AGRICULTURAL MAP OF ASIAN REGION USING TIME SERIES AVHRR NDVI DATA

Izumi NAGATANI*
Genya SAITO*
Hitoshi TORITANI*
Haruo SAWADA**

**Remote Sensing Unit, Ecosystems Group,
Department of Global Resources
National Institute for Agro-Environmental Sciences
3-1-3 Kannondai, Tsukuba, Ibaraki, 305-8604 Japan
Tel: (81)-298-38-8228 Fax: (81)-298-38-8199
E-mail: Nagatani@affrc.go.jp

**Forestry and Forest Product Research Institute
1 Matsunosato, Kukizaki, Ibaraki, 305-8687 Japan

KEY WORDS: Agricultural map, Periodic function, LMF

ABSTRACT:
In order to grasp the amount of water resources for agricultural production in Asian region, the map of cropping pattern is necessary.
In this study, we tried to create the cropping pattern map of East China using time-series NOAA-AVHRR NDVI 10-days composite data (1997-1999). The LMF method was used as the periodic function in this study, and in consequence, we confirmed that LMF method was effective to identify single or double cropping field.

1. Introduction

In Asian countries, especially in China the largest cereal producing country in the world, the water shortage is becoming a serious problem, and the optimal water resource management is needed. In order to understand the amount of the agricultural water resources in Asian region, an agricultural map is required. However, it is difficult to obtain the reliable agricultural map of an Asian region where a variety of agricultural type exists in the large area. It is expected that the satellite remote sensing technology can solve these problems.

The NOAA AVHRR data are well used to analyze the change of vegetation in global scale studies and the time series analysis using profiles of normalized difference vegetation index (NDVI) is well used. Time series analysis of satellite data such as standardized principal component analysis (Eastman and Fulk 1993) or Fourier analysis (Andres et al. 1994, Azzali and Menenti 2000), are useful technique to obtain the information of seasonal vegetation change characterized as phenology. Jakubauskas (2001) used the harmonic analysis to characterized seasonal changes for natural and agricultural land use/land cover in Finney County, U.S.

In former research, we had developed the LMF (Local Maximum Fitting) time series processing (Sawada 2001). This processing consists of the time series filtering and the fitting processing. The feature of the LMF processing is to be able to remove clouds, and to be able to capture the seasonal variation of the natural vegetation. We had considered that the LMF parameters estimated in the initial fitting processing could be used for crop-identification. In this study, we developed the methodology for creation of the agricultural map of an Asian region by using the LMF, and created the agricultural map of the east part of China.

2. LMF fitting parameters

The LMF is a time series processing which integrates the time series filtering and the fitting processing. The effects of clouds, hazes, and system noises, etc. are removed from the time series data of each pixel by this processing. The function is shown by equation (1).

$$f_i = c_0 + c_1 t + \sum_{i=1}^{N} \left\{ c_{2i} \sin\left(\frac{2\pi k_i t}{M}\right) + c_{2i+1} \cos\left(\frac{2\pi k_i t}{M}\right) \right\} \qquad (1)$$

Where c_i are coefficients, t is time. The first 2 terms are aperiodic terms, and other terms are the seasonal variation term. Since it becomes the 36 image/year, M is equal to 36, when 10 days maximum value composite data for one year are used. As a periodic function, by assuming that six periods (1 year, half year, 4 months, 3 months, 2 months, 1 month) might be used, k_i are {1, 2, 3, 4, 6, 12}. N is the number of time series data. These six periodic functions are adopted at the initial step.

Equation (1) is converted to a sine curve function.

$$f_i = c_0 + c_1 t + \sum_{i=1}^{N} \left\{ A_i \sin\left(\frac{2\pi k_i t}{M} + \alpha_i\right) \right\} \qquad (1)$$

where A is amplitude and á$_i$ is phase lag of sine curve. In this study, we use these A_i and á$_i$ parameters calculated from initial step of LMF processing.

In LMF processing, to remove the effects of clouds, hazes, and system noises, the time-series filtering and the fitting processing are repeated until obtain the optimum result functions (Sawada 2001). These processing are not explained here.

3. Processing of satellite data

The study area was east part of China. There are about 129.4 million ha of cultivable land, which is 13.5 percent of the total area in China. The area of cultivated land in 1995 was 95,851 thousand ha (Source: FAO water reports 18). These cultivated lands consist of many cropping-pattern lands, which are one crop annually, two crops annually, double-cropping rice followed by winter wheat, and so on.

The time series 10-days composite data of the NOAA-AVHRR NDVI observed between 1997 and 1999 (total 108 images) were acquired from the satellite image database system (SIDaB) at the computer center for Agriculture, Forestry and Fisheries research. The LMF processing was executed using these data, and then the fitting parameters and time series NDVI were obtained as image files. Moreover, percent variances were calculated and images were created.

To obtain the statistics of NDVI, unsupervised classification (ISO-data method) was executed using the fitting parameter images . The classification result was categorized to the desert step, the typical step, the tree steppe, the north forest, the south forest, the desert, and other lands, referring to crop-calendars. Then, training area pixels for supervised classification were extracted from each category. The maximum likelihood method classification was executed by using these training area pixels, and then the agricultural map was created.

4. Result s and discussion

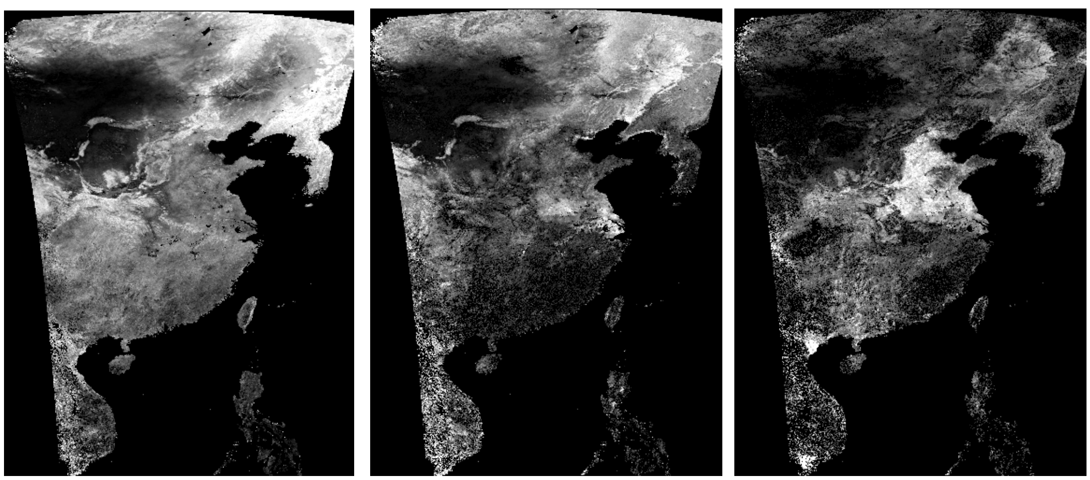
The graphs of timeseries NDVI of some crops were created from the classification results (Figure 3). These patterns of NDVI variances were almost same as the result reported by Saito (2002). That is to say, paddy field in South China, there was a high NDVI values from May to October. At winter wheat field in North China there are two peaks at May and August. First peak is made by winter wheat and the other is by corn and millet. Summer wheat field in Northeast China has only one NDVI peak in July because of the wheat and other summer crops.

Moreover, percent variances of amplitude were calculated. Jakubauskas showed the total percent variance as equation (3)

$$\text{Total variance} = \sum_{1 to n} \frac{(amplitude_j)^2}{2} \qquad (3)$$

Where j is each term in the series and n is the total number of terms. The percent variance for each term is computed by dividing the individual variance for each term by the total variance.

Unsupervised classification (ISO-data method) using percent variance images was executed for agricultural area using mask images. As a result, more detailed cropping-patterns were caught. It was suggested that two stages classification would be effective. The first step is the processing using fitting parameters and the second is using percent variance images.



(a) (b) (c)

Figure 1 Amplitude images created by LMF time series processing
(a)1^{st} term (1year cycle) amplitude, (b)2^{nd} term (half year) amplitude, (c) 3^{rd} term (4 months) amplitude

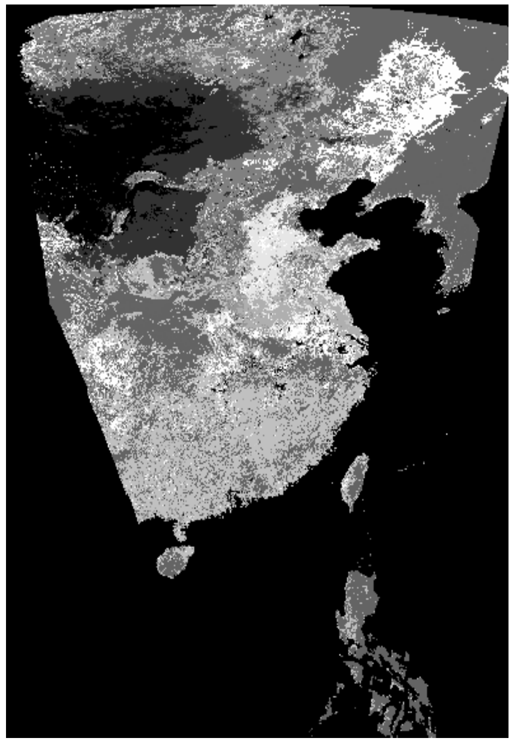
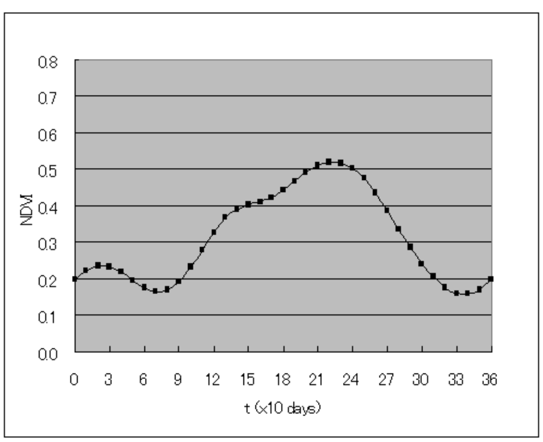


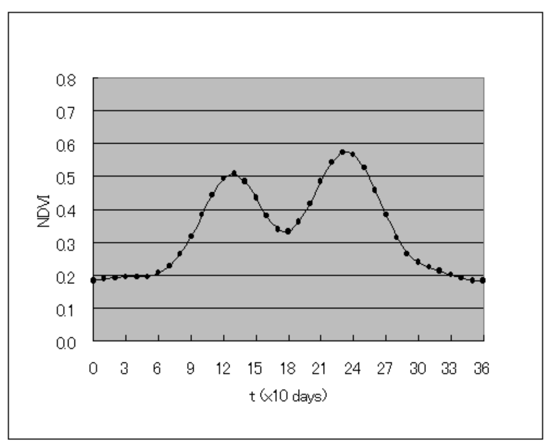
Figure 2 The clustering result image

Colors like white show agricultural lands. Black and dark gray show desert and steppe. Light gray shows forest.

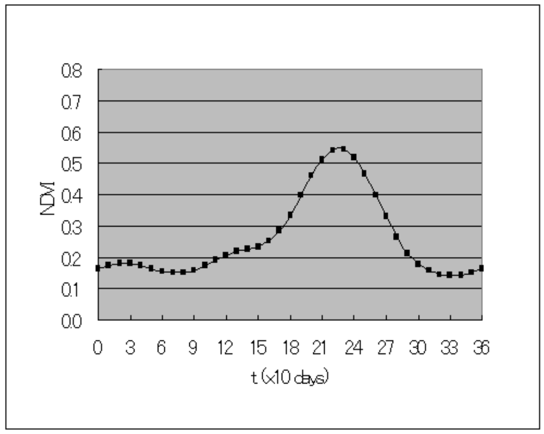
Agricultural lands can be categorized into three cropping-patterns such as one crop annually in northeast China, two crops annually in north China, and south China's double-crop rice.



(a) Winter wheat fields



(b) Summer wheat fields



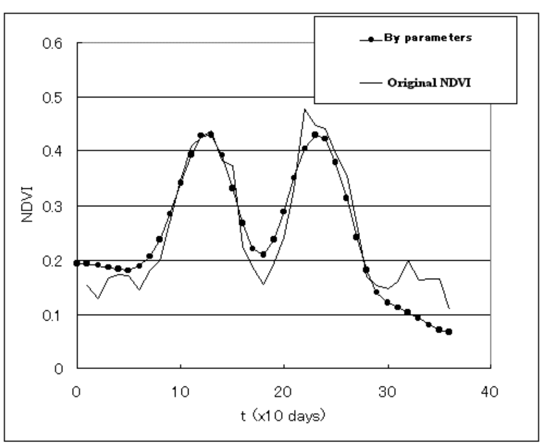
(c) Summer wheat fields

Figure 3 Profiles of NDVI mean values of typical clusters.

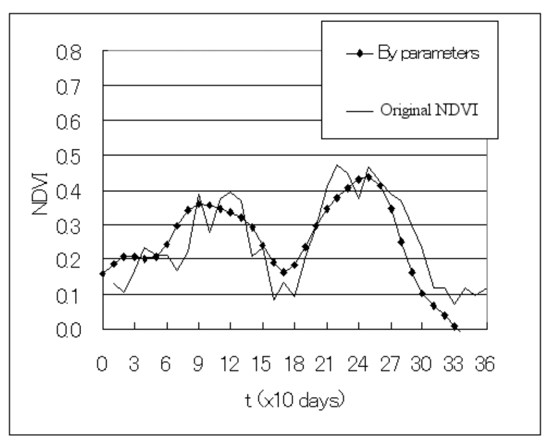
Categorized patterns are (a) paddy fields in South China, (b) winter wheat fields in North China, and (c) summer wheat fields in North China.

X-axis indicates time (t) with 10 days unit. Y-axis indicates NDVI values.

Paddy fields in South China, there was a high NDVI values from May to October (t are from12-30). At winter wheat fields in North China there are two peaks at May and August. First peak is made by winter wheat and the other is by corn and millet. Summer wheat field in Northeast China has only one NDVI peak in July because of the wheat and other summer crops.



(a)



(b)

Figure 4 Comparison of two NDVI profiles of two crops annually(a) and one crop rice(b).

The LMF parameters may create similar pattern NDVI profiles. Therefore, to use percent variance images is effective for detail classification.

5. Conclusion

We developed the methodology for creation of an agricultural map, and the agricultural map of east part of China was created. From this map, the distribution of each cropping-pattern can be understood, and our understanding of some typical farmlands (Saito 2002) can be extended to wide area of east China. We confirmed that the LMF processing is very effective in crop pattern identification. The methodology developed in this study, will be adopted to create the agricultural map of Asian region.

Acknowledgement

This study used the results of the research project on 'Research and Development for Applying Advanced Computational Science and Technology' supported by the Japan Science and Technology Corporation (ACT-JST).

References

Andres, L., W.A. Salas, and D. Skole, 1994. Fourier analysis of multi-temporal AVHRR data applied to a land cover classification. International Journal of Remote Sensing, 15 (5), pp.1115-1121.

Azzali, S., and M. Menenti, 2000. Mapping vegetation-soil-climate complexes in southern Africa using temporal Fourier analysis of NOAA-AVHRR NDVI data. International Journal of Remote Sensing, 21(5), pp.973-996.

Eastman, J.R., and M. Fulk, 1993. Long sequence time series evaluation using standardized principal components. Photogrammetric Engineering & Remote Sensing, 59 (8), pp.1307-1312.

Jakubauskas, M.E., D.R. Legates, and J.H. Kastens, 2001. Harmonic analysis of timeseries AVHRR NDVI data. Photogrammetric Engineering & Remote Sensing, 67 (4), pp.461-470.

Saito, G., N. Mino, Y. Li, and Y. Yasuda, 2002. Seasonal change of vegetation index obtained from NOAA/AVHRR data in China and Japan. In: Application of remote sensing technology for the management of agricultural resources, edited by S. Uchida, Y. Chen, G. Saito, China Agricultural Science and Technology Press, pp.107-114.

Sawada, H., Y. Sawada, I. Nagatani, and M. Anazawa, 2001. Proceeding for the 1st regional seminar on geo-informatics for Asian eco-system management.