THE USE OF SATELLITE DATA AND GIS IN MONITORING OF INDONESIA FOREST COVER

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ABSTRACT.

Forest damage in Indonesia increased very fast so that the monitoring of forest cover which can be conducted swiftly is needed. The evaluations of forest cover require to be done at national level and also at forest management unit (FMU) level. The use of low resolution satellite data and Geographic Information System (GIS) are suitable for quick evaluation of forest cover at national scale, while use GIS with modeling of field condition is better used for the scale of FMU.

Satellite data of SPOT 4 Vegetation (SPOTVEG) used for the classification of forest cover in Indonesia. From three classification methods that were implemented such that maximum likelihood, fuzzy and fuzzy knowledge based classification, the last method gives the best result to recognize good forest cover. Hereinafter by the help of GIS, the change of Indonesia forest cover from 2001 – 2004 based on the district could be identified quickly (good forest cover change into degraded forest or even converted into other land use). The rate of forest cover change was found related to the original forest cover acreage, population density and income per capita.

Forest disturbances at forest management unit level can be modeled through its vulnerability classes of wood encroachment, in this cases, we use variable of the percentage of stolen wood volume. From 500 data of wood encroachment (spatial and temporal data) in Forest plantation management unit, we obtained that stolen wood volume are determined by forest age classes and road distance. By using GIS modeling, we can make a simulation of forest vulnerability classes at FMU level spatially and temporarily. The simulation result showed that the level of vulnerability classes can change according to time and the compartments location.

(Cloud cover time series analysis, maximum likelihood, fuzzy classification, fuzzy knowledge base classification, Relationship with socio-economic variables, GIS modeling).

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INTRODUCTION

According to the data obtained by Forest Watch Indonesia (FWI) in 2001, the rate of deforestation was not less than 2 million hectare per year, or twice compared to that of the decade of 1980-an. The technology of remote sensing could be implemented to monitor the land cover changes. Information of land cover which is relatively detail and also global can be yielded from remote sensing at relatively short time and with the cheap expense.

The accuracy of classification result is dependent on spatial and spectral resolution of the image used and also atmosphere condition at the time of data collection. For global monitoring covering wide area such as big island or continent a satellite image with the lower spatial resolution, like NOAA and SPOT 4 Vegetation can be used. Although VEGETATION look like NOAA in the case of spatial resolution, VEGETATION has the band of short wave infrared (SWIR) so that more suitable for identifying the humidity of soil and vegetation (Philippe et al., 2000).

At the level of forest management unit, the use of GIS and modeling appropriately can assist to conduct the monitoring of forest disturbances. Forest management in Java has been done intensively, but the disturbances such as wood encroachment still are happening due to the high density population.

The research aims at 1) evaluating the ability of SPOT 4 Vegetation image in identifying forest condition; 2) knowing the relation of socio-economic factor with the change of forest cover; 3) using of modeling and GIS to know the level of forest disturbance at forest management unit.

METHODOLOGY

A. Material and Equipment

Material used in this research is the composite of 10 days image of satellite SPOT 4 (SPOT-Vegetation) Year 2001 and 2004. Other supporting data used were 1) Image of Landsat ETM+ and Land cover map as reference and ground checking; 2) the Visual Interpretation key of Landsat TM images; and 3) Digital Map of Indonesia 1: 1.000.000 year 1999 (Bakosurtanal), Map of Indonesia District Administration Boundary 1: 50.000 year 1999 (Bakosurtanal) 4) Population data of districts in Indonesia year 2004 and also Income per Capita data of districts in Indonesia (Central Bureau of Statistic).

The modeling of GIS at FMU level used the following data: Administration Map of KPH Madiun, Road Map, Topography Map, Forest Age class map, Tabular of Data of wood encroachment for the last 10 years and 500 location of subcompartement data that wood encroachment had happened.

While equipments used are a set PC (Personal Computer) with the software ERDAS Imagine 8.5 and Arc View 3.2. This research took place from year 2004 - 2006.

B. Research Method

1. Visual Interpretation

Visual interpretation of the image of Landsat ETM+ and SPOT 4 Vegetation was conducted to identify the distribution and types of land cover at the research area so that it is as easier to determine land cover classification.

2. Cloud Omission

Cloud cover at satellite image influences the identification process of land cover classes. Therefore cloud removing was needed to get the cloud free image. One removal way of eliminating cloud cover is by exploiting time series data from original band using the composite of minimum digital value method so that images with relatively clear of cloud was obtained.

3. Field Checking (ground checking)

For this activity, several images of Landsat ETM+ of Kalimantan and Sumatra were used due to its higher resolution compared with SPOT Vegetation.

4. Image Processing

a. Making Training Area

Making Training area conducted to determine the class's signatures. This activity was done by determining sample position in color composite image Landsat ETM+ and Land cover map as reference for every class of land cover.

b. Separability Analysis

Based on statistical value among the class developed by training area, an evaluation was required. This evaluation was intended to obtained high accuracy classification. One of the measures used to evaluate the separability among the class was Transformed Divergence (TD).

c. Classification methods

Classification was conducted by employing supervised classification such as: Maximum Likelihood Classification, Fuzzy Classification and Fuzzy knowledge based classification

Fuzzy knowledge based used the knowledge interpreter as classification base. In this research, knowledge based alighted from knowledge interpreter among other things were the characteristic of spectral reflectance from land cover classes and the result of multi temporal image analysis and its membership function determination was specified with the fuzzy technique. This method used a certain band for certain class, while in fuzzy classification used all band for all class.

d. Accuracy Analysis

The measure most frequently used is value of Kappa (Kappa Accuracy) because this value considers all elements in confusion matrix. It also used Overall accuracy, User and Producer accuracy.

e. Forest cover Change Analysis

Analysis conducted by overlaying classification results of SPOT images year 2001 and 2004. While socio-economic factor influencing the rate of forest change was analyzed through regression and correlation.

5. GIS modeling

a. Determination of wood encroachment vulnerability classes

Determination of wood encroachment vulnerability classes' data was grouped based on forest age class. The class was divided into several categories i.e. severe class; medium class and light class. These categories were developed by using standard deviation of wood encroachment for each forest age class.

b. Data analysis and validation

Analysis of the variable that influences wood encroachment was done by using Linear Regression Analysis Method. For model accuracy, model validation was conducted by comparing data derived from the model and field data. Wood encroachment model was used to simulate wood encroachment up to 10 years.

RESULT AND DISCUSSION

A. Identification of the Cloud Cover Level

According to Figure 1, cloud cover decreased drastically between composite period of 10 days and one year, that is equal to 77,5 %. While for the period of 10 days, the mount of cloud cover decreased only 2,65%. These matters indicate that more image period obtained or recorded, the lower the cloud coverage.

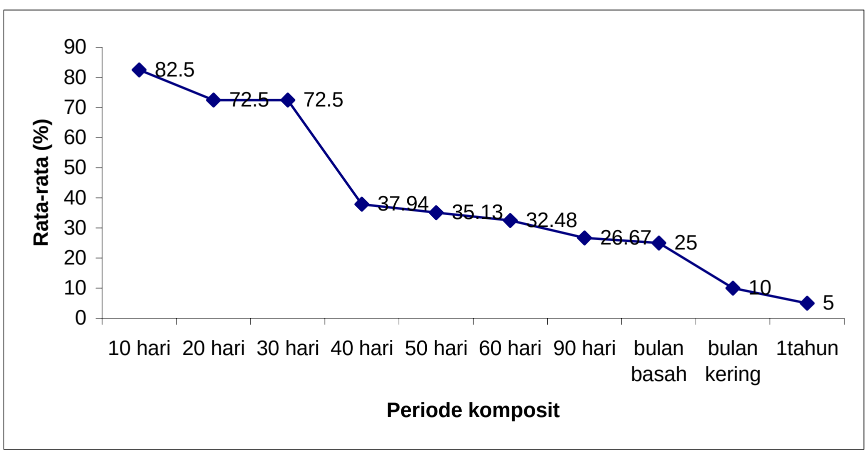

Figure 1. Percentages of Cloud cover according to SPOTVEG composite time series data in Indonesia.

B. Index of Separability and Accuracy

Training area represents a group of pixel sample which is used for categorizing each pixel into type of land cover class. In this research training area is taken 2 times for each land cover class. By using 8 land cover classes we obtained mean value of index of separability TD 1808, this means the classes was fairly separable. But there were some classes which were included in inseparable category (index of separability < 1600). This happened because the land cover classes still very homogeneous when selected as training area, but the value were close. Therefore we regroup the classes by joining some classes become the new class and yield 5 land cover classes. Lowland forest, mangrove forest, and swamp forest become one class (forest). Plantation area, shrubs and other were regrouped as non forest vegetation. The value of separability and kappa accuracy resulted from regrouping is displayed at Table 1.

Table 1. Separability Index and Classification Accuracy of SPOTVEG one year composite image

Time Period	Separability Index		*Kappa Accuracy (%)*	
	Training area 1	*Training area* 2	*Training area* 1	*Training area* 2
1 year	1952	1998	76.22*	66.45**
			71.89**	

*) fuzzy classification
**) maximum likehood

C. Visual Interpretation and Spectral pattern recognition spectral

Visual interpretation is object recognition through composite color image. Each object can be recognized from several elements such as: tone/color, texture, form, association, location etc. Jaya (2002) states that the band combination better used from visible ray, from near infra-red and from medium infra-red because those bands have very small intra band correlation

Lulus Febrianti (2004) and Kartikasari (2004), conclude that 5 land cover classes identified by SPOT 4 Vegetation are the best, they are forest class, non forest vegetation class, and open area class, water body and cloud. Visually, all land cover class can be recognized clearly. The pixel value of each class at band combination 4-3-2 can be seen in Figure 2.

From Figure 2, every land cover has the typical pattern in each band. At visible band vegetated area is clearly different from open area. At red and blue visible wavelength, vegetation has lower reflectance than open area does because at wavelength 0,45 μ m and 0,65 μ m chlorophyll absorption is at peak (Lillesand and Kiefer, 1994). While at infra-red band, vegetation has higher reflectance compared to that of visible band.

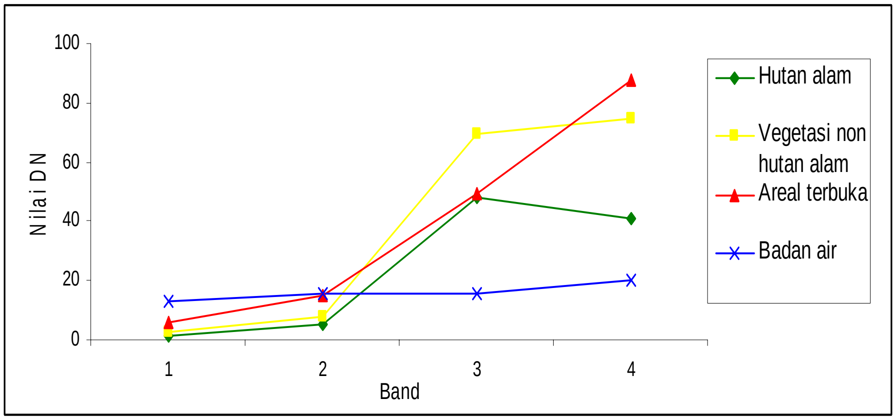

Figure 2. Spectral Pattern of Land Cover on SPOTVEG image.

D. Fuzzy Knowledge Based Classification

The knowledge about reflectance characteristic is utilized to choose the determinant band. The band represents the capability to recognize land cover class specifically. From Figure 2 we know that band 1 (blue) can be utilized as determinant band for the open area and water body. Band 2 (red) can be utilized as determinant band of forest cover. Band 3 (NIR) represents the determinant band for the vegetation of non forest, open area, and water body. While band 4 (SWIR) can be utilized as determinant band for the forest cover, open area, and water body.

The value from determinant band was utilized in compiling fuzzy rule. The logic goes as follows: if membership function at determinant band is true for certain land cover then the pixel will be classified into such a class. For example, the descriptions of membership function in each determinant band are drawn at Figure 3, 4, 5 and 6. Besides using rule from determinant band, classification was also done by using maximum total value of all membership function.

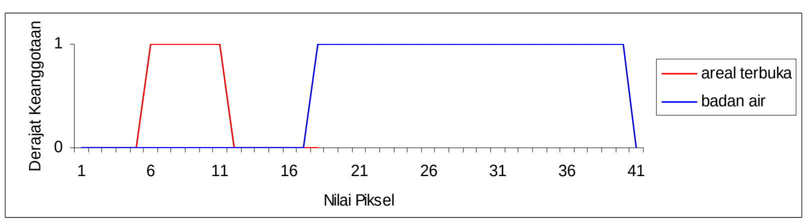

Figure 3. Membership function on Band 1

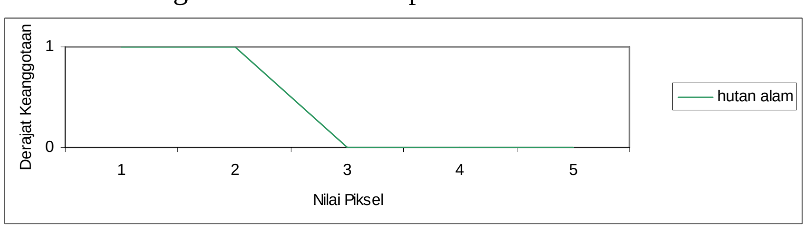

Figure 4. Memberships function on Band 2.

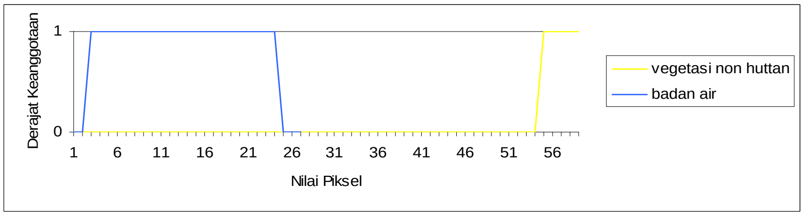

Figure 5. Memberships function on Band 3.

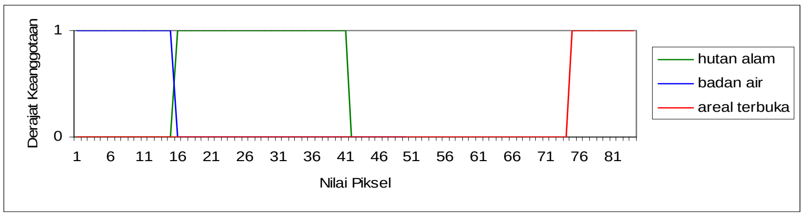

Figure 6. Memberships function on Band 4.

E. Analyze of the Multitemporal Image

With the same rule, classification was conducted for image SPOT 4 Vegetation 2001 and 2004. This activity was done to know the rule ability in classifying each land cover class for different year due to the possibility of different value.

By temporal, it is assumed that any class which was classified as forest in the year 2004 should be also forest in the year 2001. Based on this assumption, some digital sample value was taken ought to represent forest in the year 2001. This digital value intended to improve the rule so that land cover class can classified correctly.

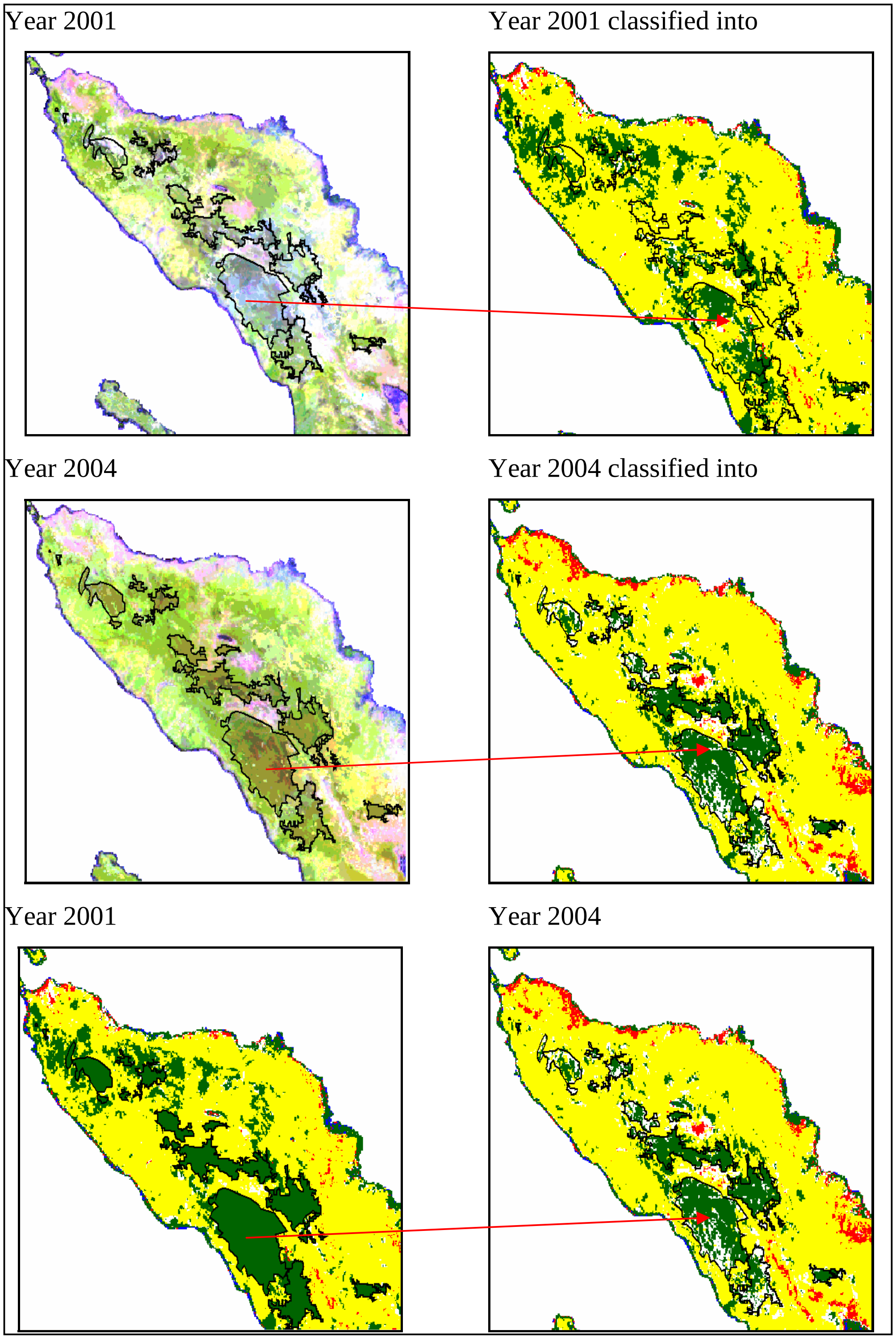

Figure 7. Rule change analysis based on multi temporal data (Sumatera).

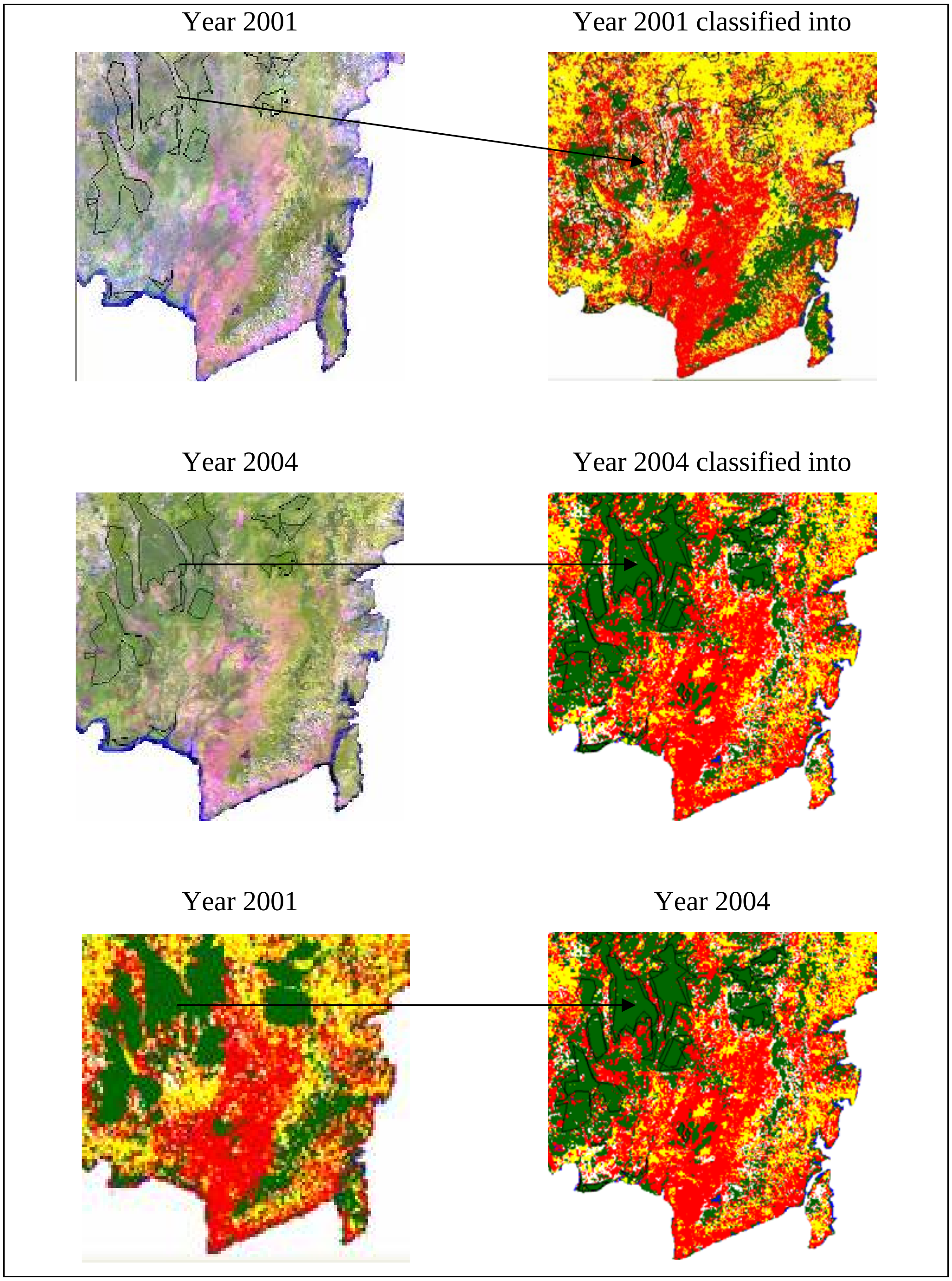

Figure 8. Rule change analysis based on multi temporal data (Kalimantan).

The result of Fuzzy knowledge based classification on image 2001 both for Sumatra and Kalimantan analyzed by confusion matrix is depicted in Tables 2.

Table 2 Accuracy analysis of SPOTVEG image 2001.

Location	Land cover class			
	Natural forest	Vegetation of non forest	Open Area	Water body
Producer Accuracy				
Sumatera	94.8	88.94	75.74	87.59
Kalimantan	99,37	91,16	100	71,25
User Accuracy				
Sumatera	88.15	75.68	98.70	96.62
Kalimantan	95,18	98,86	78,30	100
Overall Accuracy				
Sumatera	86.84			
Kalimantan	92,36%			

The overall accuracy obtained with this knowledge based classification is higher than other supervised classification accuracies. For general and quick forest monitoring, compared to high spatial resolution like Landsat, this system needed much more lower cost, and is easier and faster in handling the data. Problems, which emerge because of cloud and haze, can be overcome by exploiting multi temporal of other image like NOAA AVHRR.

F. Forest cover change distribution base on the district in Indonesia

Among more than 400 districts in Indonesia, the forest cover in most districts is decreasing in range between 200 Ha to 250,000 Ha per year. The natural forest of Sumatra at year 2001 was about 15.971.000 Ha, and of year 2004 was 10.475.400 Ha. The natural forest of Jawa and Bali at year 2001 was about 2.336.600 Ha, and of year 2004 was 1.884.000 Ha. The natural forest of Nusa Tenggara at year 2001 was about 1.425.500 Ha, and of year 2004 was 1.205.300 Ha. The natural forest of Kalimantan at year 2001 was about 23.751.000 Ha, and of year 2004 was 18.062.900 Ha. The natural forest of Sulawesi at year 2001 was about 12.893.300 Ha, and of year 2004 was 11.911.600 Ha. The natural forest of Maluku at year 2001 was about 4.450.000 Ha, and of year 2004 was 4.065.700 Ha. The natural forest of Papua at year 2001 was about 24.301.300 Ha, and of year 2004 was 20.304.700 Ha. Figure 9 showed the distribution of forest cover changes based on the district in Indonesia.

Analysis of forest change was conducted by looking at original forest cover, income per capita and population density on the district basis. The results showed that the three variables are well correlated. The original forest cover and income per capita have positive relation with forest change, while population density has negative relation with it. The relation between forest existence and socio-economic factors, in case of Indonesia, is that the bigger we have the bigger we lost, and the bigger we lost the lesser we gain.

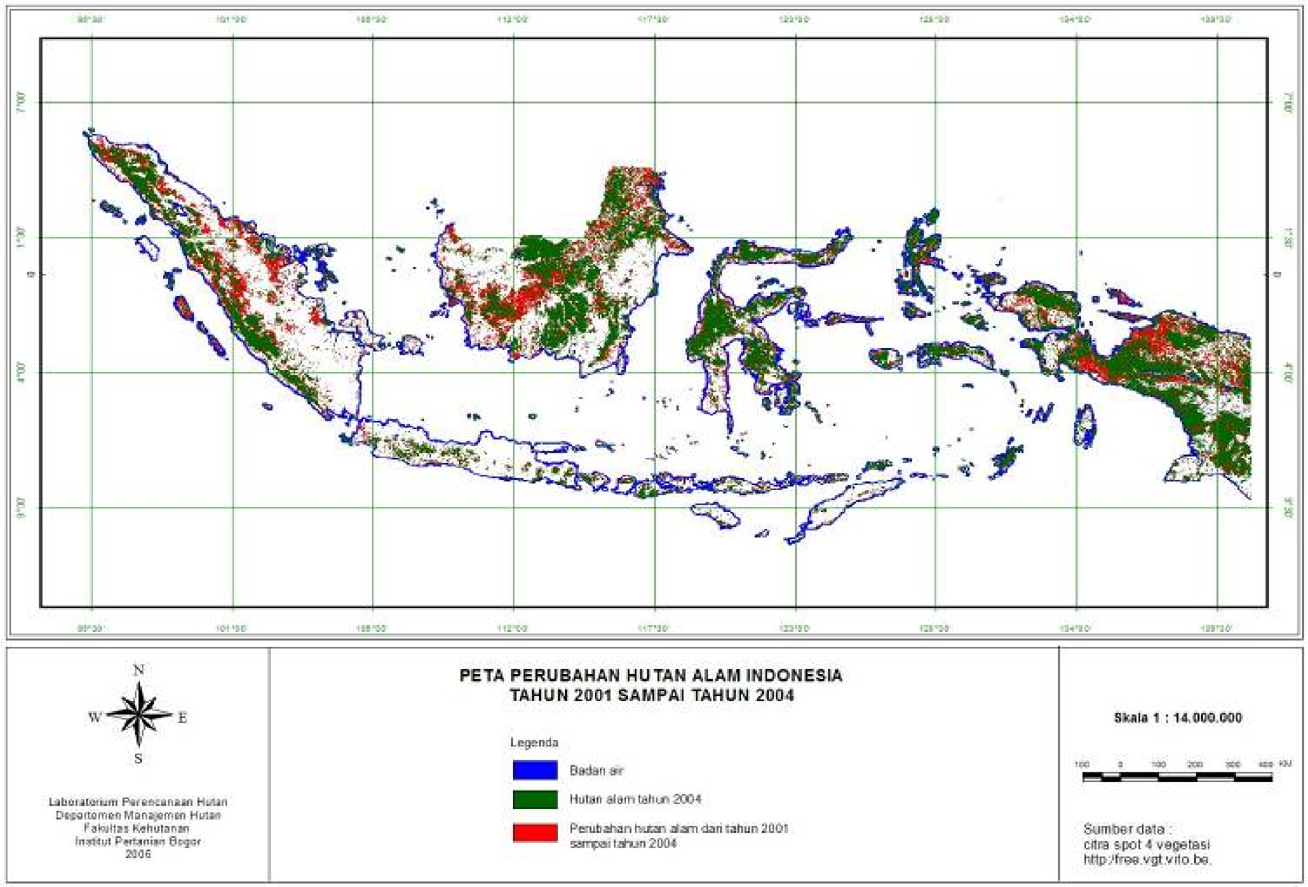

Figure 9. Distribution of Forest Cover Change in Indonesia (2001-2004).

G. Spatial Analysis of Wood Encroachment at FMU level

In determination of vulnerability classes, wood encroachment data are grouped on the basis of stand age class that has relatively similar diameter. There are 4 groups of age class on vulnerability classes: age 0-20 year class, age 20-40 year, age 50-60 year and age more than 70 year. For each group we divided the vulnerability classes into safe, moderate to safe and unsafe, by using each standard deviation values.

Regression model used the volume of wood encroachment as fixed variable with independent variables were Age Class (X1), Slope Class (X2), Village distance Class (X3) and Road distance Class (X4). The best model of wood encroachment is: Y = -1,94 + 1,91 X1 + 0,000865 X4. Validations of the model results in Figure 10.

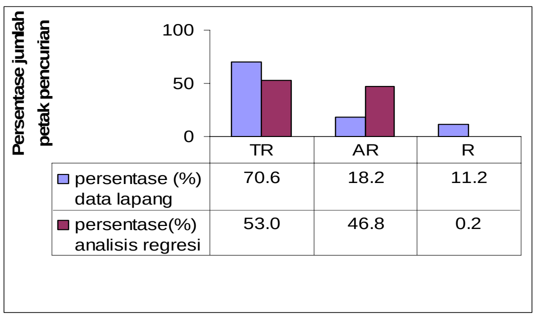

Figure 10. Validation model of Wood encroachment vulnerability classes.

With Geographical Information System, the simulation result of mapping for wood encroachment in KPH Madiun on 2010 and 2015 is displayed at Figure 11.

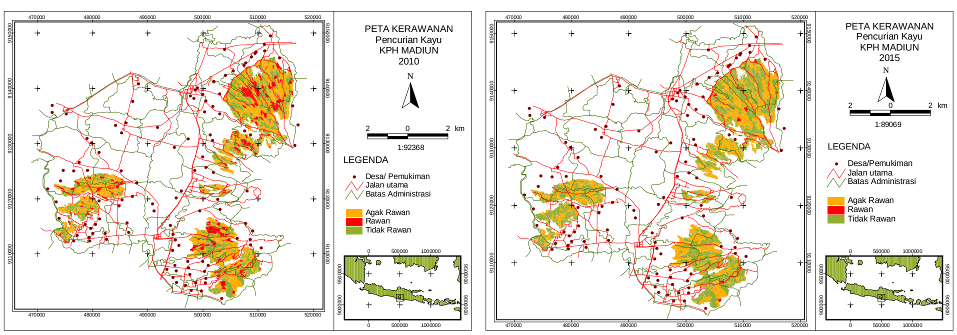

Figure 11. Map of wood encroachment vulnerability classes in KPH Madiun on 2010 and 2015.

CONCLUSION

The application of SPOTVEG with fuzzy knowledge based method to identifying the forest cover change globally, enable us to make a quick monitoring system. The rate of forest cover change is influenced by biosocio-economic factors such as original forest cover acreage, population density and income per capita.

Modeling and GIS can be used for forest monitoring at FMU level. From the case study in teak plantation of KPH Madiun it is found that wood encroachment can be predicted through the stand age class and road distance.

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