]

Brescale = Band specific rescaling bias factor $[W/(m^2 \text{ sr } \mu m)]$

$$\rho_{\lambda} = \frac{\pi \times L_{\lambda} \times d^2}{E_{SUN_{\lambda}} \times \cos \theta_s}$$
(2)

Where;

 ρ_{λ} = Unitless planetary reflectance

 L_{i} = Spectral radiance at sensor's aperture (Wm⁻² sr⁻¹µm⁻¹)

d = Earth-sun distance in astronomical units

 E_{SUN_2} = Mean solar exoatmospheric irradiances

 $\theta_s =$ Solar zenith angle

Normalized Difference Vegetation Index (NDVI) is calculated from the ratio between the difference and the sum of the reflection of visible red light and near Infrared objects on the Earth's surface. The results of the calculation are index values between -1 and +1, ground water with NDVI values less than 0, open ground with NDVI values between 0 to 0.1, and plant covered area with NDVI values over 0.1 (Kogan and Sullivan, 1993; Kogan, 1995; Dipanwita et al., 2015). The researchers adopted the equation 3 in order to analyze the NDVI values in this study.

$$NDVI = (NIR - RED) / (NIR + RED)$$
(3)

Where; NIR = Near Infrared Band RED = Red band

Transformed Normalized Difference Vegetation Index (TNDVI) is measure index of the amount of green biomass and composition of chlorophyll in plants. The value of TNDVI was added by 0.5 to avoid the negative value together with applying the square root with the value (Solaimani et al., 2011; Farooq, 2012; Malini and Somashekar, 2013). The researchers adopted the equation 4 to analyze the TNDVI value in this study.

$$TNDVI = \left(\left(NIR - Red \right) / \left(NIR + Red \right) + 0.5 \right)$$
(4)

Where;

NIR = Near Infrared Band

RED = Red band

The finding the coefficient of fractional cover: In this process, the researchers would find the coefficient of fractional cover of NDVI and TNDVI by applying equation 5 (Teerawong and Pornchai, 2014; Teerawong and Pornchai, 2016).

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$$FC = \frac{(VI - VI_{open})}{(VI_{canopy} - VI_{open})} \times 100$$
(5)

Where;

FC = Tree canopy fractional cover

VI = Vegetation index

 VI_{open} = Vegetation index of open areas

 VI_{canopy} = Vegetation index of tree canopy

The finding the correlation of statistical data: In this process, the researchers would find the relationship between the amount of above ground carbon sequestration (the dependent variable) and the vegetation indices by using the pixel at the same position with sample plot as shown in Figure 2 (22 sample plots with the size of 20 x 20 meters scattered around the study area). The collection of field data by analyzing correlated coefficient value was to explore the relationship between independent variables and the dependent variables in order to decide the appropriate independent variable for forming the equation of the above ground carbon sequestration estimation.



Figure 2. The 22 sample plots with the size of 20 x 20 meters Figure 2. Sampling quadrate of 0.25 m² (0.5 m \times 0.5 m).

RESULTS AND DISCUSSION

In this study, the results of satellite data from Landsat 7 ETM+ through the adjustment process (ToA) can be presented in Figure 3 and Figure 4.

The analyzing of data from the satellite landsat 7 etm+ was done in two forms, including 1) normalized difference vegetation index (ndvi) and 2) transformed normalized difference vegetation index (tndvi). The coefficient of fractional cover was found by the satellite data from landsat 7 etm+ through the process of normalized difference vegetation index ndvi) and transformed normalized difference vegetation index (tndvi).



Figure 3. Before ToA



Figure 4. After ToA

To find the relationship of statistical data, the researchers analyzed the satellite data from Landsat 7 ETM+ to find the relationship with the field data in order to form the equation for the above ground carbon sequestration estimation. The results of the study (Figure 5 and Figure 6) from NDVI showed the

relationship equation of $y = 0.2836e^{0.0373x}$ with the defined coefficient of $R^2 = 0.872$. As a result, the estimation of above ground carbon volume was 255.712 tCO₂/rai. On the other hand, the results from TNDVI showed the relationship equation of $y = 0.2261e^{0.0388x}$ with the defined coefficient of $R^2 = 0.877$. As a result, the estimation of above ground carbon volume was 255.400 tCO₂/rai.



Figure 5. The relationship of statistical data of NDVI



Figure 6. The relationship of statistical data of TNDVI

CONCLUSIONS

This was a tree size used to calculate biomass and carbon sequestration from the field survey in order to identify the relation of the equations. Considering the coefficient of determination, the TNDVI was the most efficient way. The study also found that the result was in the same direction with other research such as Carbon Stock Assessment Using Remote Sensing and Forest Inventory Data in Savannakhet, Lao PDR (Phutchard et al., 2010), Estimating Tree Biomass via Remote Sensing, MSAVI 2, and Fractional Cover Model (Teerawong and Pornchai, 2014) and Mapping Global Forest Above ground Biomass with Spaceborne LiDAR, Optical Imagery, and Forest Inventory Data (Tianyu et al., 2016). In addition, a statistical significance of the above ground carbon sequestration collected from the field survey and analyzed by Landsat 7 ETM+ via Pair Sample T-test of both equations (NDVI, TDVI) was tested. It was found that the two equations yielded the reliability level at 95%. The results can be applied to estimate the above ground carbon sequestration of the orchards in Sang Kho sub district, Phu Phan district, Sakon Nakhon Province in northeast Thailand without having field survey for the entire area. This can reduce cost and time in doing research and obtain up-to-date information that serves urgent needs.

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