Expert Classification for Age Class Identification of Oil Palm Plantation in Krabi Province, Thailand

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Abstract: The objective of this study is to apply the Geo-Information Technology including Remote Sensing, Global Positioning System, and Geographic Information System integrated with Expert System in order to generate a knowledge base system for age class identification of oil palm plantation. Rule base under the knowledge base for oil palm classification is generated from the relationship of multiple regressions related with Water Index (WI), Bare Soil Index (BI), Normalized Differential Vegetation Index (NDVI), and Advance Vegetation Index (AVI). These equations are used to define age class stage of oil palm plantation which can be divided into 4 classes: Young stage (1-3 years old), Intermediate stage (4-10 years old), Productive stage (11-20 years old), and Mature stage (more than 20 years old). The percentages of accuracy for each class using expert classification are 92.19, 50.88, 80.00, and 12.50 respectively. Meanwhile, the percentages of accuracy for maximum likelihood classification are 90.63, 42.11, 40.54, and 72.34 respectively. Therefore, the accuracy for each age class stage from the expert classification is higher than the maximum likelihood classification. Furthermore, the overall accuracy of the expert classification is about 63.11%, and the maximum likelihood classification is only about 60.33%. Thus the accuracy of the expert classification is about 2.78% higher than the maximum likelihood classification. In conclusion, application of the Geo-Information Technology and Expert System provides useful information about classification on age class of oil palm plantation.
Keywords: OIL PALM / AGE CLASS / EXPERT CLASSIFICATION / KRABI PROVINCE / THAILAND

1. Introduction

The original oil palm was in Africa. It has been induced to Thailand through Indonesia and Malaysia. Since 1968, in the area of 40,000 rai, it has been encouraged to be in the form of trading in the South of Thailand. Its plantation was famed over the duration of time, so the area of plantation has been expanded. The area of oil palm plantation in 1988 and 2001 were 177,600 rai (6.25 rai = 1 hectare) and 655,000 rai, respectively. According to this figure, the oil palm plantation area prediction in 2006 will be 2,000,000 rai [2],[3],[4].

Oil palm plantation became more famous since it can be used in various forms including food and non-food. Besides, the oil palm's transformer has been used in not only household but also industry sectors. Moreover, it can produce much of oil, one-forth of all oil plant. Furthermore, under lacking of gasoline situation, Bio-diesel research has been supported to be alternative solution of energy crisis.

Thirty-four percent of the oil palm plantations in Thailand grow in Krabi Province. It has been expanded from 475,846 rai in 2000 to 563,908 rai in 2003 [6]. The community of oil palm management cooperative such as Land Settlement Co-operatives Limited was founded in each amphoe. In 2004, The Krabi Oil-Palm Farmers Cooperative Federation Limited (KFCF) was established in order to managing oil palm stock, operating the cooperation, and doing research on oil palm development topic.

To improve the potential of oil palm plantation management, it needs enough information in order to make the best strategies. The age class of oil palm plantation area are one of the basic information which is classified only by expertise. Application of expert system and geo-informatics technology can generate the expert-like system to classify age class of oil palm plantation. Therefore, this application can also lead to intense updating informational requirements for management of oil palm. This study takes place in Krabi province which is located on the west coast of south region in Thailand. The area is 4,708.512 square kilometres where consists of 8 Amphoes, 51 Tambols, and 383 Villages (Fig. 1)

2. Objectives

1) To develop knowledge base for classify age class of oil palm plantation in Krabi province by using geo-informatics technology.
2) To generate expert system for classify age class of oil palm plantation in Krabi province by using ERDAS IMAGINE knowledge classifier.

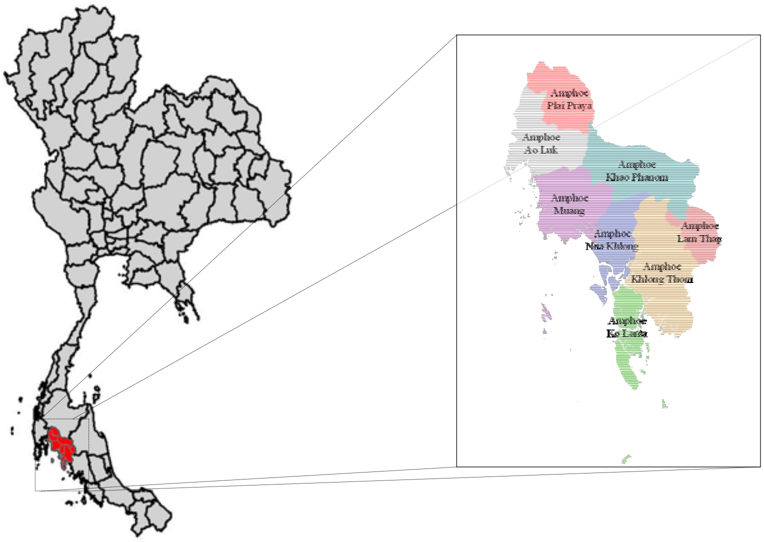


Fig. 1 Study Area

3. Conceptual Framework

Apply expert system with geo-informatics technology including Remote Sensing (RS), Geographic Information System (GIS) and Global Positioning System (GPS) as illustrate in Fig. 2

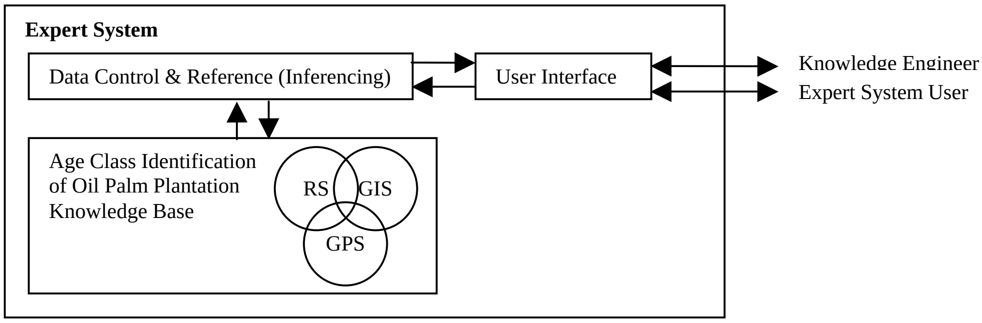


Fig. 2 Conceptual Framework Diagram

4. Materials

The hardware and software utilized in this study are as the following:

1) Hardware:
   Personal computer with a specification of Intel Pentium IV Processor 2.4 GHz., 1GHz RAM, 60 GB. Hard disk, Other devices: GPS Receiver, Digital Camera and Printer and Plotter.
2) Software:
   Image Analysis software: Erdas Imagine 8.5
   GIS software: ArcViewGIS 3.3 and ArcGIS 8.3
   Statistics Software: SPSS

Operation System: WindowsXP Professional

5. Data Sources

Data sources of this study are gathered from various sources. To generate expert knowledge, Landsat-5 TM is mainly source for image data which overlaid with other GIS data and DEM sources. Table 1 is shown the data attribute and their details.

Table 1. Various data sources for the study

Raster Image					
Data	Path/Row	Bands	Resolution	Date	Source
Landsat-5 TM	129/054	1-5,7	25 m	25 Feb 2005, 03:18:40	GISTDA*
Vector Data					
Data	Type	Scale		Date	
Boundary	Polygon	1 : 50,000		No reference	DEQP**
Contour	Line, Point	1 : 50,000		No reference	DEQP**

Remark * Geo-Informatics and Space Technology Development Agency (Public Organization)
** Department of Environmental Quality Promotion

6. Methodology

The process of this study is separated into 4 steps including; Pre-processing, Selection of oil palm plantation area, Expert Classification, and Accuracy assessment. As it's shown in Fig. 3

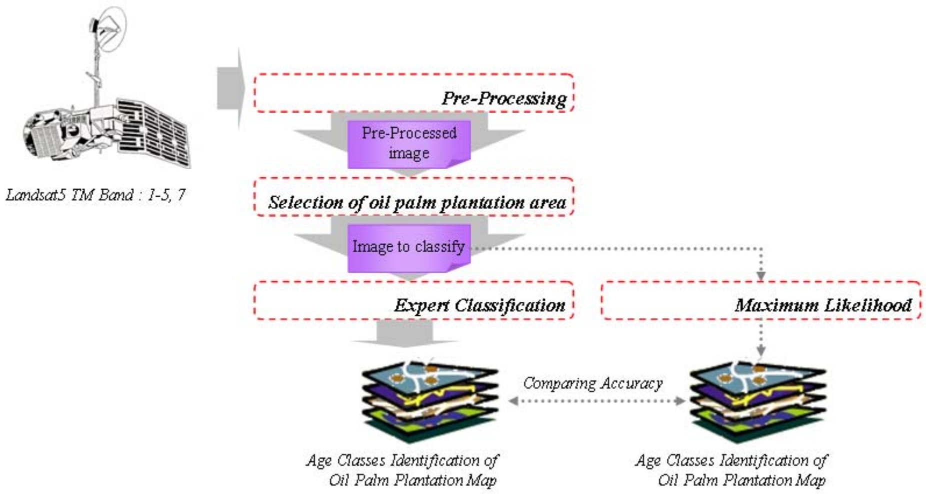


Fig. 3 Study process

1) Pre-processing

Landsat-5 TM images (Band: 1-5 and 7) with path/row 129/054 have been used for data processing. To preparing this image, Radiometric, Atmospheric (Using 5S model: Simulate the satellite signal in the solar spectrum), Geometric correction method has been applied prior classification by using image-to-image method. Thus, the pre-processed image was performed to ensure high accuracy on both standardize reflectance value and coincide map projection.

2) Selection of Oil Palm Plantation Area

Semi-automatic image interpretation by mean of integration between computerized and visualize interpretation were used. ISOData, texture application, threshold of spectral indices, and sieve-out techniques were used to prepare remote sensing image for visual classification as the detailed following.

In computerized section which most of the higher age class of oil palm area were depicted, the remote sensing image was used to generate 30 classes of ISOData. Then, threshold value of band ratio indices (AVI, NDVI, BI and WI) were chosen to delineated non-palm area. By using field survey's data, which were undertaken on the 16th - 22nd

December, 2004 and 10^{th} - 16^{th} February, 2005, collaborated with spectral reflectance, the threshold of AVI, NDVI, BI, and WI were depicted as 141-155, 0.7-0.77, 55.6-61.9, and 0.49-0.55, respectively.

3) Expert Classification

The Expert Classification is focuses on information extraction from semi-structured data by using rule and relationship of the information. Thereby, it consists of two parts: the Knowledge Engineer and the Knowledge Classifier.

3.1) Knowledge Engineer:

It constructs knowledge bases to process the classification. It provides a user interface allows inputting a limited set of parameters to control the use of the knowledge base which consist of identification of the variables, rules, and output. As the procedure of this study is following:

3.1.1) Variables Defining

The variables used in Knowledge Engineer were raster imagery, vector overages, spatial models, external programs, and simple scalars. The variables were used in this study are as following:

1. Satellite Imageries: this study has been utilized the after pre-processing image to be the main source.
2. Advanced Vegetation Index (AVI) [1]: It is assessing the vegetation status of forests; the new methods firstly examine the characteristics of chlorophyll-a, that is calculated with the following formula as in (1) with run by expert classifier Model (Fig. 4).

If **NIR**-**RED** < 0 then **AVI** = 0
Else if **NIR**-**RED** > 0 then **AVI** = ((**NIR** + 1) x (256 - **RED**) x (**NIR** - **RED**)) $^{1/3}$ (1)

Where	AVI	=	Advanced Vegetation Index
	RED	=	Visible Red reflectance value (spectral band 0.6-0.7 µm)
	NIR	=	Near Infrared reflectance value (spectral band 0.76-0.9 µm)

3. Normalized Difference Vegetation Index (NDVI) : It shows the density of plant growth over the entire globe. The value was then normalized to the range between -1<=NDVI<=1 to partially account for differences in illumination and surface slope. The very low values of NDVI (0.1 and below) correspond to barren areas of rock, sand, or snow. Moderate values represent shrub and grassland (0.2 to 0.3), while high values indicate temperate and tropical rainforests (0.6 to 0.8). It is a simple formula to generate NDVI image by using 2 image bands. If one band is in the visible region (RED band or band 3 of LANDSAT-TM data) and the other region is near infrared (NIR band or band 4 of LANDSAT-TM data).NDVI was run step by step (Fig. 5) using a popular mathematic equation as in (2)

$$\mathbf{NDVI} = \frac{\mathbf{NIR - RED}}{\mathbf{NIR + RED}} \qquad (2)$$

Where	NDVI	=	Normalized Difference Vegetation Index
	RED	=	Visible Red reflectance value (spectral band 0.6-0.7 µm)
	NIR	=	Near Infrared reflectance value (spectral band 0.76-0.9 µm)

4. Bare Soil Index (BI): it is formulated with medium infrared information. The underlying logic of this approach is based on the high reciprocity between bare soil status and vegetation status. By combining both vegetation and bare soil indices in the analysis, one may assess the status of forest lands on a continuum ranging from hi vegetation conditions to exposed soil conditions [1].

$$\mathbf{BI} = \frac{(\mathbf{SIR} + \mathbf{RED}) - (\mathbf{NIR} + \mathbf{RED}) \times 100}{(\mathbf{SIR} + \mathbf{RED}) + (\mathbf{NIR} + \mathbf{RED})} + 100 \qquad (3)$$

Where	BI	=	Bare Soil Index
	BLUE	=	Visible Blue reflectance value (spectral band 0.45 - 0.52 µm)
	RED	=	Visible Red reflectance value (spectral band 0.6-0.7 µm)
	NIR	=	Near Infrared reflectance value (spectral band 0.76-0.9 µm)

SIR = Shortwave Infrared reflectance value (spectral band 2.08 – 2.35 µm)

The range of BI is covered within 0 < BI < 200 (only 8 bits range) .They were run as the following steps (Fig. 6):

5. Water Index (WI) [7] : It was calculated from the reflected solar radiation in the shortwave-infrared (SIR) and green (GREEN) wavelength bands, which can be defined by following step (Fig. 7) and formula as in (4)

$$\mathbf{WI} = \frac{\mathbf{GREEN}}{\mathbf{SIR}} \quad (4)$$

Where WI = Water Indices
GREEN = Visible Green reflectance value (spectral band of 0.5-0.6 µm)
SIR = Shortwave Infrared reflectance value (spectral band of 1.55 – 1.75 µm)

The value was then calculated to the range in between 0 to 255, but the typical range of non-water area ranges between 0 to 1 and the typical range of water area is in between 1 to 255. So, the values were used to differentiate the water area and non-water area.

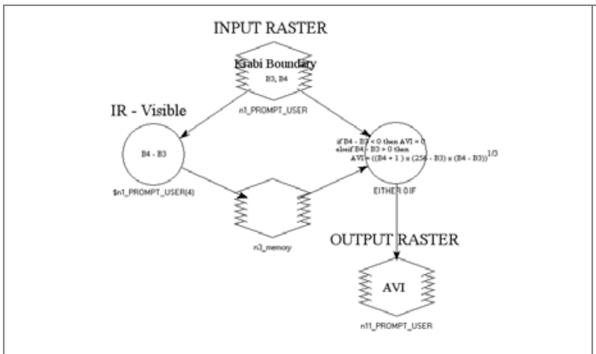


Fig. 4 Advanced Vegetation Index (AVI) Model in Expert Classifier Model

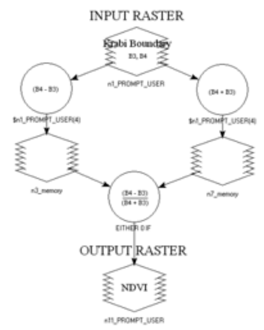


Fig. 5 Normalized Difference Vegetation Index (NDVI) model in Expert Classifier Model

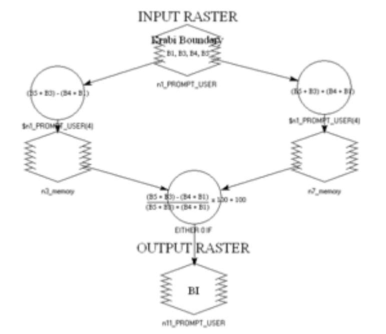


Fig. 6 Bare Soil Index (BI) model in Expert Classifier Model

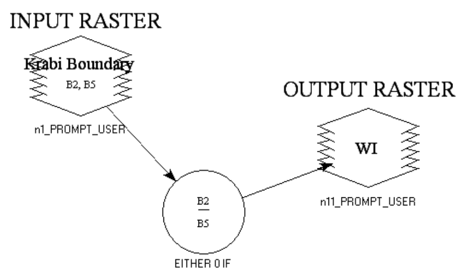


Fig. 7 Water Index (WI) model in Expert Classifier Model

3.1.2) Rules Defining

A rule was a conditional statement, or list of conditional statements about the variable's data values and/or attributes that determine an informational component or hypothesis. Multiple rules and hypotheses can be linked together into a hierarchy that ultimately describes a final set of target informational classes or terminal hypotheses. Confidence values associated with each condition were also combined to provide a confidence image corresponding to the final output classified image [5].

In this study, simple or multiple regressions of defined-variables were generated. They have been used to be the threshold of rule base and to classify age class of oil palm plantation.

3.1.3) Output or Hypothesis

According to the characteristic of oil palm age classes or stages, this study tends to classify of each categories following by their physical factors and characteristics. In which separated into four age classes, including:

- 1 to 3 year old after planting : Young stage
- 4 to 10 years after planting : Intermediate stage

- ❑ 11 to 20 years old after planting : Productive stage
- ❑ More than 20 years old after planting : Mature stage

3.2) The Knowledge Classifier

It provides an interface for a non-expert to apply the knowledge base and create the output classification. Using created knowledge base, it can determine each area of age classes of oil palm plantation.

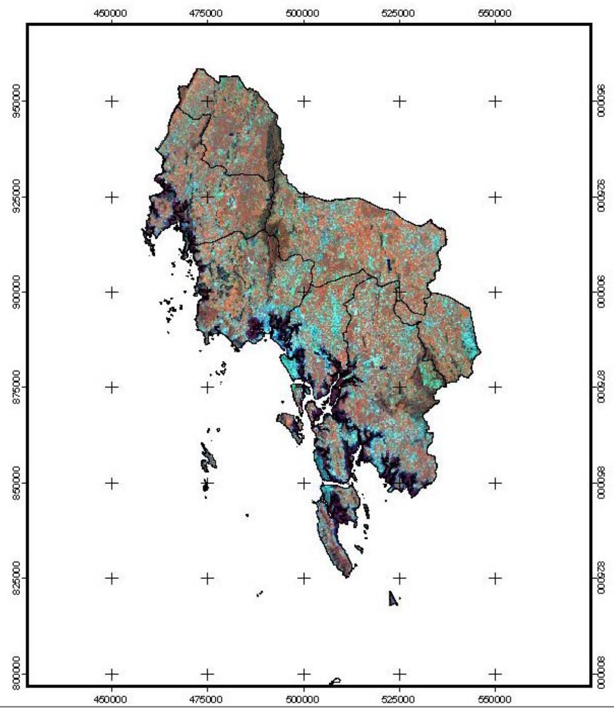
4) Verifying an Accuracy

The result of expert classification was analyzed and examined in both accuracy and reliability of the classification that provided the accuracy as more than 60 percent. Finally, knowledge-based system was obtained for expert classification. Hence, the result from maximum likelihood classification has been chosen in order to compare with the result from expert classification.

By using ground truth data, we are able to know the accuracy of the age class maps that enhance the expertise knowledge model and maximum likelihood.

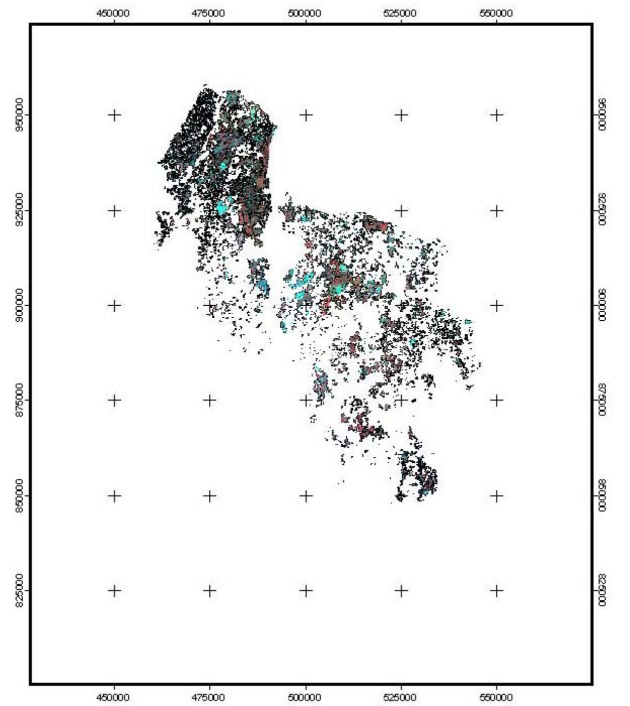
7. Result

After finishing all of image preparing processes (show in Fig. 8), visual interpretations based on extensive ground truth data was use to delineated the lower age class of oil palm, which has almost the same spectral value of bare soil and abundant land, from non-oil palm plantation area. Hence, the main data source for next process was produced as shown in Fig. 9.



Source: Analysis

Fig. 8 LANDSAT-5 TM, Krabi province, 2005



Source: Analysis

Fig. 9 Pre-processed image of LANDSAT-5 TM, for oil palm plantation area , Krabi province, 2005

Expert Classification was process by creating application models based on model spatial modeller for variables of knowledge-based generation by following:

Rule bases of which used in this expert system are developed from stipulated interval values of band ratio indices. Interval values of each indices, AVI, NDVI, BI, and WI, were performed from the best fits equation of non-linear regression in SPSS for Windows software which can be in various forms such as logarithmic, inverse, quadratic, power, s-curve, growth, exponential, etc. Then, the best fits equation was selected by the least of Coefficient of Determination (R^2) and Standard Error of the Estimate (SE) value of each index equation.

Then, the best of non-linear regression model of each band ratio indices are defined. The detail as shown as the following in Eq. (5) – (8):

- ❑ Advanced Vegetation Index (AVI) model

$$\textbf{Age} = 2.2937\times10^{-7}\,\textbf{AVI}^{3.7184} \qquad (R^2 = 0.6044) \qquad (5)$$

- Normalized Difference Vegetation Index (NDVI) model

$$\textbf{Age} = 0.4747e^{5.4332\textbf{NDVI}} \qquad (R^2 = 0.7274) \qquad (6)$$

- Bare Soil Index (BI) model

$$\textbf{Age} = 788.3813e^{-0.0580\textbf{BI}} \qquad (R^2 = 0.7856) \qquad (7)$$

- Water Index (WI) model

$$\textbf{Age} = e^{6.3853-\frac{1.6227}{\textbf{WI}}} \qquad (R^2 = 0.7022) \qquad (8)$$

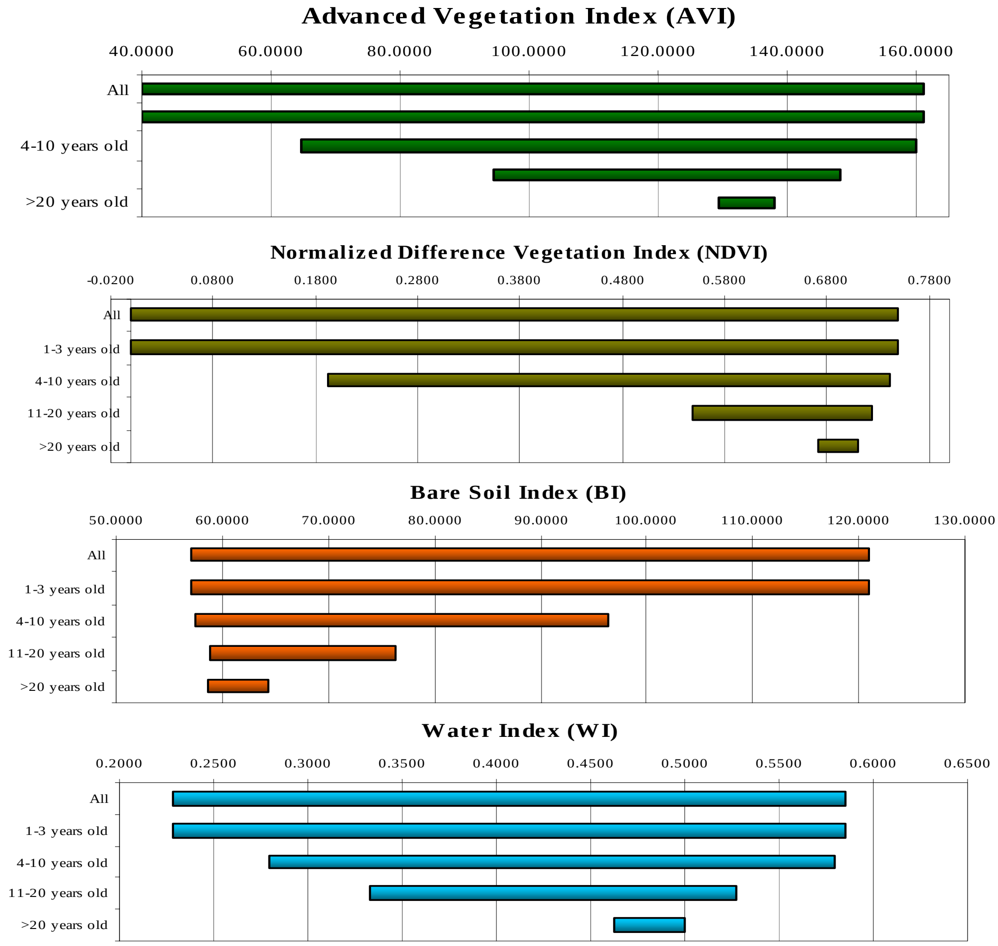
Next, Model Maker was used to generate each of the relation maps between indices and oil palm age. Then, those maps were integrated in order to generate the determining map. The integrated process used the probability of each map to decide what age class stage can be implied in those pixels. The probabilities were produced form the amount of the Coefficient of Determination (R^2) value which indicated more influent than the others.

The determining map was use to seek for stipulated interval values of each rule base. Thus, stipulated interval values of each age class stages are expressed in indices of suitable regression equation. Then, the signature of oil palm age class graphs were generated from those relations.

The rule bases of age class were generated form intersection of all stipulated interval values of band ratio indices that is the same result when interpolated from all equations. In other word, again, if all of the results were not the same, it would be used the Coefficient of Determination (R^2) value of each equation to decide what age class stage imply in each pixel.

All defined variables, which included LANDSAT-5 (TM) imageries (band 1-5 and 7), AVI model, NDVI model, BI model, WI model, were used to generate the knowledge-based system for classifying the age class stages of oil palm in Krabi province.

Knowledge-base system inference was depicted from the relationships among variables data, rules, and outputs, with union or mixed forms from decision tree. Each stage classification rules were created from stipulated interval values of four indices value and their defining condition as mention above. The details of each stage classification rule were described as:



Source : Analysis

Fig. 10 Signature of Oil Palm Age Class

1) Young stage of oil palm plantation (1-3 year) **:** This class was classified when calculated, AVI, NDVI, BI, and WI, in between 18.2035 to 161.2300, 0 to 0.75, 57.1429 to 120.9960, and 0.2282 to 0.5847, respectively. Then age class of oil palm plantation was identified as stage 1 or young stage of oil palm plantation.

2) Intermediate stage of oil palm plantation (4-10 year) : The assumption for intermediate stage was described when AVI, NDVI, BI, and WI, were ranging between 64.6043 to 159.7550, 0.1923 to 0.7407, 57.4899 to 96.3211, and 0.2796 to 0.5790., respectively.
3) Productive stage of oil palm plantation (11-20 year) : The criteria for productive stage was described when AVI, NDVI, BI, and WI, fall between 94.2714 to 148.2000, 0.5489 to 0.7241, 58.8235 to 76.2963, and 0.3333 to 0.5273, respectively.
4) Mature stage of oil palm plantation (more than 20 year) : This rule was described like flow diagram when calculated, AVI, NDVI, BI, and WI, in classes between 129.2760 to 138.1050, 0.6714 to 0.7099, 58.6873 to 64.3939, and 0.4630 to 0.5000, respectively. Then age class of oil palm plantation was identified as stage 4 or young stage of oil palm plantation.

Classification Accuracy assessment process, The total number of 244 age class sample points around Krabi province selected from ground truth data, which were undertaken on the 16^{th} - 22^{nd} December, 2004 and 10^{th} - 16^{th} February, 2005, were used to verify classification accuracy of each stage. There were use to examined with results from the expert classification and the maximum likelihood classification. The results were show in percentage of each classification stage. The accuracy from the expert classification was 92.19%, 50.88%, 80.00%, and 12.50%, respectively (Table 2). Meanwhile, the accuracy derived from the maximum likelihood classification includes 90.63%, 42.11%, 40.54%, and 72.34%, respectively (Table 3).

Table 2. The land cover confusion matrix of expert classification and ground truth.

		Expert Classification					
		Unclassified	Stage 1	Stage 2	Stage 3	Stage 4	Overall
ou nd Tr	Stage 1	1	59	4	0	0	64

	Stage 2	0	4	29	24	0	57
	Stage 3	1	0	13	60	1	75
	Stage 4	0	0	5	37	6	48
	Overall	2	63	51	121	7	244
% Accuracy		0.00	92.19	50.88	80.00	12.50	63.11

Note: Stage 1 is oil palm of 1 to 3 year old after planting (Young stage)
Stage 2 is oil palm of 4 to 10 years after planting (Intermediate stage)
Stage 3 is oil palm of 11 to 20 years old after planting (Productive stage)
Stage 4 is oil palm more than 20 years old after planting (Mature stage)

Source: Analysis

Table 3. The age class of oil palm classification confusion matrix of maximum likelihood classification and ground truth.

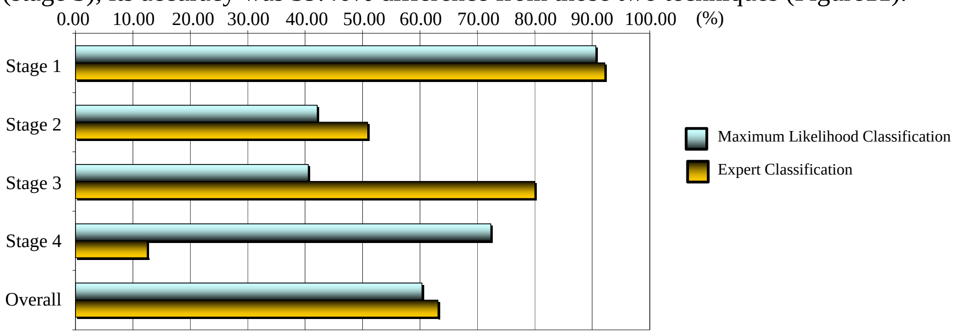
		Maximum Likelihood Classification					
		Unclassified	Stage 1	Stage 2	Stage 3	Stage 4	Overall
Ground Truth	Stage 1	0	58	6	0	0	64
	Stage 2	0	4	24	15	14	57
	Stage 3	1	0	8	30	36	74
	Stage 4	1	0	1	12	34	47
	Overall	2	62	39	57	84	242
% Accuracy		0.00	90.63	42.11	40.54	72.34	60.33

Note: Stage 1 is oil palm of 1 to 3 year old after planting (Young stage)
Stage 2 is oil palm of 4 to 10 years after planting (Intermediate stage)
Stage 3 is oil palm of 11 to 20 years old after planting (Productive stage)
Stage 4 is oil palm more than 20 years old after planting (Mature stage)

Source: Analysis

Comparison on accuracy obtained from expert classification and maximum likelihood classification had been done, subsequently (Fig. 11). It can be concluded that the result of the expert classification by selecting some sample area (244 points around Krabi province), provided the overall accuracy of about 63.11%, while the maximum likelihood classification gained about 60.33% only. Fig. 4-14 illustrated the accuracy of the expert classification of which 2.78% higher than the maximum likelihood classification.

Furthermore, it found that the accuracy for each age class stage of oil palm plantation from the expert classification, except stage 4, also provide higher accuracy than the maximum likelihood classification. Especially for productive stage (stage 3), its accuracy was 39.46% difference from those two techniques (Figure11).



	Stage 1	Stage 2	Stage 3	Stage 4	Overall
Expert Classification	92.19	50.88	80.00	12.50	63.11
Maximum Likelihood Classification	90.63	42.11	40.54	72.34	60.33
Summary	1.56	8.77	39.46	-59.84	2.78

Source: Analysis

Fig. 11 The histogram of comparison between expert classification and maximum likelihood classification output

However, the result of expert classification of stage 4 was much less than that from maximum likelihood because indices band ratio values of stage 3 and stage 4 are almost the same. Thus, the classification value of stage 4 by using expert system was filled up in to stage 3 that may be why the result of stage 3 classification was better than that stage 4.

The knowledge base of age class identification of oil palm in Krabi province has processed with Landsat–5 TM imagery. Then, the areas of each stages of oil palm plantation were calculated which can be summarized as the table 4

Table 4. The areas of each age class of oil palm plantation by using Expert System.

Age (years)		Stage 1	Stage 2	Stage 3	Stage 4	Grand Total	Percentage
		1-3	4-10	11-20	> 20		
Amphoe Khao Phanom	km^2	7.11	67.61	107.15	0.14	182.01	20.72
	*Rais	4,444.05	42,257.08	66,968.56	88.67	113,758.37	
	Percent	3.91	37.15	58.87	0.08	100.00	
Amphoe Khlong Thom	km^2	2.73	42.54	91.35	0.29	136.89	15.59
	*Rais	1,704.01	26,584.78	57,091.12	179.30	85,559.21	
	Percent	1.99	31.07	66.73	0.21	100.00	
Amphoe Ko Lanta	km^2	0.05	1.26	2.73	0.00	4.04	0.46
	*Rais	32.03	785.94	1,705.08	2.34	2,525.39	
	Percent	1.27	31.12	67.52	0.09	100.00	
Amphoe Muang	km^2	7.89	34.64	33.17	0.08	75.77	8.63
	*Rais	4,929.08	21,648.71	20,733.88	47.66	47,359.33	
	Percent	10.41	45.71	43.78	0.10	100.00	
Amphoe Lam Thap	km^2	0.88	13.56	19.26	0.03	33.73	3.84
	*Rais	549.05	8,477.36	12,039.61	17.58	21,083.60	
	Percent	2.60	40.21	57.10	0.08	100.00	
Amphoe Nua Khlong	km^2	1.33	17.41	32.23	0.14	51.11	5.82
	*Rais	830.41	10,881.05	20,144.80	85.55	31,941.80	
	Percent	2.60	34.07	63.07	0.27	100.00	
Amphoe Ao Luk	km^2	6.69	64.50	124.93	0.27	196.38	22.36
	*Rais	4,181.17	40,309.98	78,080.14	167.19	122,738.46	
	Percent	3.41	32.84	63.62	0.14	100.00	
Amphoe Plai Praya	km^2	4.83	66.05	127.22	0.18	198.29	22.58
	*Rais	3,020.82	41,282.68	79,514.53	112.06	123,930.09	
	Percent	2.44	33.31	64.16	0.09	100.00	
Grand Total	km^2	31.50	307.56	538.04	1.12	878.23	100.00
	*Rais	19,690.62	192,227.56	336,277.72	700.34	548,896.23	
	Percent	3.59	35.02	61.26	0.13	100.00	

Source: Analysis

8. Conclusion and Discussion

This study is to apply geo-information technology with expert system in order to generate the knowledge base which used to identify age class of oil palm plantation. Landsat-5 TM imagery is main data source. The representation of vegetation index (Normalize Differentiate Vegetation Index: NDVI, Advance Vegetation Index: AVI), soil index (Bare Soil Index; BI), and Water Index (WI) were formulated by using imagery band ratio. Meanwhile, the rule base used in knowledge base was produced form regressions analysis. It was performed in order to formulate best fit equation for age class identification of oil palm by each index. The best suitable of equation were depicted by Coefficient of Determination (R^2).

The classified age classes of oil palm include 4 stages: Stage 1 or young stage (age of 1-3 years), Stage 2 or intermediate stage (age of 4-10 years), Stage 3 or productive stage (age of 10-20 years), and Stage 4 or mature stage (age of more than 20 years). The overall accuracy of expert classification is 63.11% which is satisfactory.

Moreover, the accuracy of comparison between expert classification and the maximum likelihood classification concluded that the overall accuracy of the expert classification is about 2.78% which higher than the maximum likelihood classification. Furthermore, it can be concluded the accuracy of each category from the expert classification is higher than one from the maximum likelihood classification.

Ultimately, by comparing with the result of maximum likelihood classification, the integrating of geo-information technologies with expert system can efficiency creates the age class classification of oil palm plantation. Therefore, the expert classification can duplicate human knowledge and provides a rules-based approach to image classification. Thus, it shows the expert classification that can be increased the classification accuracy.

Due to several of oil palm plantation management in Krabi province, the growing of oil palm in each owner must not be the same. Even if oil palm has the same size and physical characteristics, they are not in the same age. So, it is very difficult to clearly distinguish them to their ages.

Even though, the result form expert classification is better than those from maximum likelihood classification. The developed expert system can not exactly distinguish between stage 3 (productive stage) and stage 4 (mature state). It may be because the quality of sample point that use to generate the rule base or the limitation of non-linear regression equation and those mention reasons above that can not determent their differences.

▪ This research should be added with the details of GIS data (e.g., rainfall, soil water content, suitability, and etc.), the various image operations (e.g., Modified Soil-Adjusted Vegetation Index; MSAVI, Normalized Difference Water Index; NDWI, and etc.), shape analysis, and texture analysis, into the knowledge-based to identify age class of oil palm.

▪ Increasing of the models in the knowledge-based system, which created for image classification, will be time consuming for image processing.

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