SEASONAL CHANGES OF FOREST ENVIRONMENTS IN THE MEKONG RIVER BASIN

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ABSTRACT:

Although the problem in tropical forest has been widely concerned, deforestation and forest degradation is still hot issue in the world. In some countries in the Mekong River Basin, scientific knowledge about forest ecosystem and forest law enforcement are not enough to maintain their forests in good condition from the natural environmental point of view. Remote sensing technology is considered one of the useful and important tools for monitoring various forest conditions. The phenological change of each forest is greatly related to the changes of natural environmental factors, such as water, temperature, soil and solar radiation. The authors proposed a monitoring system to get environmental information of forested area using remote sensing data. The pre-processing method named LMF and LMF-KF (Local Maximum and Fitting with the Kalman Filter) was introduced, which modelled the seasonal changes for time series data of frequent observation satellite data. This technology overcomes the influences of cloud cover and sensitivity fluctuations of the sensors. We applied these methods to SPOT-Vegetation and NOAA-AVHRR data of the Mekong River Basin. These dataset could show the environmental conditions, such as vegetation cover, temperature, snow cover area and leaf water condition in Mekong River Basin.

1. INTRODUCTION

1.1 Background

The forest meteorological tower with 60m high and wells for underground water measurement were constructed and many new instruments are monitoring environmental conditions at a evergreen forest in Cambodia since 2003. The activity is strengthen under the project “Establishment of the Integrated Forest Ecosystem Observation Sites and Network in the Lower Mekong (2008-2011)” funded by the Ministry of Environment of Japan. And a new observation site is going to be constructed in a deciduous forest.

Although the problem in tropical forest has been widely concerned, deforestation and forest degradation is still hot issue in the world. In most of the countries, scientific knowledge about forest ecosystem and forest law enforcement are not enough to maintain the forest are in good condition from the natural environmental point of view in South East Asia.

We have set up four subjects for the new joint project between Forestry Administration of Cambodia and Forestry and Forest Products Research Institute of Japan, such as:

1) Biodiversity and Forest Site Environment Study
2) Observation System for Water Cycle in Tropical Seasonal Forest
3) Near-real-time Observation System of Forest Environment by Satellite
4) Archiving System of Forest Observation Sites in the Lower Mekong

1.2 Remote sensing data for environmental issues

Remote sensing technology is considered one of the useful and important tools for monitoring various forest conditions in the world. However, appropriate monitoring system using remote sensing is not yet clear. Sader et al. (1990) suggested that higher resolution sensors (MSS, TM, SPOT, aircraft scanners and mapping cameras) are necessary tools to record the spectral and spatial details needed to link intensive ecological field studies to the forest community and biome levels. Even though these ideas on multi-stage observation are considered quite useful for studying environmental conditions, most of the activities could get limited results because of the remote sensing data which are obtained “by chance” depending on cloud cover and other problems.

While remote sensing data give us various data of the ecosystem related to the electro-magnetic reflectance and/or radiation, it is necessary to find the appropriate “remote sensing indices” for monitoring forest environment conditions. The phenological changes of ecosystem are greatly related to the changes of natural environment, such as water, temperature, soil and solar radiation. Therefore, “appropriate remote sensing indices” shall reflect the environmental conditions.

We studied to get information about seasonal changes of environmental conditions by remote sensing data. Various researches on global environment study utilize frequent observation satellite data. The NOAA-AVHRR and SPOT-Vegetation are commonly used for such purpose (Ricotta et al., 1999) and "the ten-day composite images", which are created by choosing the best data in ten days for every pixel, are often used to monitor seasonal changes of terrain conditions (Defries et al., 1994). However, the influences of cloud and haze still remain in those data and it makes difficult to monitor phenology with 10 days interval (Roerink et al., 2000). On the other hand, the "monthly" composite data to reduce the influence of noises are not appropriate for following phenological aspects because most of the dynamic seasonal changes of vegetation occur within a few weeks (Viovy et al., 1992).

Therefore, the authors developed the processing method named LMF (Local Maximum and Fitting) and LMF-KF (Local Maximum and Fitting with the Kalman Filter), which modelled the seasonal changes for time series data of frequent repeat observation satellite data. The LMF-KF introduces the form of the sum of cyclic functions with time-dependent coefficients (Sawada et al., 2005) and produces clear images with 10 days interval.

We applied these techniques to SPOT-Vegetation data to detect snow cover area and NOAA-AVHRR data to reveal the environmental conditions in the Mekong River Basin. These methodologies give us the opportunity to monitor environmental conditions of forest area in both global and national scale, which will help us monitoring with rather high spatial resolution satellite. We think that it will give us an ideal system for multi-stage monitoring as well.

2. DATASET FOR MONITORING IN GLOBAL SCALE

2.1 SPOT-Vegetation Data

The SPOT-Vegetation sensor was launched on the SPOT-4 in 1998. The sensor has four channels which have 1 km resolution at the nadir. The dataset called "S10" is the ten-day composite data which is created by the same concept with the NOAA 10-day composite data. These data are open to the public after a few month of observation. The SPOT-Vegetation has the same channel with SPOT-HRVIR which has 20 m resolution (10 m for panchromatic channel) and the combination of these two sensors are considered useful for monitoring in both global and local scale.

2.2 NOAA-AVHRR data

NOAA satellite data provide a valuable tool for vegetation mapping and monitoring at regional and global scales (Justice et al., 1985). The computer center of Ministry of Agriculture, Forestry and Fisheries, Japan, produces ten day composite images of NOAA AVHRR with 1 km resolution for South-East Asia region. The NOAA-AVHRR Pathfinder dataset (by NOAA) is one of the most popular one for global study.

2.3 LMF and LMF-KF Processing to the Dataset

The SPOT and NOAA datasets, however, have some difficulties in applying them to long-term change detection in regional scale. One of the main problems is the influences of cloud cover and other noises for observing terrain conditions even by the best composite images in 10 days. The changes of sensitivity of sensors on different satellites also make indispensable problem for data comparison in a long period of time (ex. the NOAA-Pathfinder data). Then, the LMF and LMF-KF processing were applied to minimize the effect of clouds and the sensitivity differences of sensors in these dataset.

2.4 NDVI and Temperature data

After the processing, we could get the same number of "clear (cloud-free)" images as the original dataset. The characteristics of each forest site on NDVI and temperature are evaluated from these data. For example, we created the summation data of NDVI in one year when the surface temperature is greater than 5 degree Celsius (this value is commonly used for the warm index). It seems that the summation values correspond to the vegetation production of one year, although further research is still needed.

2.5 Snow Index

The snow cover is one of the key environmental factors for forest ecosystem. Therefore many researchers have conducted to create snow cover maps. However, during the snow season, it is quite difficult to obtain clear sky remote sensing data. The LMF and LMF-KF processed images are effective even in this case. Saito et al(1999) reported the snow cover index for GLI data as the Eq. 1

$$S3=\{NIR1 \cdot (VIS-NIR2)\} / \{(NIR1+VIS)/(NIR1+NIR2)\} \quad (1)$$

where NIR= near infrared data
NIR= middle infrared data
VIS= visible red

The results show that the snow index S3 has quite sensitive with snow cover. The LMF processed SPOT-Vegetation 10-day composite data made us possible to create snow cover maps every 10 days. The images showed the duration of snow cover for each pixel (1km). According to our pre-check, it was the first time that snow cover map with 1 km resolution was created for Mekong River Basin. However, where snow covers less than one month, the original SPOT S10 data itself does not useful to detect the duration of snow cover because of its characteristics of the data composition procedure.

2.6 Leaf Water Content Indices

2.6.1 LWCI (Leaf Water Content Index): The LWCI (Leaf Water Content Index) was reported effective to monitor leaf water condition or water availability (Anazawa et al., 2002). The LWCI is defined for the Landsat-TM as the Eq. (2).

$$LWCI = \frac{-\log[\alpha \times (TM4/A - \beta\, TM5/B)]}{-\log[\alpha \times (TM4\,ft/A - \beta\, TM5\,ft/B)]} \quad (2)$$

where
TM4= energy value of Landsat TM4
TM5= energy value of Landsat TM5
TM4ft=energy value of TM4 at full turgor (at the minimum water stress)

TM5ft=energy value of TM5 at full turgor (at the minimum water stress)
A=Maximum value of TM4 through a year
B=Maximum value of TM5 through a year
A=the correction coefficient (usually 1)
B=the coefficient for converting he energy value into the reflectance (the reflectance ratio at the season of the minimum water stress in a leaf = the ration of TM5 to TM4 in the theoretical solar radiation spectrum curve: the representative value=0.2)

2.6.2 NDII(Normalized Difference of Infrared Index): The NDII is defined as follows;

$$NDII = \frac{TM4 - TM5}{TM4 + TM5} \quad (3)$$

The NDII is highly correlated to vegetation water content (Hunt, 2004). Both the LWCI and NDII are consisting from TM4 and TM5. The relationship between the two indices in vegetated area is quite high, although it somehow depends on ground cover.

2.6.3 Water Indices for NOAA data: Because the NOAA-AVHRR does not have middle infrared channel, we tried to develop an index that is suitable for monitoring water condition in forest area using NDVI, VTI (modified NDVI) and thermal data. The steps were as follows;

(1) Step 1 : to develop a suitable linear regression model related to NDII for Landsat TM (20 Feb. 2002).

The result showed that the best model was obtained as Eq. (4)

$$NDII = 390 + 1.20NDVI - 0.749VTI - 1.65CH6 \quad (4)$$

where
NDVI= Normalized Difference of Vegetation Index
VTI= Modified NDVI
CH6=Channel 6 (Thermal channel)

(2) Step 2 : to apply the linear regression model to NOAA data (in middle Feb. 2002, LMF-KF processed)

Base on the idea in Step 1, the linear regression model related to TM-NDII was developed for NOAA-AVHRR. The obtained equation was Eq. (5)

$$NDII = 77.5 + 4.4NDVI - 2.04VTI - 0.014CH4 \quad (5)$$

(3) Step 3 : to create NOAA water content images

The regression model was applied to each pixel to create the estimated NDII image (Fig.1).

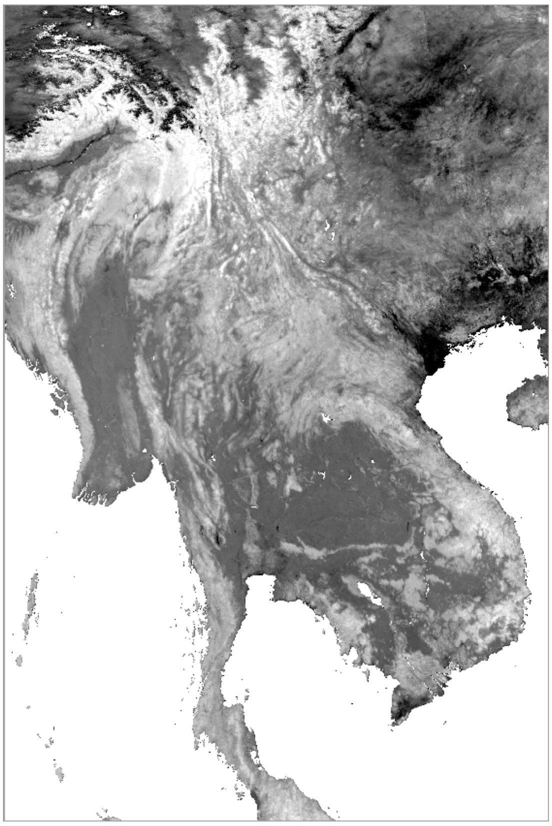

Figure 1. Water Index Image

3. DISCUSSION

The LMF and LMF-KF processing was found useful technique for deleting the effect of clouds and other noises for observing the ground condition in this region. Because the differences of sensitivity of the AVHRR sensors are also corrected by this method, it makes us possible to compare the phenological changes for a long period of time.

The LMF processed SPOT-Vegetation data were useful to create snow cover map every 10 days.

Water content indices were analyzed for Landsat TM and NOAA AVHRR data. A linear regression model was developed for estimating the water content of vegetation by the NOAA-NDVI and CH4 (thermal channel). The results show that the coarse resolution satellite data gives time sequential data by deleting the affect of clouds and other noises that interrupt the terrain observation. Therefore, these approaches are considered effective to reveal the most important environmental condition, such as water and temperature, in forest area.

Because the SPOT-Vegetation has middle infrared data, the water content index (NDII) is directly created by its own data. However, because the SPOT-Vegetation does not have thermal data and NOAA or other satellite data is needed to monitor surface temperature. Further study on water content index for NOAA data is still needed with sufficient data comparison with Landsat data and ground information (meteorological information).

Because high resolution satellite data are obtained “by chance” depending on the weather condition and system management, it is quite often difficult to get the "appropriate data" both in spatially and temporally. The multi-stage monitoring design with "cloud free" images shall be useful not only for broad-scale but also for local forest cover monitoring in various areas because of its usefulness of the monitoring efficiency of seasonal changes.

The combination of NDVI and the Surface Temperature derived from NOAA with 10 day interval show various information on ecological characteristics in regional scale (Fig. 2).

Figure 2. Summation of NDVI when temperature > 5 C

REFERENCES

Anazawa, M., G. Saito, Y. Sawada and H. Sawada (2002) Utilization of Leaf Water Content index for Selected Terrestrial Ecosystem Monitoring using SPOT Vegetation Data, Asian Journal of Geoinformatics, 3(1):55-62

Defries,R. S. and J. R. G. Townshend (1994) NDVI- derived land cover classifications at a global scale. International Journal of Remote Sensing, 15:3567-3586.

Hunt, E.R., B. N. Rock and P.S. Nobel (2004) Measurement of leaf relative water content by infrared reflectance, Remote Sensing of Environment, 22:429-435

Justice, C. O., J. R. G. Townshend, B. N. Holben and C. J. Tucker (1985) Analysis of the phenology of global vegetation using meteorological satellite data, Int. J. Remote Sensing, 1985, 6(8):1271-1318

Nishiyama, K.(1991) Estimation of time varying spectrum, Journal of the institute of Electronic, Information and Communication Engineers, J74-A(6):916-918,

Ricotta, C., G. Avena and A. De Palma (1999) Mapping and monitoring net primary productivity with AVHRR NDVI time-series: statistical equivalence of cumulative vegetation indices, ISPRS Journal of Photogrammetric Engineering and Remote Sensing, 54:325-331.

Roerink, G. J., M. Menenti and W. Verhoef (2000) Re-constructing cloud free NDVI composites using Fourier analysis of time series, International Journal of Remote Sensing, 21:1911-1917.

Sader, Steven A., Thomas A. Stone and Armond T. Joyce (1990) Remote Sensing of Tropical Forests: An Overview of Research and Applications Using Non-Photographic Sensors, Photogrammetric Engineering and Remote Sensing, 56:1343-1351

Sawada, Y., N Mitsuzuka and H. Sawada (2005) Development of time-series model filter for high revisit satellite data, Proc. the 2nd International VEGETATION Users Conference, Office for Official Publication of the European Communities, 83-89

Shabanov, N. V., L. Zhou, Y Knyazikhin, R. B. Myneni and C. J. Tucker (2002) Analysis of Interannual Changes in Northern Vegetation Activity Observed in AVHRR Data from 1981 to 1994, IEEE Transactions on Geoscience and Remote Sensing, 40(1):115-130

Viovy, N., O. Arino and A. S. Belward (1992) The Best Index Slope Extraction (BISE): A method for reducing noise in NDVI time-series, International Journal of Remote Sensing, 13:1585-1590.

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Names of journals can be abbreviated according to the "International List of Periodical Title Word Abbreviations". In case of doubt, write names in full.