

CHAPTER III

METHODS AND TOOLS

3.1 Materials and Tools

The following materials and tools are used in the conduct of the study:

- 1) LANDSAT-5 TM image path 130 row 47; dated May 05, 2010 which has been supported from Geo-Informatics and Space Technology Development Agency (Public Organization)
- 2) Khun Mae Kham Mee Plantation Boundary (*Source: FIO*)
- 3) Remote Sensing and GIS software: ERDAS and ARCGIS
- 4) GPS
- 5) Computer
- 6) Diameter tape
- 7) Hypsometer
- 8) Steel tape
- 9) Camera

3.2 Study Process

The study methodologies were defined into 4 broad parts: 1) Pre-processing 2) Teak plantation and non-Teak plantation identification in Khun Mae Kham Mee Plantation 3) Age stage identification of Teak plantation in Khun Mae Kham Mee Plantation 4) Estimate biomass and carbon storage of Teak plantation are explained as follows:

3.2.1 Pre-processing

Pre-processing includes geometric correction and radiometric calibrations are as follows:

3.2.1.1 Geometric correction

LANDSAT-5 TM image with least cloud cover was selected for data processing. Corrections on radiometric and atmospheric were carried out. Perform geometric correction using the map to image registration approach, using a model Polynomial Oder 2 and then using the ground control points (GCP) of at least 6 points from a topographic map of Royal Thai Survey Department with the L7018 series and the scale of 1:50,000. The reference is Universal Transverse Mercator (UTM) datum. The Root Mean Square Error (RMS) is less than 1.0 [42]. Spatial resolution for this matter was 30x30 meter.

3.2.1.2 Radiometric calibration

The radiometric calibration is covert digital numbers (DN) to physical unit which this study will be converted to Top-of-atmosphere (TOA). The fundamental step is calculation of at sensor spectral radiance (L_λ). During first step, pixel values from raw are converted to unit of absolute spectral radiance using 32-bit floating-point calculation. The absolute radiance values are then scaled to 8-bit numbers representing calibrated digital numbers (Q_{cal}) before output to distribution media. The conversion requires knowledge of the lower and upper limit of the original rescaling factors [16]. The following equation is used to perform the Q_{cal} to L_λ conversion for Level 1 products:

$$L_\lambda = \left[\frac{LMAX_\lambda - LMIN_\lambda}{Q_{cal\ max} - Q_{cal\ min}} \right] (Q_{cal} - Q_{cal\ min}) + LMIN_\lambda$$

Where:

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

Q_{cal} = Quantized calibrated pixel value [DN]

$Q_{cal\ min}$ = Minimum quantized calibrated pixel value corresponding to $LMIN_\lambda$ [DN]

$Q_{cal\ max}$ = Maximum quantized calibrated pixel value corresponding to $LMAX_\lambda$ [DN]

$LMIN_\lambda$ = Spectral at-sensor radiance that is scaled to $Q_{cal\ min}$ [$W/(m^2\ sr\ \mu m)$]

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

Level 2 is conversion to TOA reflectance that compensates for different values of the exoatmospheric solar irradiance arising from spectral band differences which computes according to the equation [16]:

$$\rho_{\lambda} = \frac{\pi \cdot L_{\lambda} \cdot d^2}{ESUN_{\lambda} \cdot \cos\theta_s}$$

Where:

ρ_{λ} = Planetary TOA reflectance [unitless]

π = Mathematical constant approximately equal to 3.14159 [unitless]

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

d = Earth-Sun distance [astronomical units]

$ESUN_{\lambda}$ = Mean exoatmospheric solar irradiance [W/(m² μ m)]

θ_s = Solar zenith angle [degrees]

In this study, the image-based COST method which the streamline model improved dark-object atmospheric correction for Landsat TM5 multispectral data (band 1-5 and 7) is developed by Chavez [43] was used. The output was masked to Khun Mae Kham Mee plantation boundary and used in the next process.

3.2.2 Teak plantation and Non-Teak plantation identification in Khun Mae Kham Mee plantation

3.2.2.1 Hybrid interpretation

Hybrid interpretation including visual and computer assisted approach was employed to identify Teak plantation area in Khun Mae Kham Mee plantation. Defined nomenclatures were Teak plantation and Non-Teak plantation. And then display image through the RGB color model using 4, 5 and 3 bands, respectively, which called the false color composite that suitable for visual interpretation [42]. The maximum likelihood classification was likewise conducted for supervised classification. The training areas were set more 30 sites of each nomenclature [44].

3.2.2.2 Accuracy Assessment

Accuracy assessments were purposed at the level of more than 80 percent and limit 10 percent of errors then find a minimize amount of pixel for audit by using equation as follows [42]:

$$n = \frac{Z^2(p)(q)}{E^2}$$

Where: n = Minimize amount of pixel

P = Probability that the pixel would be corrected

$q = 100-p$

E = Percent of errors

Z = Standard normal distribution value of the 95 percent confidence level

Next step, the error matrix manipulation was used for comparing the result of the classification systems by ground truth data. The total of sample point from ground truth was selected and checked. Then correcting accuracy was not least than 60 percent.

Kappa Index can be used as a measure of agreement between model predictions and reality [45]. The possible ranges of Kappa are separated into three groups: a value greater than 0.80 represents strong agreement; a value between 0.40 and 0.80 represents moderate agreement; and a value below 0.40 represents poor agreement. Kappa is computed as follows [46]:

$$K = \frac{N \sum_{i=1}^r x_{ii} - \sum_{i=1}^r (x_{i+} \times x_{+i})}{N^2 - \sum_{i=1}^r (x_{i+} \times x_{+i})}$$

Where: N = the total number of sites in the matrix

r = the number of rows in the matrix

x_{ii} = the number in row i and column i

x_{+i} = the total for row i

x_{i+} = the total for column j

3.2.3 Age stage identification of Teak plantation in Khun Mae Kham Mee Plantation

Teak plantation was further classified into age stage using computer assisted approach which starting with image operation to focus section of interest, and then this information is used to classification. Comparisons between logical operation method and regression model method to identification of Teak age stage. The details of this process are discussed as follows:

3.2.3.1 Image operation

In the image operation that is extracting data by the vegetation indices. The indices selected for this study include Advanced Vegetation Index, Bare Soil Index and water index. The application models were created on the modeler maker of the Spatial Modeler Language of ERDAS Imagine software. The Spatial Modeler Language is a modeling language linked internally with Model Maker to execute operations specified in the graphical model. The details of the vegetation indices which used in the study were described and illustrated as follows:

1) Advanced Vegetation Index (AVI) [22] is calculated with the following formula:

$$\text{NIR} - \text{RED} < 0 \quad \text{AVI} = 0$$

$$\text{NIR} - \text{RED} > 0 \quad \text{AVI} = [(\text{NIR} + 1) \times (256 - \text{RED}) \times (\text{NIR} - \text{RED})]^{1/3}$$

Where:

AVI	=	Advanced vegetation Index
NIR	=	Near Infrared reflectance value
RED	=	Visible Red reflectance value

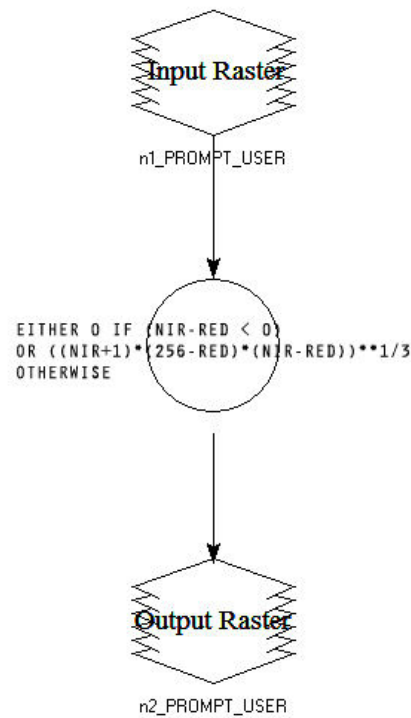


Figure 3-1 Advance vegetation index (AVI) model by Spatial Modeler Language

2) Bare soil Index (BI) [22] is calculated with the following formula:

$$BI = \frac{(MidIR + RED) - (NIR + BLUE)}{(MidIR + RED) + (NIR + BLUE)} \times 100 + 100$$

- Where:
- BI = Bare soil Index
 - BLUE = Visible Blue reflectance value
 - RED = Visible Red reflectance value
 - NIR = Near Infrared reflectance value
 - MidIR = Middle Infrared reflectance value

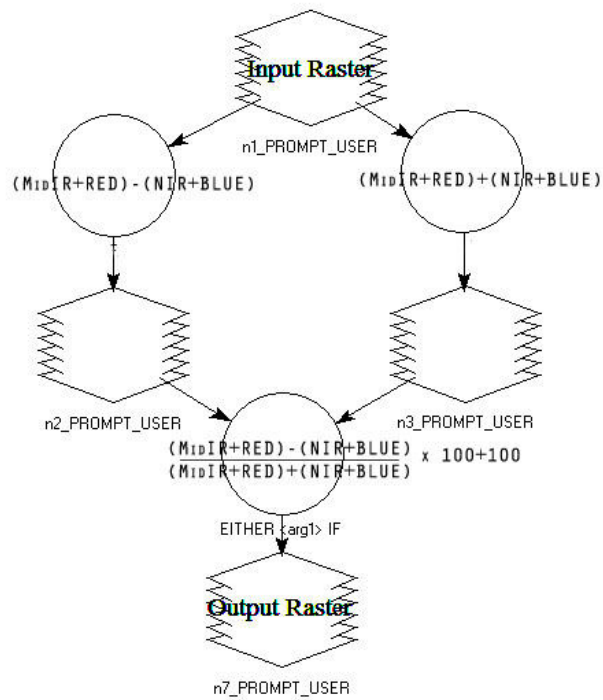


Figure 3-2 Bare soil Index (BI) model by Spatial Modeler Language

3) Water Index (WI) [47] is calculated with the following formula:

$$WI = \frac{GREEN}{MidIR}$$

Where:

WI	=	Water Index
GREEN	=	Visible Green reflectance value
MidIR	=	Middle Infrared reflectance value

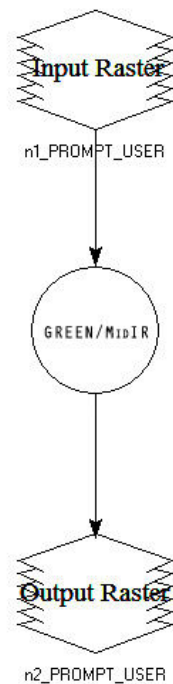


Figure 3-3 Water Index (WI) model by Spatial Modeler Language

3.2.3.2 Collected sampling data

Each index was operated over then used to design for ground data sampling. The sample plot size of 30x30 meters equal to pixel size of Landsat imageries was proposed for data collection with the number of 10 sample plots for each available age in Khun Mae Kham Mee Plantation. Then, sort out the sample plot that has been influence of clouds and road (Total remaining 105 plots from 180 plots). And split into 2 groups were experimental group (75 plots) and check group (30 plots). The coordinates of each the experimental group's sample plot was also recorded to identify the pixel values for each index. The values of each index were used in the model development.

And this study tended to classify each category following their physical factors, characteristics and utility and was separated into two stages including:

- 1) Primary stage (3-7 years old), was the replanting period of Teak after block cutting operation.
- 2) Rotation stage (25-38 years old), was the period before harvested which consist of non-thinning and thinning operation.

3.2.3.3 Age stage identification of Teak using logical operation

Age stage classification using logical operation was developed from the conditional statement about the variable's data values that determined an informational component. Multiple conditions could be linked together into a hierarchy that ultimately describes a final set of target informational classes. Confidence values associated with each condition were also combined to provide a confidence image corresponding to the final output classified image [25].

In this case, the logical operation was defined from the value of AVI, BI and WI for each age stage. The values of these band ratio indices from experimental group were derived from the stand division and normal distribution curve. Calibrating model by cut off minimum and maximum values from the stand division. And only values that fall near the mean were considered and use as the representative value of each stage. Final, entered the range of each stage to Knowledge-base system of ERDAS for classifying the age stage of Teak in Khun Mae Kham Mee Plantation.

3.2.3.4 Age stage identification of Teak using regression model

Age stage models were developed using each vegetation index as variable. Extract the value of each index based on experimental group's sample plot coordinate. The first analyze is correlation analysis which chooses Pearson correlation measures. The measurement could describe the strength of the relationship between two continuous variables. By the magnitude of the correlation describes the high of the relationship. And in the case of very low correlation the study may decide to select another index that was related in the classification of plantation. The related index including Normalized Difference Vegetation Index (NDVI) [21], the Greenness Index (from Tasseled Cap transformation) [48] and the simple ratio (SR) [19]. The details of each index as follows:

$$\text{NDVI}; \quad NDVI = \frac{NIR - RED}{NIR + RED}$$

$$\text{Greenness}; \quad \text{Greenness} = -0.2848 (\text{TM1}) - 0.2435 (\text{TM2}) - 0.5436 (\text{TM3}) + 0.7243 (\text{TM4}) + 0.0840 (\text{TM5}) - 0.1800 (\text{TM7})$$

$$\text{SR}; \quad SR = \frac{NIR}{RED}$$

Where; RED = Visible Red reflectance value
 NIR = Near Infrared reflectance value
 TM 1-5, 7 = TM band 1-5, 7 reflectance value

Then, the variable with maximum correlation value will be selected to age stage model. Second, the linear and non-linear regression analysis was used to perform the age stage model. The model was calibrated by deleting outliers of extreme values thereby considering values within the average of the normal distribution curve. Outliers were determined based on the RMS of each index value.

The age stage model with the highest Coefficient of Determination (R^2) and least Standard Error was selected for application in the classification of age stage for Teak plantation in Khun Mae Kham Mee Plantation. The best fit equation was built in Model Maker Language of ERDAS. The output was according to two age stage: Primary stage and Rotation stage.

3.2.3.5 Post classification

The age stage maps of Teak plantation in Khun Mae Kham Mee Plantation were produced from two methods. Post classification that means updating a pixel is enclosed by another nomenclature and edit to value that is around.

3.2.3.6 Classification Accuracy

The differentiation of results was analyzed by using 2 methods: The error matrix method and Kappa Index method which the procedure shown in 3.2.2.2

3.2.3.7 Computation of Teak Plantation Area by Age stage

The resulting map from the classification system with the highest accuracy was used to compute the area for each age stage. The computed area for each age stage was used in the determination of carbon storage of Teak in Khun Mae Kham Mee Plantation.

3.2.4 Determination of aboveground biomass and carbon storage

Purposive sampling was undertaken such that 10 sample plots per available age class were laid on Khun Mae Kham Mee Plantation. Data taken on the sample plots were used to calculate the quantity of above ground biomass and carbon

storage of Teak plantation. The steps of this study process are further discussed as follow:

3.2.4.1 Data Sampling

The sample plots with dimensions of 30 x 30 meters were laid over in area for age stage 1) Primary stage (3-7 years old) and 2) Rotation stage (25-38 years old). The dimension of the sample plots was based on the pixel resolution of LANDSAT image.

In each plot, five trees located on the corners and on the center of the plot were taken as samples that showed in figure 2-4. Diameter-at-breast height (DBH), total height of individual trees and number of tree per plot were measured. The geographic location or coordinates of each plot were also recorded.

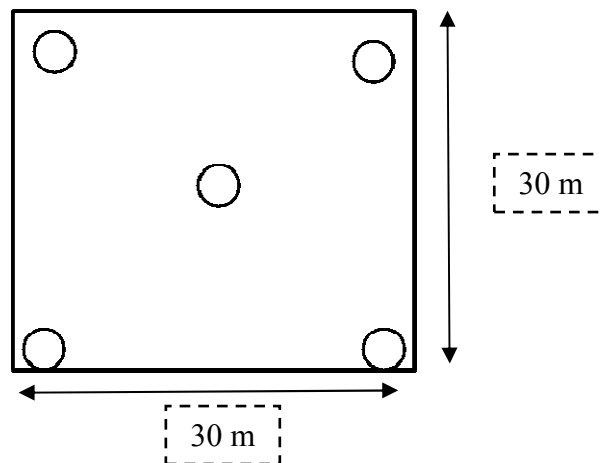


Figure 3-4 The Sample plot and The Data Sampling

3.2.4.2 Determination of aboveground biomass

Determinate aboveground biomass of individual trees was calculated separately for stem, branch, and leaf using the following equations [31]:

$$W_s = 0.0271(\text{DBH}^2\text{Ht})^{0.9435} \quad R^2 = 0.9915$$

$$W_l = 0.0205(\text{DBH}^2\text{Ht})^{0.6850} \quad R^2 = 0.8090$$

$$W_b = 0.0013(\text{DBH}^2\text{Ht})^{1.1339} \quad R^2 = 0.9304$$

Where:

W_s = Stem biomass (kg)

W_l = Leaf biomass (kg)

W_b = Branch biomass (kg)

DBH = Diameter-at-breast height (cm)

Ht = Total height (m)

Total above ground biomass for each tree was computed as:

$$\text{Biomass T} = W_s + W_l + W_b$$

Bring the aboveground biomass per tree of various teak age-classes to build the equation of relationship between biomass and age using regression analysis. The best fits equation was selected by the highest of the correlations coefficients (R^2) value.

Convert the number of trees per age stage to the density. The biomass from all sample plots of each age stage was added to represent the biomass for each age stage. The biomass was then converted to tons/hectare. The determination of aboveground biomass for each age stage of Teak plantation was manipulated to the output analyzed by the mentioned model.

3.2.4.3 Carbon storage

The aboveground carbon content was calculated as 50 percent of the total aboveground biomass [49].