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APPLICATION OF GEO-INFORMATICS AND VEGETATION INDICES TO ESTIMATE ABOVE-GROUND CARBON SEQUESTRATION

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ABSTRACT: This research aims to estimate above-ground carbon sequestration of orchards by using the data collected from Landsat 8 OLI. Regression equations are applied to study the relationship between the amount of above-ground carbon sequestration and vegetation indices from Landsat 8 OLI, in which the data was collected in 2015 in 3 methods: 1) Difference Vegetation Index (DVI), 2) Green Vegetation Index (GVI), and 3) Simple Ratio (SR). The results are as follows: 1) By DVI method, it results in the equation $y = 0.3184e^{0.0482x}$ and the coefficient of determination $R^2 = 0.8457$. The amount of above-ground sequestration's calculation result is 213.176 tons per rai. 2) By GVI method, it results in the equation $y = 0.2619e^{0.0489x}$ and the coefficient of determination $R^2=0.8763$. The amount of above-ground sequestration's calculation result is 220.510 tons per rai. 3) By SR method, it results in the equation $y = 0.8900e^{0.0469x}$ and the coefficient of determination $R^2 = 0.7748$. The amount of above-ground sequestration's calculation result is 234.229 tons per rai.

Keywords: Geo-informatics, remote sensing, above-ground carbon sequestration

INTRODUCTION:

The levels of carbon dioxide in the atmosphere nowadays are not only higher due to the burning of fossil fuels such as oil, coal and natural gas by human hands, but also the deforestation. Forestry areas especially several tropical rain forests in developing countries are destroyed for trading or agricultural purposes (OEPP, 1994; IPCC, 2010; Jundang et al., 2010). The destruction of forests produces large amounts of greenhouse gases. When the trees are burned or destroyed, the carbon dioxide collected in those trees will be emitted to the atmosphere. In addition, the amounts of carbon dioxide in the world's atmosphere have been excessive since the past century until now and they tend to increase continually. At present, the global concentration of carbon dioxide in the atmosphere has reached 383 ppm (Usa et al., 2011). The increase of carbon dioxide in the atmosphere is a significant factor that causes the greenhouse effect. It has a profound impact on the rise of the earth's temperature. Forests play an important role in changing of carbon dioxide levels in the atmosphere as 20% of carbon dioxide increase caused by the loss of carbon in biomass burning due to deforestation and loss of soil carbon due to the land use (Ogawa et al., 1965; Senpaseuth et al., 2009; UNFCCC, 2013a; UNFCCCb, 2013b). In addition, trees can absorb carbon dioxide from the atmosphere by photosynthesis process and being stocked in biomass forms which include above-ground parts such as stems, branches, and leaves; and underground parts such as roots. The process makes carbon stay in the trees until they are cut down (Ogawa et al., 1965; Senpaseuth et al., 2009; Malini and Somashekar, 2013; Chicago Climate Exchange, 2014). Thus, cutting off trees should be reduced, while forestry areas should be more increased by announcing forest protected areas. However, the estimation of carbon storage of wide forest areas by surveying is difficult and expensive. For this reason, therefore, Geo-informatics by application of remote sensing technology is applied to calculate the amounts of carbon storage in forestry areas (Schlerf et al., 2005; Samaniego and Schulz, 2009; Solaimani et al., 2011; Laosuwan et al., 2011; Dong and Shao, 2014; Laosuwan and Uttaruk, 2014; Wang and Liu, 2015). This method makes it very convenient and reduces the cost of estimating the amounts of carbon storage in forestry areas.

In Thailand, most researches focus on the estimation of carbon storage of forestry areas and forest parks. Nevertheless, the data collection of carbon storage in fruit orchards has not been brought to focus. Therefore, this research aims to study the amounts of above-ground carbon sequestration by using remote sensing technology of orchards in Sang Kho sub district, Phu Phan district, Sakon Nakhon Province in northeast Thailand

MATERIALS AND METHODS:

Data Preparation from remote sensing: This research used the data from Landsat 8 OLI, Path 127 Row 48 dated on the 8th of January in 2016 (Fig. 1). The procedures are as follows (Fig. 2):

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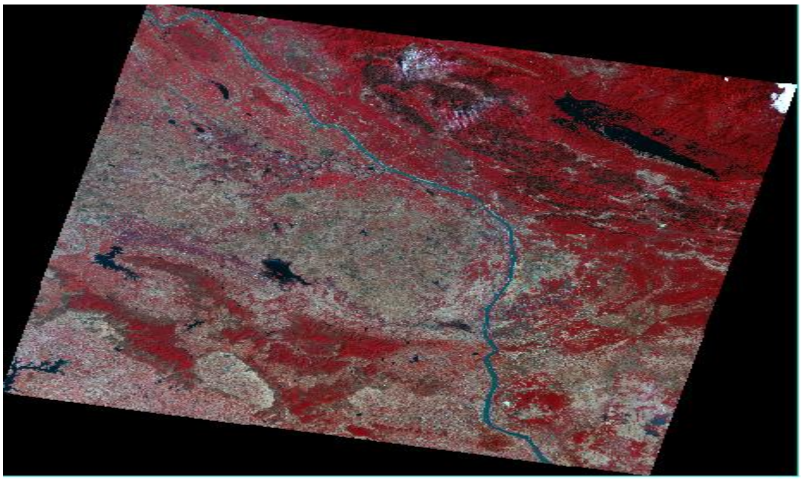

Fig. 1. Landsat 8 OLI, Path 127 Row 48

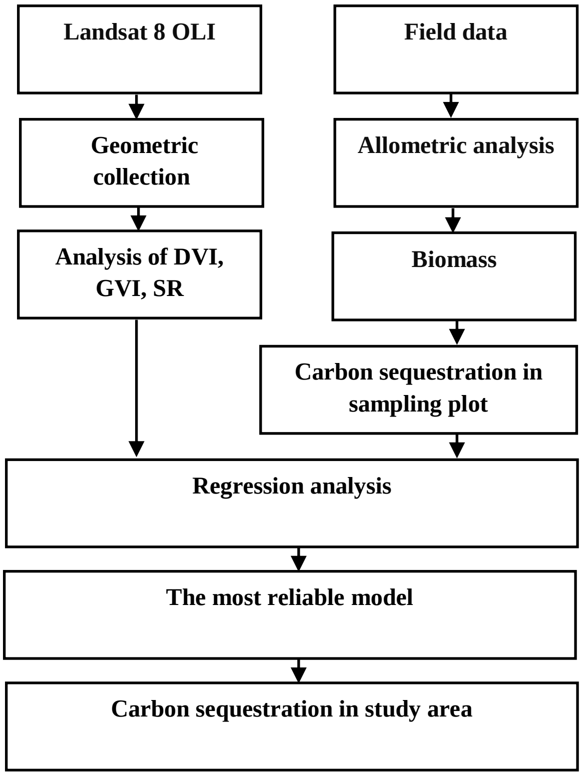

Fig. 2. Flowchart of the study

1) The image data covering the area of study was chosen. Then the geometric correction was applied to correct the image data.

2) The Top of Atmosphere (ToA) reflectance was adjusted to reduce the mistakes of the energy reflected from objects on the earth to the data recorder based on the current environmental conditions including the weather, landscape, temperature, and angle of incident by using equation 1 and equations 2 (Lu et al., 2002; Richard; 2015; Yale University, 2015).

$$L_\lambda = Grescale * Qcal + Brescale \qquad (1)$$

Where;

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

$$Brescale = LMIN_\lambda - \left(\frac{LMAX_\lambda - LMIN_\lambda}{Qcalmax - Qcalmin}\right) \times Qcalmin$$

Where;

L_λ = Spectral radiance at the sensor's aperture [W/(m^2 sr µm)]

$Qcal$ = Quantized calibrated pixel value [DN]

$Qcalmin$ = Minimum quantized calibrated pixel value corresponding $LMIN_\lambda$

$Qcalmax$ = Maximum quantized calibrated pixel value corresponding $LMAX_\lambda$

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

$LMAX_\lambda$ = Spectral at sensor radiance that is scaled to *Qcalmax* [W/(m^{2}sr µm)]
Grescale = Band specific rescaling gain factor [(W/(m^2 sr µm))/DN]
Brescale = Band specific rescaling bias factor [W/(m^2 sr µm)]

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

Where;
ρ_λ = Unitless planetary reflectance
π = 3.14
L_λ = Spectral radiance at sensor's aperture (Wm^{-2} sr^{-1}µm^{-1})
d = Earth-sun distance in astronomical units
E_{SUN_λ} = Mean solar exoatmospheric irradiances
θ_s = Solar zenith angle

3) The pixel of the corrected data from the previous steps was chosen in the same spot of the permanent plots for data collection. After that, the data was analyzed together with DVI, GVI and SR by applying equations 3 to equations 5 (Schlerf et al., 2005; Malini and Somashekar, 2013; Odindi et al., 2015; Harrisgeospatial Soulution, 2015; Portland State University, 2015). Incidentally, the values of DVI, GVI and SR greater than 0 to 1, it would be the vegetation. If the value was equal to or less than 0 and 0, it was non-vegetation areas. Moreover, in this study using Fractional Cover (FC) (equation 6) to set up data and classify plants that were from 0 to 100.

$$DVI = NIR - RED \quad (3)$$

Where;
NIR = Near Infrared Band
RED = Red band

$$GVI = -(0.2848\ x\ Band\ 2) - (0.2435\ x\ Band\ 3) - (0.5436\ x\ Band\ 4) + (0.7243\ x\ Band\ 5) + (0.0840\ x\ Band\ 6) - (0.1800\ x\ Band\ 7) \quad (4)$$

Where;
$Band$ = $Band$ 2 to $Band$ 7 of Landsat 8 OLI (0.45 – 2.29 micrometers)

$$SR = NIR / RED \quad (5)$$

Where;
NIR = Near Infrared Band
RED = Red band

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

(6)
Where;
FC = Tree canopy fractional cover
VI = Vegetation index
VI_{open} = Vegetation index of open areas
VI_{canopy} = Vegetation index of tree canopy

Preparation for Field Work: In this research, 22 permanent plots with 20 m x 20 m were created as the simulated orchards of the study area which is 72.20 rai (6.25 rai = 1 hectare). After that the data of types and numbers of big trees with 4.5 cm: DBH (Diameter at Breast Height) was collected. This process also included tree height measurement. The survey data was recorded into the data recording form. Then Allometric equation (equation 7) was used for plants in agroforestry in Thailand (Usa et al., 2011) to calculate the amounts of above-ground biomass.

$$Ws = 0.0389\left(D^2H\right)^{(0.9417)} \qquad r^2 = 0.9106$$
$$Wb = 0.0678\left(D^2H\right)^{(0.6618)} \qquad r^2 = 0.8347$$
$$Wl = 0.0084\left(D^2H\right)^{(0.7660)} \qquad r^2 = 0.9109$$

(7)
Where;
Ws = Stem
Wb = Branch
Wl = Leaf

Analysis of Data: The estimation of above-ground carbon sequestration by using the data collected from Landsat 8 OLI is as follows:

1) The regression equation was used to analyze the relationship between the amounts of above-ground carbon storage and spectral reflectance rate in connection with the data of vegetation indices from Landsat 8 OLI in 2015 such as DVI, GVI and SR.

2) The data results were compared to determine the most suitable equation to estimate above-ground carbon sequestration in orchards in Sang Kho sub district, Phu Phan district, Sakon Nakhon Province in northeast Thailand.

RESULTS :

In this study, the results of satellite data from Landsat 8 OLI data through the correction process (ToA) can be presented in Fig. 3.

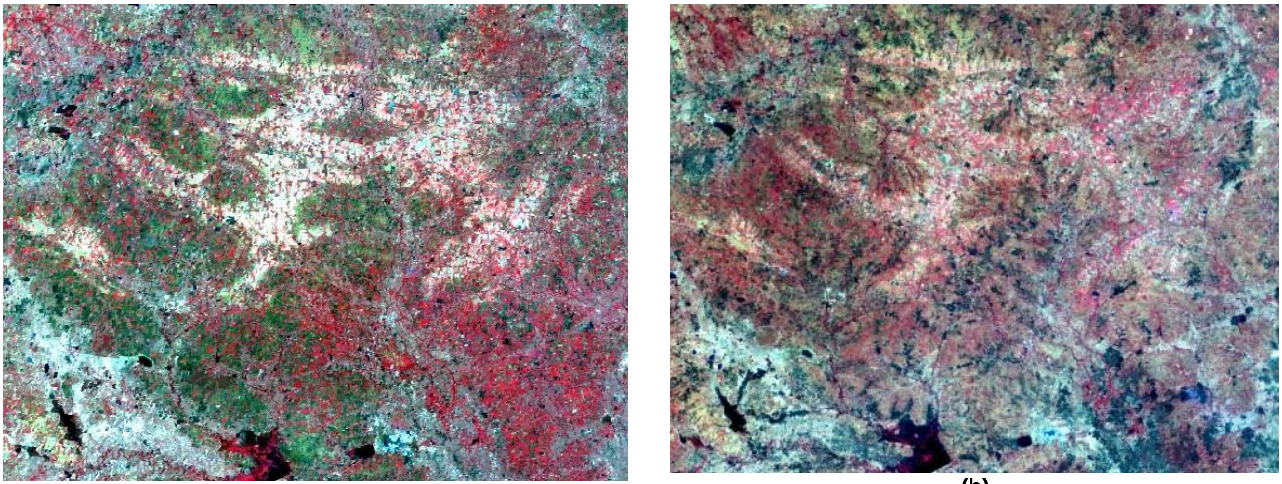
(a) (b)

Fig.3. Illustration of correction process (ToA) of Landsat 8 OLI (a) Before ToA, (b) After ToA

In order to determine the relationship of statistical data, the researcher used the data collected from Landsat 8 OLI to analyze the relationship together with the field work data to create equations for estimation of above-ground carbon sequestration. The results can be explained as follows:

1) By DVI method, it results in the equation $y = 0.3184e^{0.0482x}$ and the coefficient of determination $R^2 = 0.8457$ (Fig 4). The amount of above-ground sequestration's calculation result is 213.176 tons per Rai.

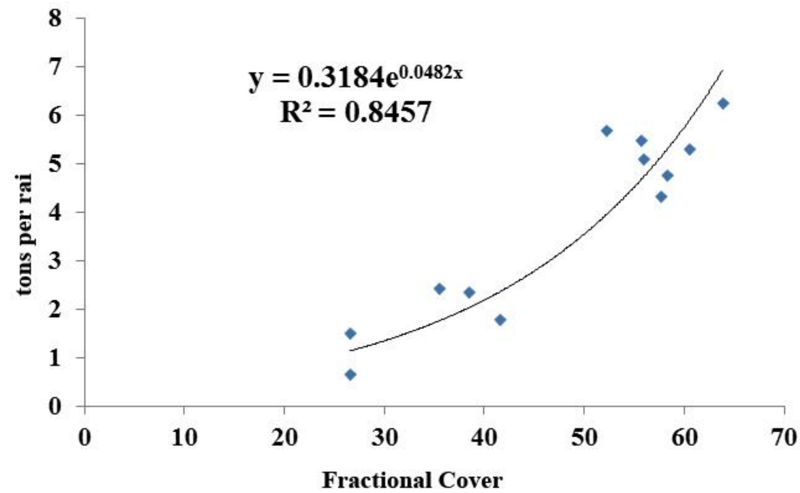

Fig. 4. The equation by DVI method

2) By GVI method, it results in the equation $y= 0.2619e^{0.0489x}$ and the coefficient of determination $R^2 = 0.8763$ (Fig 5). The amount of above-ground sequestration's calculation result is 220.510 tons per Rai.

3) By SR method, it results in the equation $y = 0.8900e^{0.0469x}$ and the coefficient of determination $R^2 = 0.7748$ (Fig 6). The amount of above-ground sequestration's calculation result is 244.229 tons per Rai.

Furthermore, the researcher also tested the statistical correctness of above-ground carbon data collected from Landsat 8 OLI and the field work by using Pair Sample T-test. As a result, it could be concluded that DVI, GVI, and SR methods had 95% confidence level of the statistical significance.

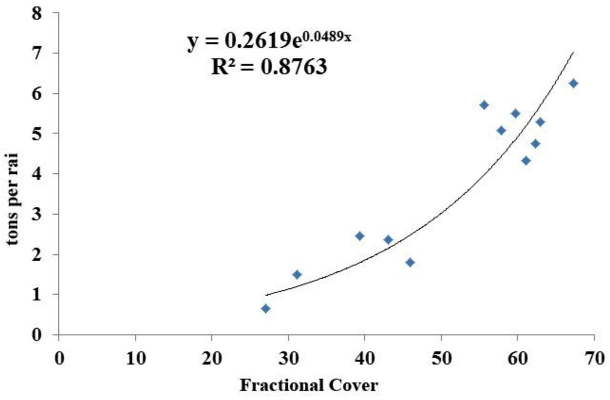

Fig.5. The equation by GVI method

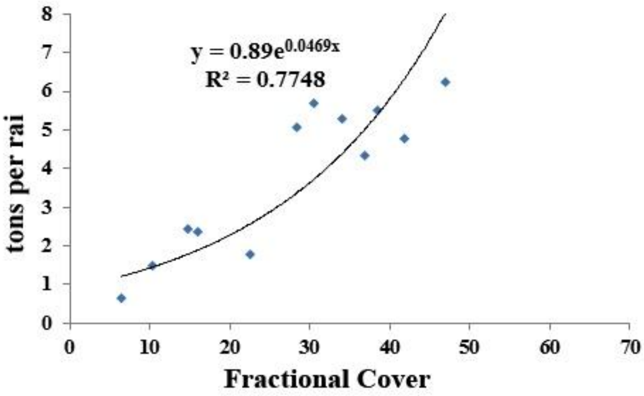

Fig. 6. The equation by SR method

CONCLUSIONS

The study of above-ground carbon sequestration by using the data collected from Landsat 8 OLI and vegetation indices including DVI, GVI, and SR of orchards in in Sang Kho sub district, Phu Phan district, Sakon Nakhon Province in northeast Thailand to determine the relationship between the amounts of above-ground carbon storage (dependent variable) and vegetation indices such as DVI, GVI and SR from the data collected from Landsat 8 OLI (independent variable) by applying 3 regression equations to calculate the relationship between the variables resulted that the best method was GVI with the equation $y = 0.2619e^{0.0489x}$ and the coefficient of determination $R^2=0.8763$. After the Pair Sample T-test was applied, however, it was found that the 3 equations had 95% confidence of statistical significant level. For further studies, one of the 3 equations is able to be applied to estimate above-ground carbon sequestration of orchards in other areas of Thailand.

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