Detecting cropping pattern change using time-series satellite images in Vietnam: the Mekong Delta

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ABSTRACT

We examined the cropping pattern change in the Vietnamese Mekong Delta using multi temporal MODIS data. The type of cropping patterns is identified from the wave profile of the time-series Enhanced Vegetation Index (EVI) data. The spatial distribution of cropping pattern is revealed based on the combination of the number of the local maximal value and its time of appearance in the temporal EVI data, which were smoothed by the wavelet transformation technique. As a result of comparison between the estimated cropping patterns in 2002 and 2003. We could newly detect the region where the cropping pattern was changed from double cropping system to triple cropping system. The discriminative cropping pattern change is determined especially in the southern part of An Giang Province and the eastern part of Soc Trang Province. And it was suggested that the harvesting in the early period of flood season was newly conducted on the former region, and that the area cultivated in the dry season was expanded around the latter region.

1. INTRODUCTION

Vietnam is the second largest exporter of rice in the world (FAOSTAT, 2003). The most of exported rice is produced in the Mekong Delta (Nguyen et al., 2004). The high productivity of the Mekong Delta is a consequence of the Mekong and Bassac rivers supplying abundant water resources and fertile sediments. The water flowed from both rivers is, as it were, the lifeblood of rice production in the Mekong Delta. On the other, it was reported that the distribution and intensity of precipitation would change in response to the global warming (IPCC Working Group I, 2001). We therefore set about to assess the impact of water resource changes in the Mekong and Bassac rivers on rice productivity in the near future. As the preliminary step toward this goal, we tried to reveal the overview of the agricultural activity and its relationship with the seasonal water flow regimes in the Mekong Delta by using Remote Sensing Techniques.

2 Data & Methods

2.1 Satellite Data

The temporal MODIS images are used to observe the temporal crop growth in the Vietnamese Mekong Delta (VMD). MODIS measures the land surface in 36 spectral bands with the 2300-killemeter wide-swath. And the recurrent period of the platform (Terra) is 16 days. The MODIS product used in this study were the 8-days composite data covering the Cambodia and VMD in 2002 and 2003 (Fig. 1). The MODIS products are distributed from NASA Earth Observation System data gateway and the downloaded products here are

"MODIS/TERRA SURFACE REFLECTANCE 8-DAYS L3 GLOBAL 500M SIN GRID V004". The product represents the surface reflectance with the minimum cloud coverage over every 8 days. It had already been systematically calibrated for the atmospheric effects. It contains 13 layers as shown in Table 1 with the Integerized Sinusoidal (ISIN) projection. The map projection was converted to UTM projection in the preprocessing scheme.

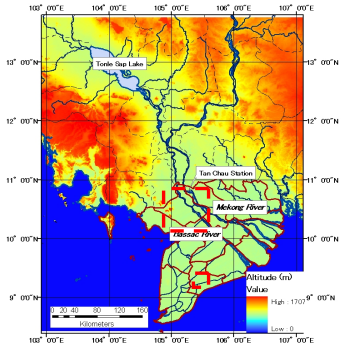

Figure 1. Location of research area

Table 1. The list of image layers included in "MODIS/TERRA SURFACE REFLECTANCE 8-DAYS L3 GLOBAL 500M SIN GRID V004"

Type	Layer Name	Description	[Bandwidth]
Surface Reflectance	sur_refl_b01	Red	[620-670nm]
	sur_refl_b02	Near infrared	[841-876nm]
	sur_refl_b03	Blue	[459-479nm]
	sur_refl_b04	Green	[545-565nm]
	sur_refl_b05	Near infrared	[1230-1250nm]
	sur_refl_b06	Short wave infrared	[1628-1652nm]
	sur_refl_b07	Short wave infrared	[2105-2155nm]
Angle	sur_refl_szen	Solar zenith angle	
	sur_refl_vzen	View zenith angle	
	sur_refl_raz	Relative azimuth angle	
Data Quality	sur_refl_qc_500m	Quality assurance (QA) data	
	sur_refl_state_500m	State QA data	
Date	sur_refl_day_of_year	Observational day (Day of year)	

2.2 Wavelet based Filter for determining Crop Phenolgoy (WFCP)

In our previous study (Sakamoto, 2005), we developed the new method for detecting the crop phenology using the temporal MODIS data, which named as Wavelet based Filter for determining Crop Phenology (WFCP). The WFCP contains the three procedures as described following.

(1) The available pixels used for the time-series analysis are selected by the band 3 reflectance data or the view angle data (Applying the WFCP in the VMD, we used only the band 3 reflectance for prescreening the input pixels. When the band 3 reflectance is more than 0.2, the same pixel is treated as the unavailable data affected by the thick clouds). And the Enhanced Vegetation Indexes (EVI) are calculated on every these prescreened pixels as the following equation.

$$\mathrm{EVI} = \frac{2.5 \times (\rho_{NIR} - \rho_{RED})}{1 + \rho_{NIR} + 6.0 \times \rho_{RED} - 7.5 \times \rho_{BLUE}} \quad (1)$$

where ρ_{NIR} is the reflectance on the near infrared (sur_refl_b02), ρ_{RED} is the reflectance on the red (sur_refl_b01). ρ_{BLUE} is the reflectance on the blue (sur_refl_b03). The observed EVI data

are rearranged in order of the observational date. And the missing values between the available EVI data are filled by the linear interpolation method.

(2) The discrete wavelet transform and inverse transform are adopted for filtering out noise component from the observed EVI profile. The types of mother wavelet applied here was Coiflet (order = 4). After eliminating the high frequency component with time cycles less than 32 days, the smoothed EVI profile is recomposed by the inverse wavelet transform.

(3) The local maximal points (EVI ≥ 0.4) in the smoothed EVI profile are detected as the heading date in paddy fields. In the case of Japanese paddy fields in 2002, the accuracy of estimating heading date was 9.0 days (RMSE) when comparing with the statistical data in 30 test sites.

2.3 Wavelet Based Filter for evaluating the spatial distribution of Cropping Systems (WFCS)

We newly developed the WFCS in succession to the WFCP for revealing the spatio-temporal characteristics of the cropping patterns (e.g. the triple cropping system, the double cropping system in rainy season, the double cropping system in dry season and the single cropping system in the certain season) and the annual cropping-pattern change in the VMD. The principal criterion for classifying cropping pattern is combination of the number of estimated heading dates and the season of these appearance. The specific definitions of the major cropping systems are described as following. If the double maximal points are detected from January to June in the smoothed EVI profile, these pixels are defined as the double cropping system in dry season (Figs. 2A1 and 3A1). If the double maximal points are detected from July to December, these pixels are defined as the double cropping system in rainy season (Figs. 2B1 and 3B1). If the triple maximal points are detected in the space of a year, these pixels are defined as the triple cropping system (Figs. 2A2, 2B2, 3A2 and 3B2).

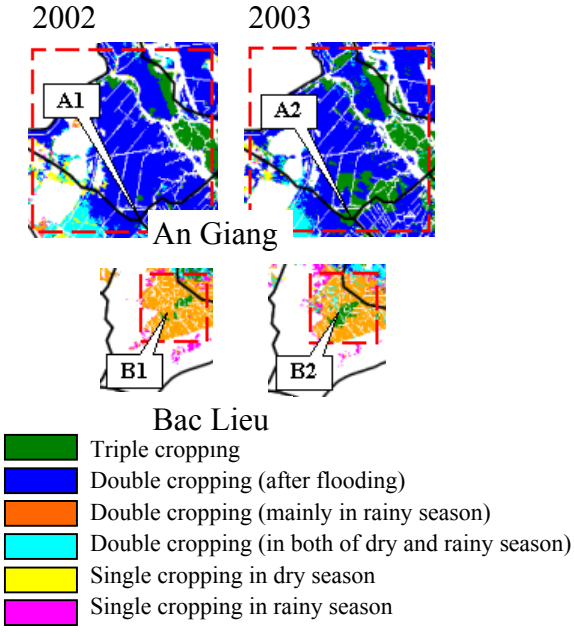

Figure 2. Estimated cropping system in An Giang and Bac Lieu Provinces. These Locations are shown in Fig. 1

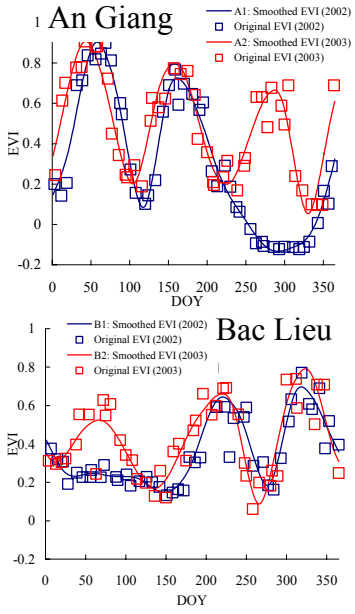

Figure 3. Temporal EVI data for areas in which the cropping system changed from double in 2002 to triple in 2003. Both locations are same as directed in Fig. 2

3.1 Seasonal changes of the smoothed EVI data

As in Figures 3A1 and B1, we considered that the smoothed EVI profile on the agricultural land represented the characteristics of the regional cropping systems very well. It is obvious that there are two maximal points in the smoothed EVI profile (in year 2002) of the two pointed pixels. These two peaks would represent the characteristic profile of the double cropping system. Besides the number of crops per year, there were differences in the cropping seasons (the estimated heading date). In Figure 3A1, the two maximal points appeared in March and June. Considering that the both of EVI peaks reflect the rice growing, the first peak would represent the winter-spring rice and the second peak would represent the summer-autumn rice. In a similar explanation about the smoothed EVI profile in Figure 3B1, the first peak in August would represent the summer-autumn rice and the second peak in November would represent the rainy-season rice.

3.2 Spatial pattern of the cropping systems in the VMD

Figure 4 shows the spatial pattern of the smoothed EVI data on March, April, September and December in 2002 and 2003 and the MODIS false color images around the same time. The spatial EVI images and MODIS false color images on March and April show the sharp contrast between the Cambodian (the upper half of the Figs. 4EVI02_Mar and 4EVI02_Apr) and Vietnamese territories (the lower half). Because of the high vegetation indexes, the dry-season crops were widely cultivated in the VMD. While on the other hand, there was out of crops on the flat plain in Cambodia during the same period, except for the riverside area. This would mean that the paddy fields on the upper region of the VMD are well irrigated due to the huge network of canals. When it comes to the agricultural land in Cambodia, it seems to be difficult to cultivate the dry-season crops probably due to the undeveloped irrigation system. And this finding about the difference of the dry-season cropped area between the Cambodia and VMD evidently suggests the potential problem described as following. If the Cambodian government develops the irrigation system and expands the dry-season cropped area for feeding the increasing Cambodian population in the future, the dry-season river water flowing into the VMD through the Mekong and Bassac rivers may be decreased. Shortages of the dry-season river water in the VMD effect on the dry-season cropping due to the lack of the irrigation water and expand the salinity-intrusion affected area along the coastal region.

3.3 Cropping-pattern change in the VMD from 2002 to 2003

The spatial distributions of cropping pattern in the VMD of years 2002 and 2003 were well detected by the WFCS. The spatial configuration of the cropping pattern in the VMD is in close relationship with the geographic location. The double cropping system in dry season is distributed mainly on the upper region. Because the annul flood of the Mekong and Bassac rivers hamper the rainy-season cropping in this region. As for the coastal region, the main cropping pattern is classified as the double cropping system in rainy season. It's highly likely that the salinity intrusion due to the decreased water flow in the dry season make the farmers to give up the dry-season cropping in the coastal area. And the triple cropping system is mainly distributed on the intermediate region between the former and later regions. This geographical advantage is the least impact of both of the water-related environmental fluctuation (the flooding in rainy season and the salinity intrusion in dry season).

From a macroscopic viewpoint, the cropping pattern would be closely related with the geographical locations as above. However it was identified that there were the fields where the number of crops per year was increased from two to three in the coastal or upper regions.

In the southern part of An Giang province, double-cropped area on the dry season in 2002 (Fig. 2A1) changed to triple-cropped area in 2003 (Fig. 2A2) on the huge scale. The third crop from September to November was newly cultivated there in 2003. The smoothed EVI images during the flood season in 2002 and 2003(Figs. 4EVI02_Sep and 4EVI03_Sep) also show this change as following. The EVI value of the pixel A1 during the flood season in 2002 was quite low, which means that the area was under flooded water. However the EVI value of the pixel A2 in 2003 suggests that the rainy-season paddy was newly grown during the same period. One possible reason for this change is that it became possible to harvest in the early flood season by the dikes enclosing the fields since 2003. On the other, double-cropped area on the rainy season in 2002 changed to triple-cropped area in 2003 near the costal region (Figs. 2B1 and 2B2). The smoothed EVI values during the dry season in 2003 were relatively higher than that in 2002 (Figs. 4EVI02_Mar and 4EVI03_Mar). This would suggest that the dry-season cropped area was expanding from 2002 to 2003 probably by implementing counter measures against salinity intrusion or acid sulfate soil.

4 Conclusion

We developed WFCS by improving WFCP in order to evaluate the spatial distribution of cropping patterns in the VMD and these change between in year 2002 and 2003. Overall, the types of cropping patterns would be closely related with the geographic location and the seasonal water regime. The major cropping system on the upper region was the double cropping system in the dry season. That on the coastal region was the double cropping system in the rainy season. And that on the middle region was the triple cropping system. Though the fields were located on the coastal region or upper region, some fields were changed from double cropped area to triple cropped area from 2002 to 2003. And there cropping pattern changes were prominently detected on the southern An Giang Province, the Soc Trang and Bac Lieu Provinces.

5 Acknowledgement

Some figures and results presented in this paper are quoted from our previous study. And it is possible to download the electronic document (Sakamoto et al. 2006) from URL described in following references.

6 References

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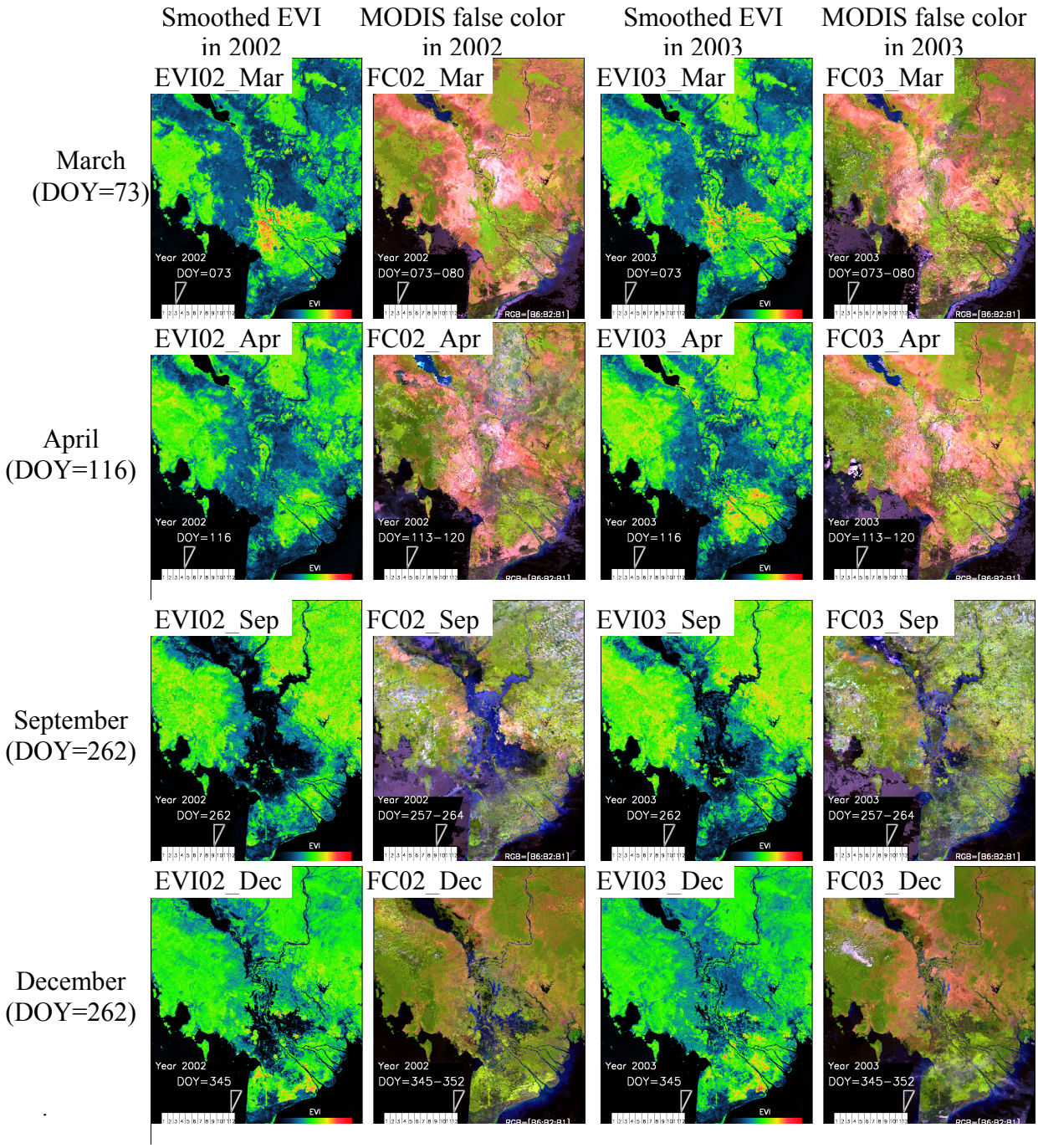

Figure 4. Smoothed EVI images and MODIS false color images in 2002 and 2003.