Application of wavelet analysis to the multi-temporal MODIS data for detecting the rice phenology

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Abstract: We examined the spatial pattern of rice phenology in the Red River Delta (RRD) by using time-series MODIS data in 2003. We applied the Wavelet based Filter for determining Crop Phenology (WFCP) to assess the seasonal change of EVI data reflecting from the crop status. Time courses of smoothed EVI derived by WFCP showed two peaks on April-March and August-September, indicating that double rice cropping is mainly being performed in RRD. It was also shown that there are winter-spring rice cropping areas in eastern RRD (Hai Duong province, Hai Phong province and Thai Binh province) where cultivation period is about two weeks earlier than the other provinces. Furthermore, spatially heterogeneous distribution of heading dates for rainy season rice was detected by the spatio-temporal EVI. MODIS EVI with WFCP enable us to grasp the geographical characteristics of agricultural activity in RRD i.e. spatial pattern of rice cropping system, phenology and its recent changing trend with high accuracy.

Keywords: MODIS, Crop Phenology, Wavelet Analysis, Red River Delta.

1. Introduction

For evaluating impacts of climate change and variation on agricultural production, information on crop phenology and cropping system is of great significance to access the degree to which crops would suffer from environmental stress. To know the timing of seeding, transplanting and harvesting and the status of crop growth during cultivation period, it is quite valuable to do risk analysis and management in agriculture against environmental changes and hazards. The Red River Delta (RRD) in Vietnam is one of the most important rice-producing regions for not only domestic but international food supply/demand system. Several crop calendars of the specific area in the RRD have so far been reported, most of them are, however, summarized as monthly base and not updated. Furthermore, little is known about the spatial pattern on regional scale. In this study, in order to know the current status on rice cropping system and its phenology pattern in the RRD and discuss the geographical characteristics, we applied our new method termed Wavelet based Filter for determining Crop Phenology (WFCP: Sakamoto et al., 2005) to multi-temporal MODIS data.

2. Material & Method

2.1. Test site

The objective area in this study is the Red River Delta (RRD) located on the northern Vietnam (Fig. 1). The red river originates from the Yunnan province in China into the South China Sea through the northern Vietnam. The length and drainage area of the Red River are approximately 1200 km and 160,000 km^2 ,respectively. The RRD in vast alluvial plain with total area of 12,600 km^2 and altitude ranging from 0.3m to 10m above sea level. According to the Koeppen classification, the climate of the RRD is classified into temperate summer rainy climate type. Seasonal changes in precipitation caused by the monsoon divides the year into well-defined dry and wet seasons, with monthly mean

temperature of 30 °C in June at highest and 16.9°C in January at lowest (General Statistics Office 2003). The water depth and water flow rate of the Red River measured at Ha Noi station in 2003 reached, 917cm and 8160m^3/s, in the rainy season and reached its shallowest, 234cm and 710m^3/s in the dry season. The reduction in discharge and rainfall in the dry seasons often caused the summer drought to the rice production. Due to a lot of clear-sky days, there are a lot of chances to observe the grand surface with the optical sensor on the satellite platform in the dry seasons.

2.2. Rice cropping

In general, double rice cropping is performed widely in the RRD; winter-spring rice is grown in dry season and rainy-season rice. The sowing period of the winter-spring rice ranges from December to February, the heading occurs from April to May and the harvesting is done from May to June. The sowing season of the rainy-season paddy is from June to July, the heading season is August to September and the harvest season is from September to October (Yanagisawa et al., 1999, USDA, 1994). According to statistics of the RRD including 11 provinces (General Statistics Office 2003), the total area of the agricultural land was estimated approximately 855,000 ha in 2002, and the total rice planted area was approximately 1200,000 ha in 2003. The production of the winter-spring rice and rainy-season rice were 3.6 Mt and 3.2 Mt respectively with yields of 6.0 t/ha, 5.3 t/ha in 2003. The yearly water-flow change of the Red River often influenced the rice production in the RRD. The brunt of typhoons in the flood season causes the flood damage in the RRD and the young seeding during the planting season are damaged by the inundation. In the dry year, the yield of the drought-affected paddy tends to be decreased (Haruyama, 2004) due to the shortage of irrigation water.

2.3. Satellite Data & WFCP

The MODIS/Terra launched by NASA in 1999 observes the earth surface everyday with the wide swath. The MODIS data were distributed through the EOS data gateway (EOS, 2005). The product data used in this study were "MODIS/TERRA SURFACE REFLECTANCE 8-DAY L3 GLOBAL 500M SIN GRID V004 ", which contains the surface reflectance data at ground level, view angle data and the date of acquisition for every pixel. We adopted Enhanced Vegetation Index (EVI) for representing the crop growth status. The characteristics of EVI were the high sensitivity in high biomass and the robustness against atmosphere influences (Huete 2002). Thus it is considered that EVI is more effective than NDVI in the high humidity are such as the RRD especially in the rainy seasons.

In this study, we applied the Wavelet based Filter for determining Crop Phenology (WFCP) to the time-sereis MODIS EVI data (Sakamoto et al, 2005) for evaluating the spatial pattern of rice phenology in the RRD. WFCP is composed of three procedures; (1) prescription of the MODIS data, (2) filtering the temporal EVI data by the discrete wavelet transform and inverse transform and (3) detecting the maximal points from the smoothed EVI data. As can be seen in the results of the previous study (Sakamoto et al, 2005), WFCP could detect the heading date with high accuracy (RMSE 9.0days) in Japanese paddy fields.

3. Results & Discussion

3.1. Seasonal changes of the smoothed EVI data.

Figure 2 shows the smoothed EVI data with the original EVI data on the 4 test sites (Fig. 1). Two characteristic maximal points appear in Fig. 2 B, C and D. These two peaks in the smoothed EVI profile would reflect the double cropping system, which includes the winter-spring rice and rainy-season rice. It was found that the first peak appeared from April to May, and the second peak appeared from August to September, which are consistent with the normal crop calendar in the northern Vietnam (USDA, 1994). The smoothed EVI profile in Fig. 2A also showed the third peak in November beside the first and second peaks. This third peak suggests that the triple cropping system is practiced in the test site A. However this third cropping is not rice, because the corresponding period is in winter so that rice cultivation is not appropriate due to low temperature for rice growth. According to the report by Yanagisawa et al, 2003, the cropping pattern in his research area changed from double cropping of rice in 1985 to double cropping of rice and an upland crop in the winter season 1996. Therefore, should note that actual cropping in this season include vegetables.

3.2. Spatial pattern of the rice phenology in the RRD.

Fig. 3 shows the spatial pattern of the smoothed EVI data on the first of each month in 2003. We can see the difference in the seasonal vegetation pattern of the delta area for agricultural use and the surrounding natural vegetation. In the delta area, the EVI values from December to March and from June to July are lower than that in the surrounding areas. These months are almost the same time as the rice planting seasons. Accordingly the lower EVI values during these periods seem to reflect the water surface during rice planting season or bare soil after plowing. We can also see from the spatial pattern of the smoothed EVI data in March (Fig. 3) that the EVI value in March around the three provinces (Hai Duong province, Hai Phong province and Thai Binh province) located on the down stream site (Fig 2 C and D) was higher than

those in the other provinces (Fig. 2 A and B). This suggests that the planting season of the winter-spring rice around the three provinces was approximately two weeks earlier than those in the other provinces in 2003. And the estimated heading date of the rainy-season rice was different among areas. (Fig.2)

4. Conclusions

In this study, we examined the spatial pattern of the crop phenology and cropping systems in the RRD by applying WFCP method to the time-series MODIS data in 2003. The spatial pattern of the smoothed EVI data showed the regional characteristics of the crop phenology and cropping systems as well. In addition, it was suggested that the earlier planting of the winter-spring rice was conducted in the three provinces. The beginning of the winter-spring rice in these provinces was estimated to be approximately two weeks earlier than those in the other areas, although it has not confirmed by ground data yet. We are planning to validate this estimated result against the field surveys and literatures.

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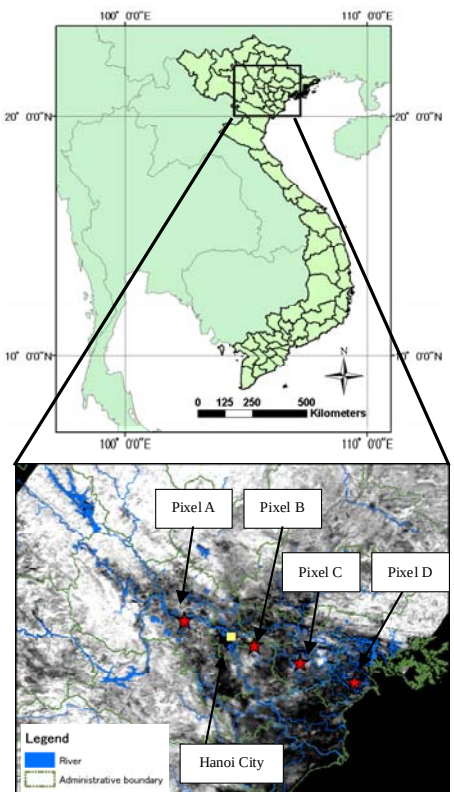

Fig 1. Objective area in the Red River Delta.

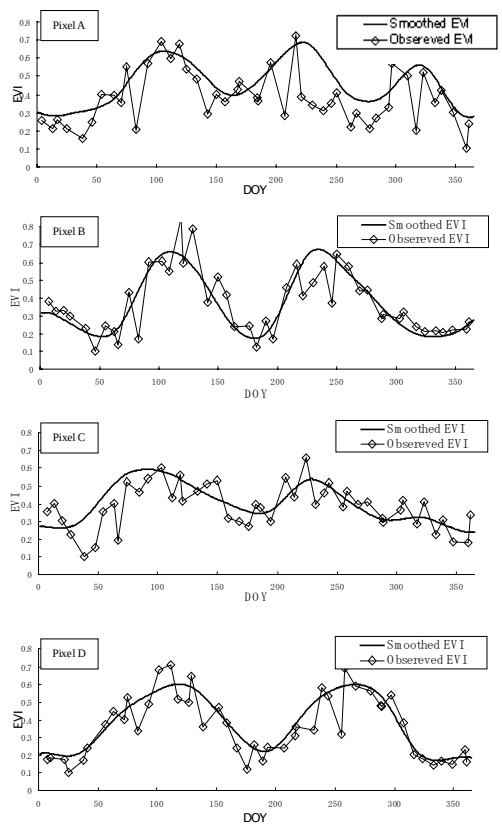

Fig 2. The smoothed time profile of EVI

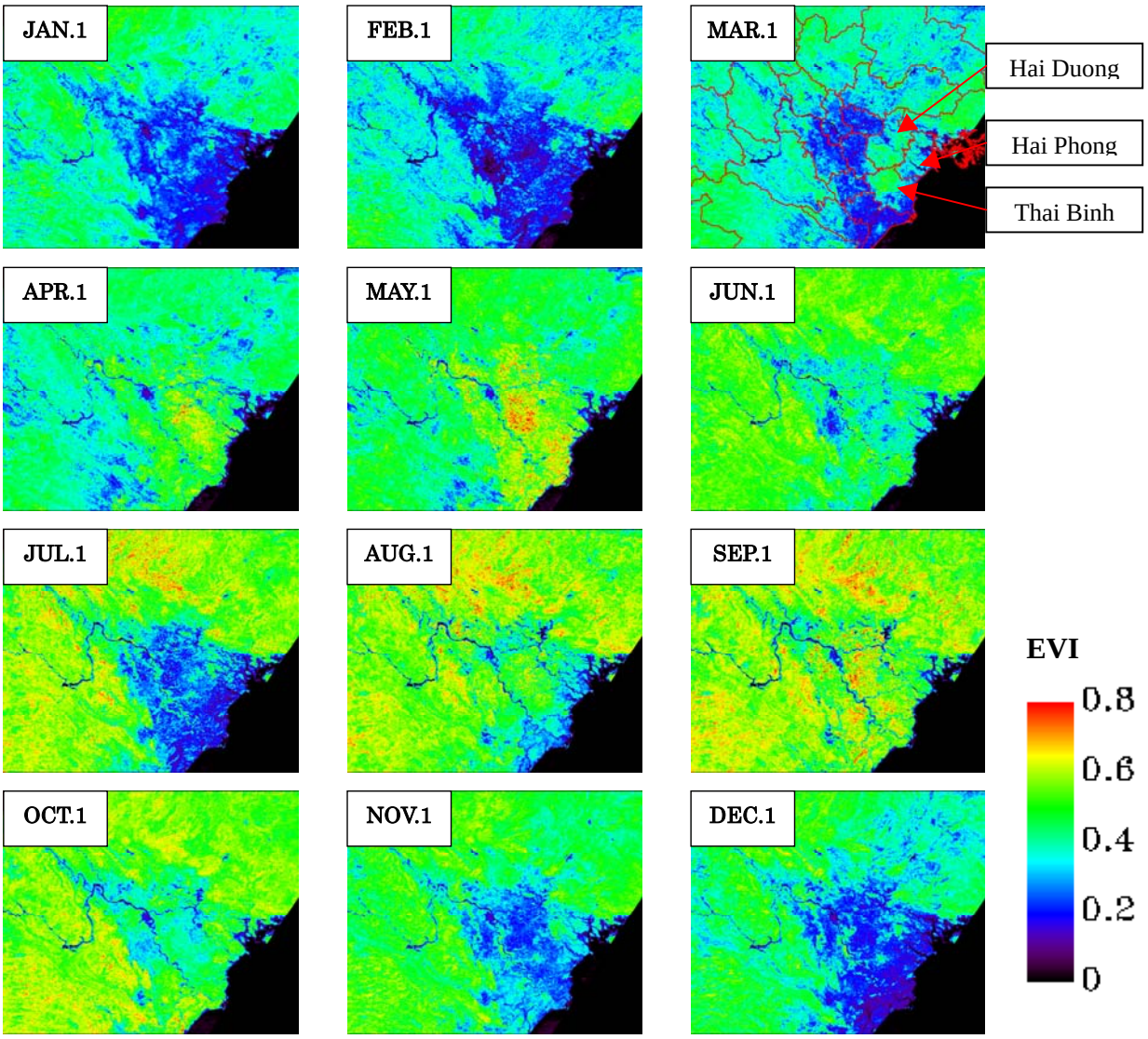

Fig 3. Spatial distribution of the smoothed EVI on the first of the month in 2003.