Detecting spatial pattern of rice cropping schedules using time-series satellite images in the Red River Delta, Vietnam

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ABSTRACT

To describe a map of rice cropping schedules in the Red River Delta, Vietnam (RRD), we examined the spatial pattern of rice phenology in the 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 the crop status. The results of the rice phenology clarified by WFCP were summarized by district level to present the cropping schedule maps in the RRD. We could find the diverse distributions of cropping schedules in the RRD from the maps. For instance, it was detected that the winter-spring season rice in the eastern regions (Hai Duong, Hai Phong and Thai Binh) was cultivated earlier than the other regions. Although most recent winter-spring season rice tends to be started on late schedule since the introduction of short-duration rice varieties and the expansion of the off-season crop, it was recognized that the area still keeping a traditional cropping schedule was not small.

1 INTRODUCTION

Geographical distribution of rice cropping schedules is indispensable information for evaluating a regional rice productivity and developing a comprehensive cultivation management. The effects of the environmental resources and stress on the rice growing are strongly related with its growth stages, e.g., seeding, tillering, heading and maturity stages.

Rice production in the Red River Delta, Vietnam (RRD) had increased approximately 1.6 times during the 1990 decade (VGSO, 2000), owing to the introduction of new high-yielding varieties, increase of fertilizer application and technical improvement associated with the introduction of the high-yielding varieties. Rice cultivations system in this region mainly consists of double cropping, i.e., the winter-spring rice (transplanting in December to February and harvest in June) and the rainy season rice (transplanting in July and harvest in September to October). While it is known that rice cropping durations in both seasons tends to be shortened in recently because of the introduction of the short-duration varieties and the expansion of the off-season crop, it is said that there are regions still keeping a traditional cropping schedule. Although these regional differences are very interesting as the regional characteristics of the RRD, there is a lot of fragmentary information but little comprehensive study so far.

To reveal the geographical distribution of rice cropping schedules in the RRD, we analyzed the seasonal change of EVI data reflecting from the crop status by using the time-series MODIS data in 2003. And to present more intelligible information, we summarized the results clarified by WFCP into the GIS map with district level.

2 MATERIALS AND METHODS

2.1 Study area

The RRD covers an area of 17,321 km^2 in the north part of Vietnam (Fig. 1). The area extends in 20° 00’ - 21° 20’ N and 105° 50’ - 106° 50’ E. The RRD is comprised of several large polders that had been developed over a long period of time as a measure for the prevention of seasonal flooding. Recently, the polders were fully obtained modern irrigation and drainage system that makes the double rice cropping a year possible.

Rice planted area in 11 provinces of the RRD in the winter-spring and the rainy season rice in 2003 were approximately 590 thousands ha and 460 thousands ha, respectively (VGSO2004). The production of the winter-spring rice and the rainy-season rice were 3.6 mega tons and 3.2 mega tons, respectively with yields of 6.0 t/ha, 5.3 t/ha in 2003.

The climate of the RRD is sub-tropical monsoon, influenced by the ocean climate. According to Köeppen's classification, this area has a Cw climate, which is defined as warm temperate rainy (C), with a dry season in winter (w). The geographical temperature distribution in the RRD is approximately uniform but the temperature in the dry season at southwest and coastal areas are slightly higher than northeast area (Cuong, 1968). The average temperatures during the period of dry and rainy seasons were 19.4 and 27.7 °C, respectively. Temperature decreases gradually from August. The daily mean temperatures drop below 20 °C from the end of November. If the rice in the rainy season crop could not harvest by this time, yields are damaged by poor ripening due to the cool temperature. The coldest period is during the period from the end of January to the beginning of March with 15.1 °C on average. The average of the minimum air temperature in this period is 13.8 °C. This cold weather often damaged rice plants as the low temperature injuries of the seedlings in the winter-spring crop.

2.2 Satellite data and WFCP

The satellite data used in this study were "MODIS/TERRA SURFACE REFLECTANCE 8-DAY L3 GLOBAL 500M SIN GRID V004 ". 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.

To evaluate the spatial pattern of rice phenology in the RRD, we applied the Wavelet based Filter for determining Crop Phenology (WFCP) to the time-series MODIS EVI data (Sakamoto et al, 2005 a, b). 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, 2005a), WFCP could detect the heading date with high accuracy (RMSE 9.0days) in paddy fields in Japan.

2.3 Cropping classification

To clarify characteristics of the geographical distribution of rice cropping schedules in the RRD, we abstract the starting time and finish time of the rice cropping in 2003, i.e. transplanting time in the winter-spring crop and harvesting time in the rainy season crop, from the seasonal changes of smoothed EVI data analyzed by WFCP. As an indicator of the

rice transplanting time in the winter-spring crop, we used 10 days averaged smoothed EVI data from 60 to 69 DOY 2003. By the begging of March (60-69DOY), transplanting would have been finished in most of paddy field in the RRD. As an indicator of the rice harvesting time in the rainy season crop, we used DOY at the maximal point of the smoothed EVI data from August to November. Although the maximal point of the smoothed EVI data would represent the rice plant status as the heading stage, the harvesting date could be expected from the heading time irrespective of seasons and varieties as approximately thirty five days after heading date.

The pixel data of these two indices were counted and averaged by every 65 districts excluding the districts which have little paddy area. Cropping schedules of the winter-spring and the rainy season crop were classified into three categories according to following traditional categories in the RRD:

For the winter-spring rice;

1. Early (*Xuân Sớm,* Transplanting from the end of Jan. to the beginning of Feb.)
2. Middle (*Xuân Trung,* Transplanting from the beginning to the middle of Feb.)
3. Late (*Xuân Muộn,* Transplanting from the middle to the end of Feb.)

For the rainy season rice;

1. Early (*Mùa Sớm*, harvesting from the end of Sep. to the beginning of the Oct.)
2. Middle (*Mùa Trung*, harvesting from the beginning to the middle of the Oct.)
3. Late (*Mùa Muộn*, harvesting from the end of Oct. to the middle of Dec.)

Cluster analysis with ward's method were applied with 10 days averaged smoothed EVI data from 60 to 69 DOY and DOY at the maximal point of the smoothed EVI data to classified four categories as follows;

1. Late winter-spring and Early rainy season rice (Land occupation by rice is short)
2. Late winter-spring and Late rainy season rice
3. Early winter-spring and Early rainy season rice
4. Early winter-spring and Late rainy season rice (Land occupation by rice is long)

3 RESULTS AND DISCUSSIONS

3.1 Seasonal and spatial pattern changes of the smoothed EVI data

Figure 2 shows the smoothed EVI data with the original EVI data on the four 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 the rainy-season rice. 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.

The test site C with higher smoothed EVI values at the begging of February (60-69 DOY) indicates that the transplanting schedule in the the winter-spring rice in this point was earlier than those in the test sites with lower EVI values (Red line in Fig 2).The test site D with later DOY at the second maximal point of the smoothed EVI value indicates that the heading and harvesting schedule in the rainy season rice in this point was later than those in the test sites with earlier DOY at the second maximal point of the smoothed EVI value (Blue line in Fig.2).

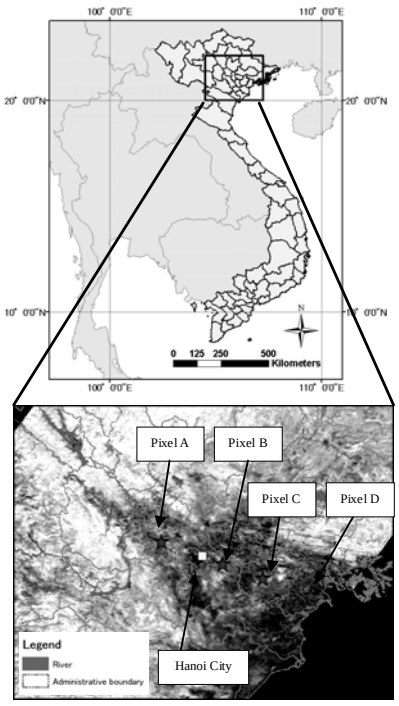

Fig.1 Study area of the Red River Delta

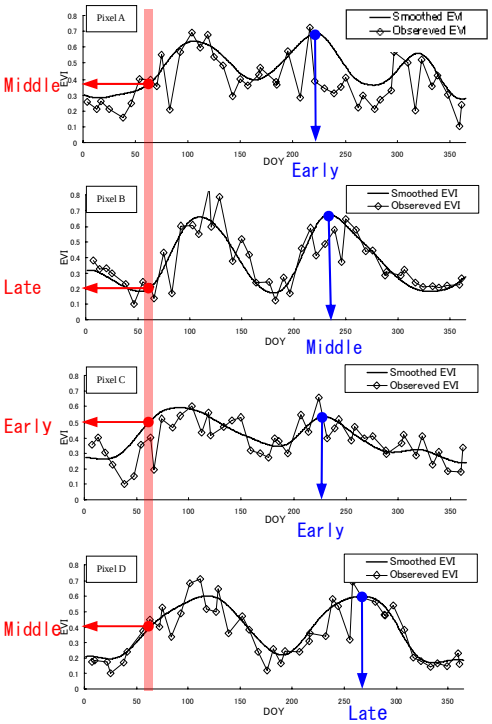

Fig.2 Smoothed time profile of EVI and indicators of cropping schedule in the winter-spring crop (red) and the rainy season crop (blue)

3.3 Rice cropping schedule map

3.3.1 *The winter-spring rice*

Figure 4 shows the map of 10 days averaged smoothed EVI data from 60 to 69 DOY in 2003 with summarized by each district area. According to our classification, the ratio of the districts with early, middle and late transplanting schedule in the winter-spring season were 12%, 25% and 43%, respectively. It was recognized that the area still keeping the early cropping schedule was not small. We could find the districts with early transplanting schedule in the winter-spring season in HaiDuong province, HaiPhong province and ThaiBinh province. Growth durations of the winter-spring rice are greatly changed depending on the sowing date because of large fluctuation of temperature in this season. The earlier the sowing date, the longer growth duration. Therefore, the harvest time, consequently, was not so different by any sowing date in the winter-spring crop (Jul. 1 in Fig. 3)

3.3.2 *The rainy season rice*

Figure 5 shows the map of the date with maximum smoothed EVI value in the period from August to September in the 2003 with summarized by each district area. According to our classification, the ratio of the districts with early, middle and late harvesting schedule in the rainy season rice were 23%, 39% and 38%, respectively. The districts with early harvesting schedule in the rainy season were found in HaTay provence, south part of VinPhuc proveince, west part of HaiDuong province and north part of ThaiBinh province. And the districts with late harvesting were found in the costal area of the RRD. In the costal area, it is famous for the production of the special rice such as *Bac Thom* and *Tam.* Since these rice varieties have long growth duration and photosensitivity, harvesting schedule in the costal area might have been delayed behind the other districts.

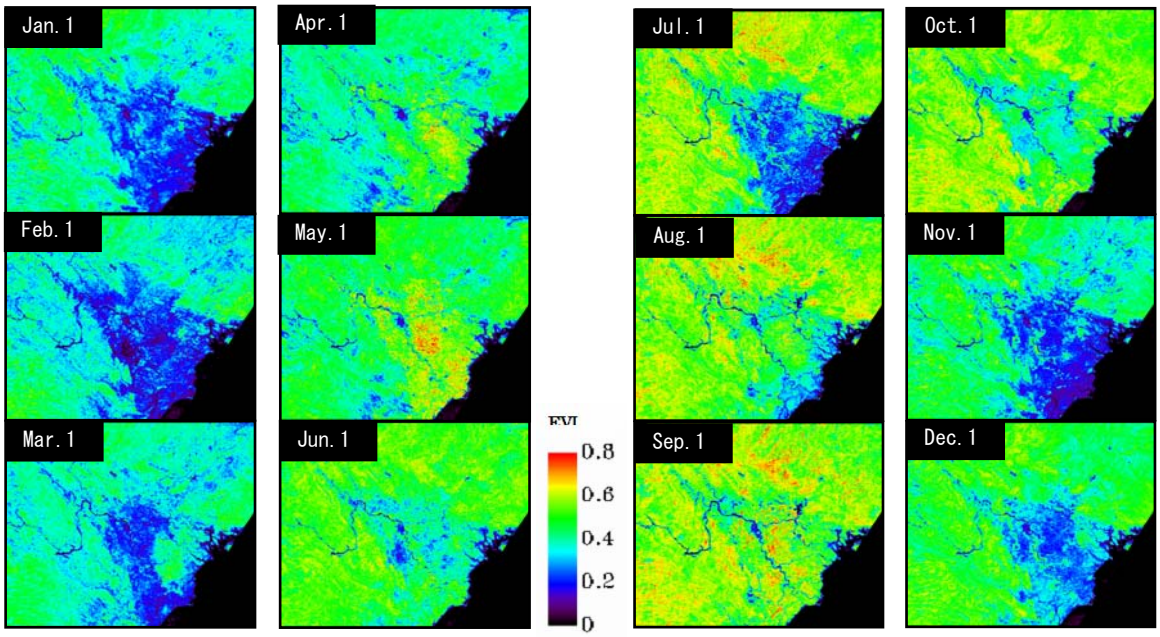

Fig. 3. Spatial pattern of the smoothed EVI data on the first of each month in 2003 (from Sakamoto et. al. 2005)

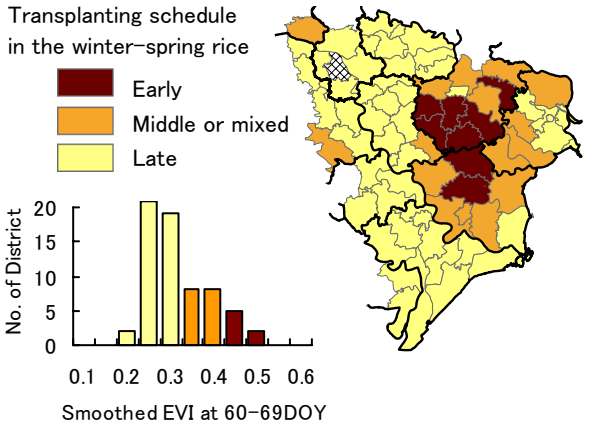

Fig. 4 Map of transplanting schedules in the winter-spring rice 2003

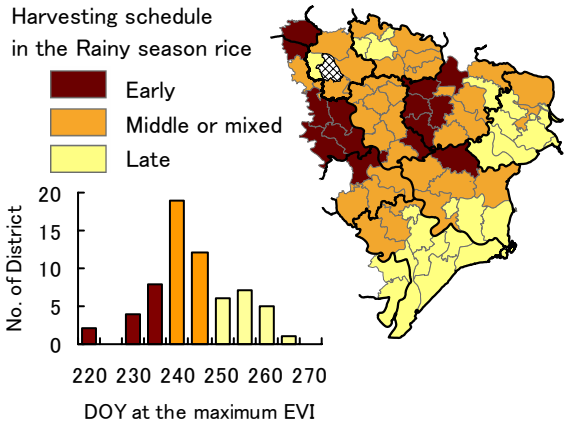

Fig. 5 Map of harvesting schedules in rainy season rice 2003

3.3.3 *Cropping combination*

The correlation between the distribution of the transplanting schedule in the winter-spring season rice in Fig.4 and the harvesting schedule in the rainy season rice in Fig. 5 was not recognized clearly. In other word, the cropping combination that begin to be early and ends early do not necessarily consist in the RRD.

Figure 6 shows the cropping combination of the winter-spring and the rainy season rice in 2003 in the RRD. Four classifications distributed not fragmentally but clearly partitioned the RRD. The classification “Late-Early” distributed in west part of the RRD, HaNoi, HaTay, BacNinh, HungYen, HaNam, and north part of NamDinh provinces. In this cropping combination, land occupation by rice is shortest. On the other hand, the classification “Early-Late” which occupies the land for rice cropping long is distributed in the east part down stream of the RRD, HaiPhong and south part of ThaiBinh province.

After the rice harvest, vegetables, legume, potato or maize are cultivated as winter crops which are extensively done since the introduction of rice varieties with early maturity. The differences of duration between “Late-Early” “Early-Late” would be 2-3 months. This time margin would be very relevant for cultivating the off-season crop well.

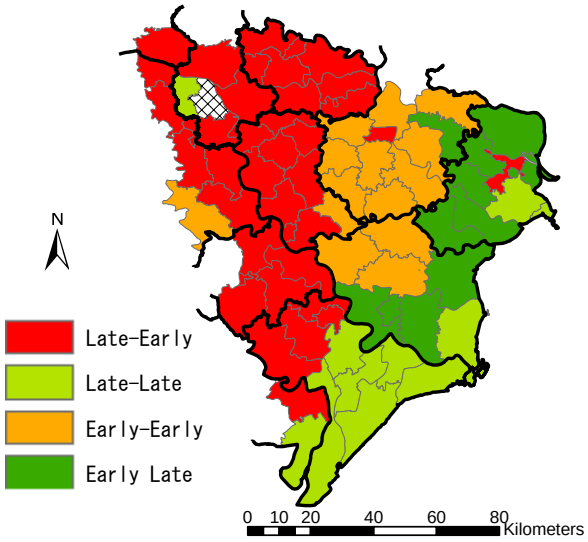

Fig. 6. Map of rice cropping combination in 2003 in the RRD

4 CONCLUSIONS

In this paper, rice cropping schedule maps of the RRD were presented by applying WFCP method to the time-series MODIS data in 2003. These maps would be strong help for us to understand the rice cultivation in the RRD. Although it was said that most recent rice cropping system tends to be started on late and finished early i.e., short cropping duration, since the introduction of short-duration rice varieties and the expansion of the off-season crop, it was recognized from this study that the area still keeping a traditional cropping schedule i.e., longer rice cropping duration was not small. These results encourage us to further study how distribution of these cropping schedules was decided. To clarify a decision factor of cropping schedules, interdisciplinary approach from the study of the environmental conditions, the social economy and various aspects is necessary.

5. ACKNOWLEDGMENTS

We would thank to Dr. Nguyen Khac Quynh of the Vietnam Academy of Agricultural Sciences for his valuable comments and conducting the field survey. This research was supported by Global Environment Research Fund.

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