Nationwide trends of forest distribution using SPOT VEGETATION time series approach in case of Myanmar

Naoki Mitsuzuka[1], Yukio Wada[1] and Thaung Naing Oo[2] ,Myat Su Mon[2]
[1]Asia Air Survey co.,ltd, 1-2-2, Manpukuji, Asao-ku, Kawasaki-city, Kanagawa 215-0004, Japan,
Email: nao.mitsuzuka@ajiko.co.jp, yuk.wada@ajiko.co.jp
[2]Forest Department, Building 39, Nay Pyi Taw, Myanmar,
Email: tnoo71@gmail.com , sumonforest@gmail.com

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ABSTRACT: Aiming for grasping nationwide forest distribution, we applied SPOT/VEGETATION 10 days composite data (1999-2011, each 10 days) to make forest distribution map of whole area of Myanmar. Harmonic Reconstruction method was applied for the time series filtering to reduce the noise of NDVI value. Forest Distribution map in 2006 were made applying Harmonic Analysis Classification of SPOT/VEGETATION data referencing classified Landsat data . And in each year between 2000 and 2010 forest distribution map keeping consistency were made . Results were assessed by Landsat data on intersection point of Latitude / Longitude, 20x20 km distributed by The Food and Agriculture Organization (FAO) portal site. Overall accuracy were between 64-80% in 3 category forest distribution map (Closed forest ,Open forest ,Non-forest).Additionally, deforest/forest degradation map in 2005 and 2010 using above products were composed and applied for grasping the drivers causing deforestation/forest degradation in whole country of Myanmar. And we analyzed trend of nationwide forest changes with future simulation in 2015 and 2020.

1. INTRODUCTION

Grasping nationwide trends in forest distribution is extremely important in supporting initiatives for sustainable forest management and preventing deforestation. According to the FAO (2010), the forest area of Myanmar is 31 million hectares, which is the largest in countries around Indochina area. However, deforestation is advancing at a rapid rate and the forest area, which was 58% of the national land area in 1990, accounted for only 48% in 2010. During this period the country lost forest area of approximately 7.4 million hectares. The main reasons for deforestation are thought to be collection of firewood, conversion to farmland and shifting cultivation. Moreover, illegal tree felling in border territories where security has not been stable since 1947 is viewed as another factor behind the loss of forests.

The Forest Department of Myanmar (FD, the Ministry of Environmental Conservation and Forestry) previously prepared forest distribution maps for the whole country of Myanmar based on Landsat data in 1989,1997,2006. However, as a result of organizational reconstruction and other circumstances in the country, only the forest distribution map for 2006 is available for use as digital data today. Hence we made nationwide forest distribution map of Myanmar in each year between 2000 and 2010.These data set can be applied to analyze the variation of trend of forest distribution.

2. MATERIALS

2.1 SPOT/VEGETATION NDVI time series data

SPOT VEGETATION satellite data was used to examine for nationwide forest cover monitoring in this study.

We decided to use SPOT VEGETATION data that is available on the free VEGETATON Products site (http: //free.vgt.vito.be/). Various types of products are included in SPOT VEGETATION data, however, here it was decided to use Normalized Difference Vegetation Index(NDVI), which is suited to vegetation analysis.

NDVI is widely used as a simple indicator of vegetation activity in remote sensing related to vegetation analysis in forestry and agriculture. NDVI can be calculated through computing the ratio of Red (red band) and NIR (near infrared band). The computing expression is shown below.

$$NDVI = (NIR - Red) / (NIR + Red)$$

Synthesized 10-day NDVI data (S10, 10 days synthesis) was downloaded and prepared. Data was taken for the period from January 1999 to December 2011. Table 1 shows the prepared SPOT VEGETATION data in detail.

Table 1 Details of the prepared SPOT VEGETATION Data

Product	Synthesized days	Data sets /Year	Data preparation period	Total scenes
S10 NDVI SE-Asia	10-day synthesis	36	1999.01.01-2011.12.21	468

When conducting vegetation observation using high-frequency observation satellite data (MODIS,SPOT/Vegetation,NOAA AVHRR etc.,), difficulties were encountered in synthesizing scenes, conducting analysis and classifying cover due to noise caused by cloud, haze and reception errors. In the conventional approach, there was no other choice but to adopt a method whereby data resolution would be lost at certain points either because observation values with the smallest cloud effect were adopted at the expense of time resolution (through synthesizing image with pixel values from points displaying the highest vegetation index during the year) or because spatial equalization was conducted (adopting average values from nearby multiple pixels are the pixel values). However, in recent years, some of proposals have been made for eliminating or mitigating noise based on phenology (seasonal variation of vegetation) making use of the time series characteristics of high-frequency satellite observation data. In this study, Harmonic Reconstruction , which can be realized with commercially available software (TNTmips, Microimages Co.,), was implemented and time series filtering is applied to SPOT VEGETATON NDVI data(Figure 1,2).

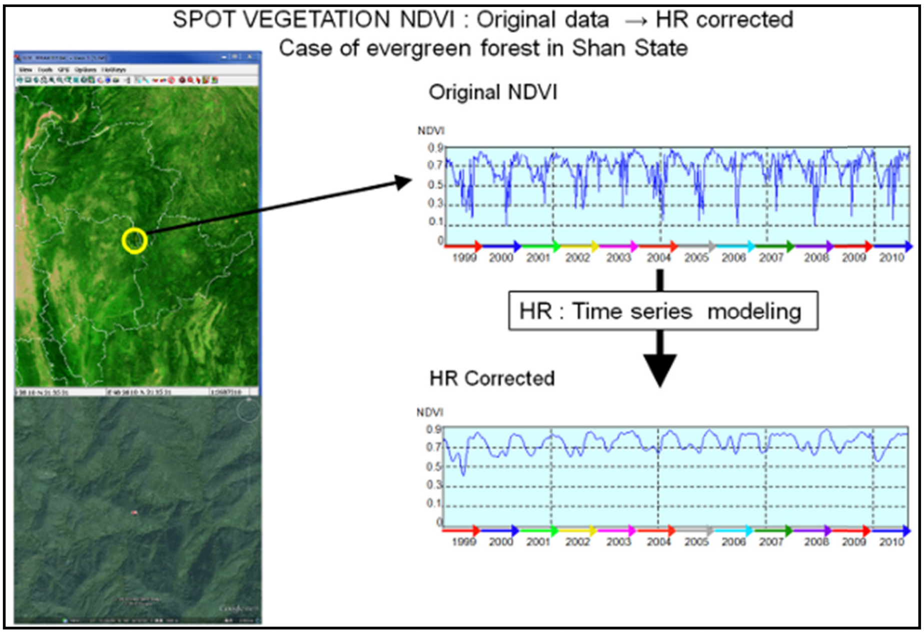

Figure 1 Harmonic Reconstruction, Case of evergreen forest in Shan State,Myanmar

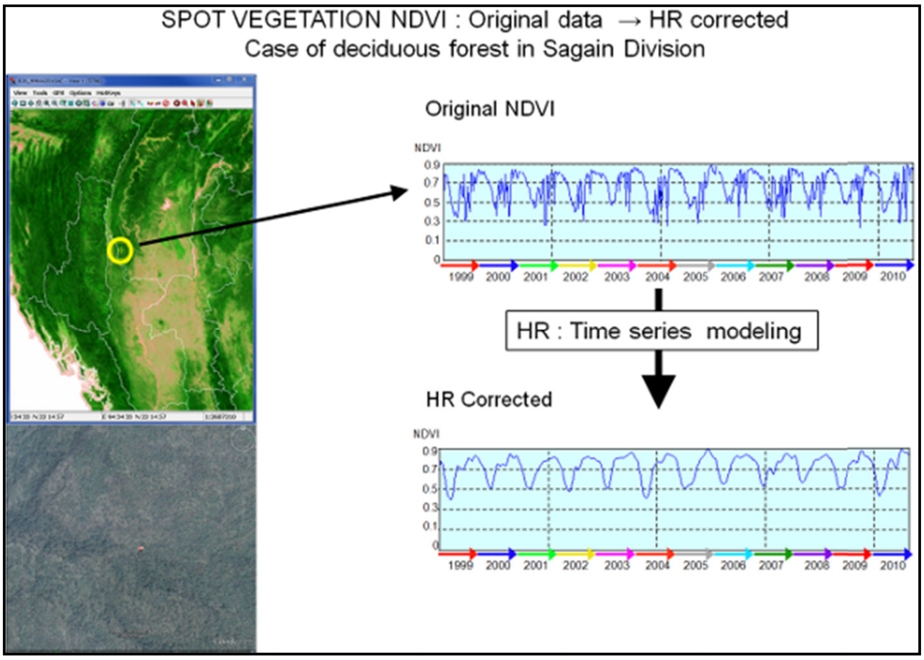

Figure 2 Harmonic Reconstruction, Case of deciduous forest in Sagaing Division,Myanmar

As a result, noise arising from cloud cover and other was mitigated and the NDVI annual fluctuation pattern that expresses vegetation characteristics was appropriately reproduced.

2.2 Detailed forest distribution map in 2006 by FD

The FD previously prepared forest distribution maps for the whole of Myanmar based on Landsat data. However, as a result of organizational reconstruction and other circumstances in the country, only the forest distribution map for 2006 is available for use as digital data today. In this study, we used the detailed forest distribution map in 2006 as source data for compiling each year's forest distribution map. The spatial resolution is 30 m (Figure 3).

2.3 Forest area information based on FAO Forest Resource Assessment (FRA) 2010

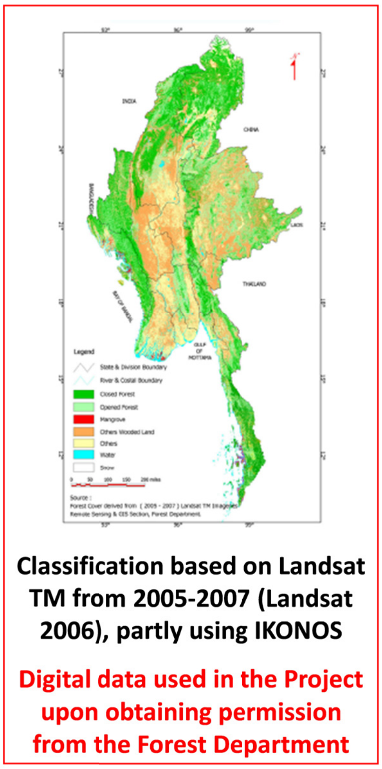

Figure 3 Detailed forest distribution map in 2006

FAO compiled the FRA report in 1990, 1995, 2000 and 2010. This is a global survey of forest resources and also contains country reports. In the country report for Myanmar, it is reported that the trend of forest area was calculated. The forest area of the whole of Myanmar was surveyed using aerial photographs and Landsat TM/MSS images, etc. for 1975, 1989, 1997, 1998 and 2006. Forest area was estimated by using a change forecasting function based on these area totals for 1990, 2000, 2005 and 2010.
In this study, in the process of compiling time series forest distribution information, the forest cover ratio was calculated from the forest cover areas for 2000, 2005, 2006 and 2010 reported in FRA, and this was used as one of the criteria for making forest distribution map.

2.4 Truth data for accuracy assessment of forest distribution map by SPOT/VEGETATION data

In recent years it has become necessary for the creators of distribution maps, etc. to disclose the accuracy of their maps. FAO has distributed the Landsat data that it used for accuracy assessment in FRA 2010 on the FRA Portal Site. This site discloses 20-kilometer-square Landsat data centering on latitude-longitude intersection points all over the world. It contains data for 13,689 locations (not including the Antarctic Continent and so on) observed at three times, i.e. 1990, 2000, and 2005. It includes a country-separate selection feature, and selecting data for Myanmar reveals 62 latitude-longitude intersection points in the country.

3. METHODS

3.1 Preparation of time series forest distribution maps

Nationwide forest distribution maps were created based on SPOT VEGETATION data (1km resolution, NDVI, 10-day composite data). Three classifications, i.e. Closed Forest (canopy coverage of 40% or more), Open Forest (canopy coverage of 10~39%), and Non-Forest, were targeted. 11 years from 2000 to 2010 were targeted.
Figure 4 shows the flow of forest distribution map preparation for each year between 2000-2010 keeping consistency . As is shown in Figure 4, the work was advanced in the order of i), ii), iii).

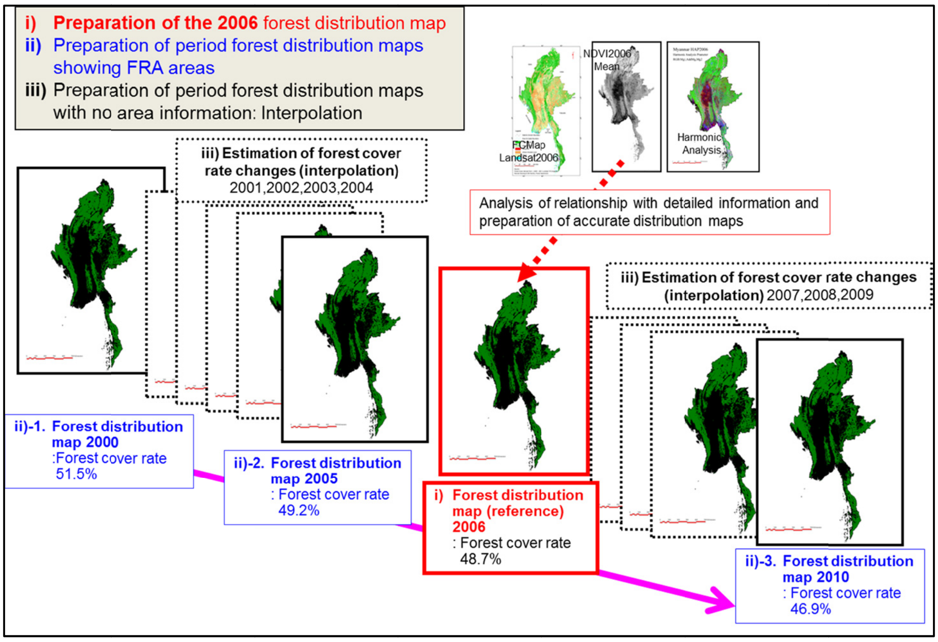

Figure 4 Flow of preparation of forest distribution maps between 2000-2010

i) Preparation of the 2006 forest distribution map

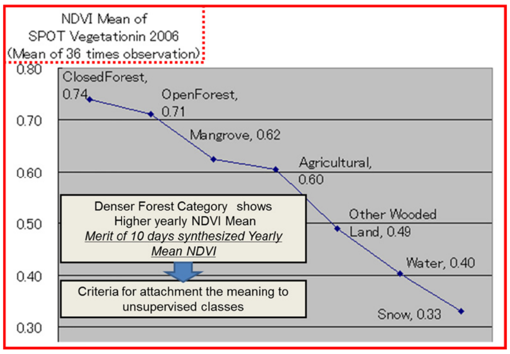

Figure 5 Relationship between SPOT VEGETATION NDVI 2006 mean and categories

For 2006, the detailed forest distribution map shown in Figure 3 exists (prepared by FD). Accordingly, the 2006 forest distribution map is important information that provides the basis for each year's eventually compiled forest distribution information. First, the 2006 SPOT VEGETATION NDVI data following HR treatment was inputted and harmonic function analysis (Harmonic Analysis, TNTmips function) was conducted to give features to the annual NDVI pattern according to each pixel. By doing this, six amplitude coefficient images (phases) and one initial phase image (additive), which characterized the vegetation index fluctuation of each pixel, were obtained. Using these seven images, unsupervised classification (FuzzyC Mean method) was conducted. Concerning the results, meaning was attached to the 2006 Mean Values and Categories in forest distribution map classes by using the relationship between the NDVI annual mean values shown in Figure 5 (upon confirming them in advance) and the forest classifications that are adopted by the FD.

From Figure 5, it is confirmed that the SPOT VEGETATION NDVI annual mean value increases as the vegetation category becomes denser. As was mentioned previously, medium resolution satellite images such as those from Landsat constitute information that indicates the state of vegetation at certain times amidst seasonal changes. In particular, seasons of low cloud cover overlap with the leaf shedding season of deciduous trees. Accordingly, in medium resolution satellite images such as those from Landsat and ALOS, adopting good quality images with little cloud cover often entails selecting images from the dry season, making it difficult to distinguish between deciduous forest, grassland and bare land. The year-round NDVI mean value that is obtained from SPOT VEGETATION following time series filtering has a marked tendency for the categories of Closed Forest, Open Forest to display a higher position than other categories, and it is confirmed to be suitable information for seeking the forest distribution. In view of this, a criteria was set in order to give meaning to the classes that were prepared in unsupervised classification.

Upon investigating the correlation between the initial phase value image and NDVI annual mean value image using the TNTmips Raster Correlation function, there was found to be regression based on the following expression:

2006 initial phase value = 1.00001 x (NDVI 2006 annual mean) - 0.00089 - (a)

The linear regression coefficient (incline) is close to 1.0 and segments are almost zero. Accordingly, both elements may be described as practically the same data. In other words, the relationship that can be expressed by the following expression exists somewhere between the initial phase value image and NDVI annual mean value.

Initial phase value image ≒ NDVI annual mean value - (b)

From this relationship (b) and the relationship between NDVI annual mean value and forest distribution map categories indicated in Figure 5, classes that comprise pixels with high initial phase value are considered to signify high-density forest. Thus, as the criteria for giving meaning to classes, high initial phase mean value is deemed to indicate forest. Based on the classes that have higher initial phase mean value, class areas were added and the selected classes were treated as Closed Forest until the area coincided with the Closed Forest cover ratio according to FRA2010. Classes coinciding with the cover ratio for Open Forest according to FRA2010 were assumed to be Open Forest. The remaining areas were regarded as Non-Forest.

ii) Preparation of forest distribution maps with FRA area values

In this process, based on the 2006 forest distribution map that was prepared in i), the pixels that should be changed so that the areas of Closed Forest and Open Forest each year coincide from the condition in 2006 were selected. As the overall trend for Myanmar (2000-2010) according to FRA2010, the total area of forest has been in decline over time. The results of offsetting the specific points of increase against the points of decrease should give the total area over the entire country, however, in the case of the time series forest distribution map here, the process was simplified by focusing only on areas of reduction over time. In this sense, the prepared distribution map is simpler than reality.

As information for selecting pixels where there has been definite deforestation and forest degradation, attention was directed to areas where the mean NDVI value between two points in time decreases greatly and areas showing a trend of decrease between 1999 and 2010.

As trend information, the coefficient (incline) in linear regression of the NDVI annual mean value between 1999-2010 was used. The trend of increase or decrease in the annual mean NDVI value was used to express the trend of vegetation change. In addition to conforming to the forest cover rates according to FRA2010, consideration was given to maintaining the consistency of forest cover positions. Table 2 shows a comparison of forest cover ratio between the forest distribution maps for 2000, 2005, 2006 and 2010 and forest area reported in FRA2010.

Table 2 Comparison of forest distribution maps prepared from SPOT VEGETATION and FRA2010 forest cover ratios

	Closed Forest		Open Forest	
	FRA 2010	SPOT Vg	FRA 2010	SPOT Vg
2000	34.7%	33.9%	16.8%	17.3%
2005	27.3%	27.4%	21.9%	21.3%
2006	25.8%	25.5%	23.0%	23.0%
2010	19.9%	19.9%	27.1%	27.0%

iii) Preparation of forest distribution maps for years with no area information

Finally distribution maps were prepared for the periods between 2000 and 2005, 2006 and 2010, i.e. 2001-2004 and 2007-2009.

First, the changes between already prepared periods were presumed. In cases of pixels where forest degradation (Closed Forest → Open Forest) occurs, the era when degradation occurred was determined. At this time, as a rough guide, in the target annual mean value image (mean value image from 36 time points in the target year, 1 raster data), the mean value for all pixels that were Open Forest in 2006 was sought, and the time when the value fell below this was assumed to be the year when forest degradation occurred. After this point, the forest classification remained as Open Forest. Based on this approach, effort was made to preserve the consistency of forest cover change.

In the case of deforestation, three patterns can be considered:

Closed Forest → Non- Forest,
Closed Forest → Open Forest → Non-Forest,
Open Forest → Non-Forest

Using the planar NDVI mean values obtained based on the distribution of Closed Forest and Open Forest in 2006 as a rough guide, the point of change (year of change) was determined. Figure 6 shows Forest Distribution map in 2000,2005,2010 prepared based on this process.

3.2 Accuracy Assessment of forest distribution maps

In this study, nationwide forest distribution maps (each year from 2000 to 2010) were prepared for the whole of Myanmar . Since the forest distribution maps made had spatial resolution of 1 kilometer, it is possible to acquire more appropriate truth data by interpretation of higher resolution Landsat data (30-meter spatial resolution).

FAO has distributed the Landsat data that it used for accuracy assessment in the FRA 2010 on the FRA Portal Site. This site discloses 20-kilometer-square Landsat data centering on latitude-longitude intersection points all over the world. It contains data for 13,689 locations (not including the Antarctic Continent and so on) observed at three times, i.e. 1990, 2000, and 2005. It includes a country-separate selection feature, and selecting data for Myanmar reveals 62 latitude-longitude intersection points in the country.

The Landsat data sets for 2000 and 2005 were downloaded and prepared from the FRA Portal Site.

Interpretation was conducted in 1-kilometer simulation units, and truth data was created. Landsat data was acquired for 62 latitude-longitude intersection points in 2000 and 57 such points in 2005; a 1-kilometer-square grid was superimposed, and the data was interpreted using the same definition with 3 categories, "Closed Forest, Open Forest, and Non Forest" definitions as used in the forest distribution maps(Figure 7).

In 2000, the overall accuracy was 79% for the two-category classification of Forest and Non-Forest and 64% for the three-category classification of Closed Forest, Open Forest, Non Forest(Figure 8). In 2005, the values were 87% for the two-category classification of Forest and Non-Forest and 80% for the three-category classification of Closed Forest, Open Forest, Non Forest (Figure 9).

3.3 Application of Forest Distribution Maps of each year between 2000 and 2010

We prepared nationwide forest change maps (deforestation, forest degradation) ,analyzed the change factors and conducted field survey at the hot spots from this information. In addition to image confirmations, the conditions leading up to forest change including social trends were clarified (Figure 10). And we analyzed trend of nationwide forest changes with future simulation using change information through 11 years, it was confirmed that such data can be referred to for indicating locations where deforestation and forest degradation will occur in the future (Figure 11).

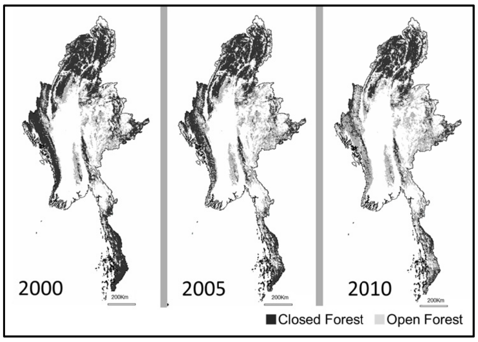

Figure 6 Forest Distribution Maps in 2000,2005,2010

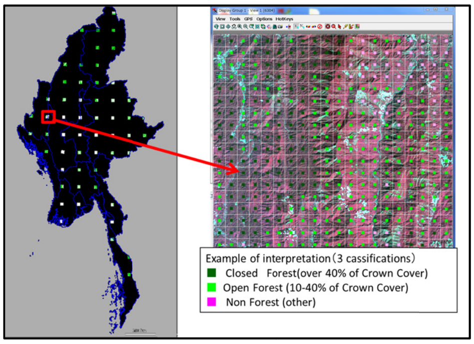

Figure 7 Truth data for accuracy assessment

Class(SPOT Vg) / Truth data(Interpretation using Landsat) Name	Closed Forest	Open Forest	Non Forest	Total	Accuracy
Closed Forest	5871	894	104	6869	85.47%
Open Forest	2666	1521	270	4457	34.13%
Non Forest	2000	2122	6977	11099	62.86%
Total	10537	4537	7351	22425	
Accuracy	55.72%	33.52%	94.91%		
Overall Accuracy =		64.08%	Khat Statistic =		45.04%

Figure 8 Accuracy of Forest Distribution Map in 2000

Class(SPOT Vg) / Truth data(Interpretation using Landsat) Name	Closed Forest	Open Forest	Non Forest	Total	Accuracy
Closed Forest	4972	723	434	6129	81.12%
Open Forest	825	3813	392	5030	75.81%
Non Forest	683	991	7494	9168	81.74%
Total	6480	5527	8320	20327	
Accuracy	76.73%	68.99%	90.07%		
Overall Accuracy =		80.09%	Khat Statistic =		69.46%

Figure 9 Accuracy of Forest Distribution Map in 2005

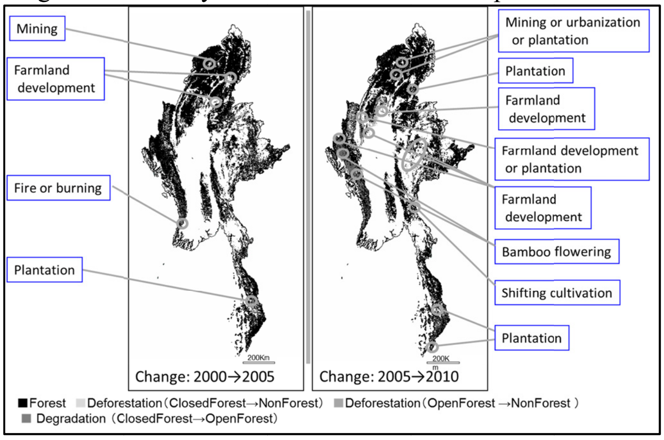

Figure 10 Forest change points and Factors

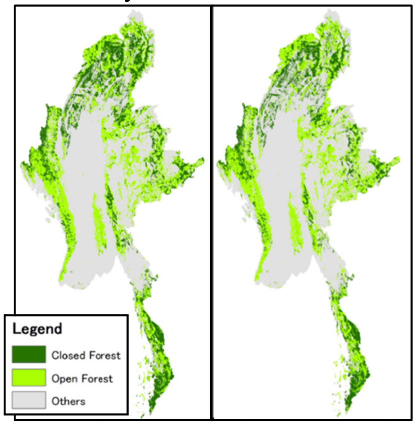

Figure 11 Future Forest Distribution Map (left 2015, right 2020)

4. RESULTS AND DISCUSSION

In this study, the nationwide forest distribution was grasped using wide-area, high frequency observation, temporal satellite data (SPOT/VEGETATION).Creating temporal nationwide forest distribution maps based on satellite data with resolution of 10~30 meters entails a lot of time and effort. In this respect, wide-area, high frequency observation, temporal satellite data is an effective tool for rapidly building data and creating temporal forest cover maps. It is difficult to apply it to carbon stock calculation because the spatial resolution is so coarse, however, it was found to be effective for rapidly grasping nationwide time series forest distributions. Another merit is that uniform forest distribution temporal data sets can be created when utilizing such data as input data for forest change information and future simulation. Considering that the environment for conducting accuracy assessment is steadily being improved (use of FRA Portal Site, etc.), it is anticipated that wide-area, high frequency observation, temporal satellite data can be further applied in the future.

Since this data is suitable for extracting large-scale forest changes, it was also effective as focus area information for investigating the social background and factors of forest changes. Focusing on areas of forest change based on wide-area, high frequency observation, temporal satellite data, it is proposed that this be utilized as starting data for comprehensive forest change survey including the grasping of forest change based on detailed images, grasping of actual conditions and investigation of causes based on field survey, hearings with government agencies and so on.

REFERENCES

Yukio WASA, 2004. Reconstructing cloud free SPOT/VEGETATION using Harmonic Analysis with local maximum fitting, ACRS 2004, Chaing Mai, pp1663-1667, from http://www.microimages.com/papers/ACRS25.pdf

FAO, 2010, Forest Resources Assessment 2010 country report, from http://www.fao.org/docrep/013/al576e/al576e.pdf

FRA Remote Sensing Portal from http://geonetwork4.fao.org/geonetwork/srv/en/fra.home