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Using temporal MODIS data to detect paddy rice in Red River Delta

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Abstract. Information on the area and spatial distribution of paddy rice fields is needed for food security, management of water resources, and estimation of Methan emission as well. MODIS remote sensing data including visible bands, near infrared band and short wave infrared band is foundation of calculating vegetation indices such as NDVI, EVI and LSWI. These remote sensing indices are very sensitive and strongly correlative to physiological status of plant, they are useful means for detecting and mapping paddy rice. This paper focus on an algorithm that uses time series of these vegetation indices to identify paddy rice areas based on sensivity of LSWI to the increased surface moisture during the period of flooding and rice transplanting.

Keywords: Remote Sensing, Paddy rice, NDVI, LSWI, Red River Delta.

1. Introduction

Rice monitoring in general and detecting identifying paddy areas in particular always have important implications for national food security, and since then this issue is closely related to other socio-economic problems, especially when Vietnam is the second biggest rice exporter in the world. At present, the anomaly weather phenomena such as droughts, floods, heatwaves, cold spells damage to crops are increasing with growing levels of damage; as a result, the risk of bad havests are also going up crop if appropiate assessments and monitoring to remedy, mitigate damage caused by them are not announced in a timely manner. In addition, the effective and timely paddy field mapping play an extremely important role in environmental sustainability, particularly in the management of water resources and management of greenhouse gas emissions, particularly in the context of global climate change have been happening complicated, threatening to the sustainable development of mankind. According to FAO statistics (FAOSTAT, 2001) [1], the Asian countries use more than 80% water resource for irrigation, even more than 95% in some countries. Paddy rice is also an vital source of methane emissions, according to some studies (Prather and Ehhalt, 2001) [2] rice cultivation contributed 10% of total methane emissions into the atmosphere, which greatly affect the chemical composition of the atmosphere and climate.

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Recently, many scientists have developed new approaches in using remote sensing to research crops in general and to research rice in particular based on the generation of new optical sensors such as VGT (Xiao et al, 2002) [3] and MODIS (Xiao et al, 2006) [4]. Optical remote sensing data owns its drawback which is dependent on atmospheric conditions and cloud, but the very high time resolution, data can be collected daily, hence that matter of fact can monitor the phenology details of each stage of the growth of rice. Based on the scientific basis which is the characteristic of absorption and emission of spectrum of plants in different bands, vegetation indices and surface water index are designed to reflect objectively about physiological performance of plants.

In this study, the authors used an algorithm based on 8-day composite MODIS data. On the foundation of the variations of rice field surface's characteristic over the growth periods, the algorithm will detect the paddy field areas in 2009 in Red River Delta region.

2. The study area

The Red River Delta occupies the area of 17.321 km^2 in northern Vietnam, extending from 21^{0}00'N to 21^{0}20'N and from 105^{0}50'E to 106^{0}50'E. Climate's characteristics is tropical and subtropical monsoon, the average temperature in this region is about 22.5 to 23.5^{0}C, annual average rainfall is 1400-2000 mm.

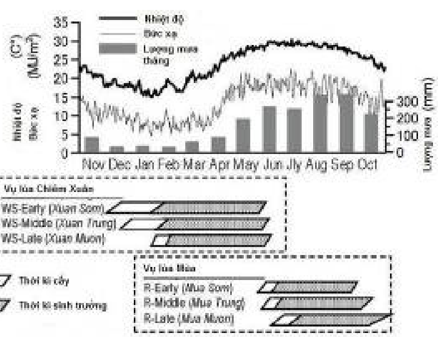


Figure 1. Structure of rice crops in the Red River Delta.

With this feature, the process of rice production in the Red River Delta has many advantages, but there are also many extreme weather phenomena causing adverse impacts on rice cultivation. The temporal structure of the rice crop Red River Delta is divided into two crop, the summer-autumn season and the winter-spring season (Figure 1). In 2007, the total planted area of 10 Red River Delta provinces during the two crop seasons was approximately 553,200 and 558,500 ha (General Statistics Office, 2009), respectively, total production reached 3.2 and yield 3.1 million tons and 5.7 and 5.5 tonnes/ha, respectively.

3. Database and methodology

3.1. Database

MODIS sensor has 36 spectral bands, the first 7 bands which is designed for research land cover and land surface. Each combination MODIS 8 days (MOD09A1) include surface reflectance of the above seven spectral bands at 500 m spatial resolution, in which the atmosphere calibration such as elimination of aerosol, thin clouds have been performed. During the process of detecting rice field areas, the authors have used a number of spectral bands (Table 1) in the 8-day composite data of Terra MODIS MOD09A1 during the entire duration of 2009, including 46 images, the extent of the study area is located entirely in one patch named h27v06, containing the entire Red River Delta.

Table 1. The selected MODIS bands

Bands	Wavelength Ranges	Spatial Resolution
1 (Red)	0.620-0.670	500 m
2 (NIR)	0.841-0.876	500 m
3 (Blue)	0.459-0.479	500 m
6 (SWIR)	1.628-1.652	500 m

3.2. Research Methodology

A unique physical feature of paddy rice fields to identify and distinguish between rice field and any other types of land cover is that rice plants are grown on flooded soils in a short time. The temporal aspect of rice field's surface development is classified into 3 main periods: the sowing–transplanting period, the growing period, and the after-harvest period (Le Toan et al, 1997) [5]. During the sowing-transplanting period, soil surface is a mixture of water and plants with water depth of 2 cm to 15 cm. About 50 to 60 days after sowing-transplanting period, rice foliage covers almost the entire land surface area. The end of this period to the beginning of harvesting, moisture storage of stem, foliage, and the amount of leaf decrease dramatically.

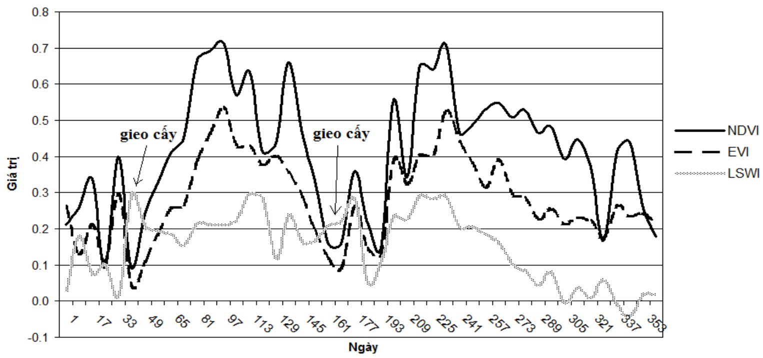


Figure 2. The temporal change of vegetation indices in paddy field.

Based on the characteristics mentioned above, to determine the change of the mixture of surface water and rice in the field over periods, the spectral bands or vegetation indices sensitive to both water and vegetation are needed. The vegetation indices were calculated from the analysis process using spectral bands such as near infrared, mid-infrared bands is that the intermediate parameters which reflect the distinct characteristics and dynamics of development characterized by paddy land in the growing period. Figure 2 demonstrates the dynamics of growth and development over time of a pixel corresponding to a field rice field samples. Two distinct peaks of EVI and NDVI index for the period shown in the second rice crop to be a viable crop and crop, which is the stage where the vegetation index reached maximum values, the opposite poles NDVI and EVI's and primary,there is also the only time in two years of paddy land which LSWI higher value NDVI and EVI values, is the new rice transplanting period, the surface is covered by farmland water.

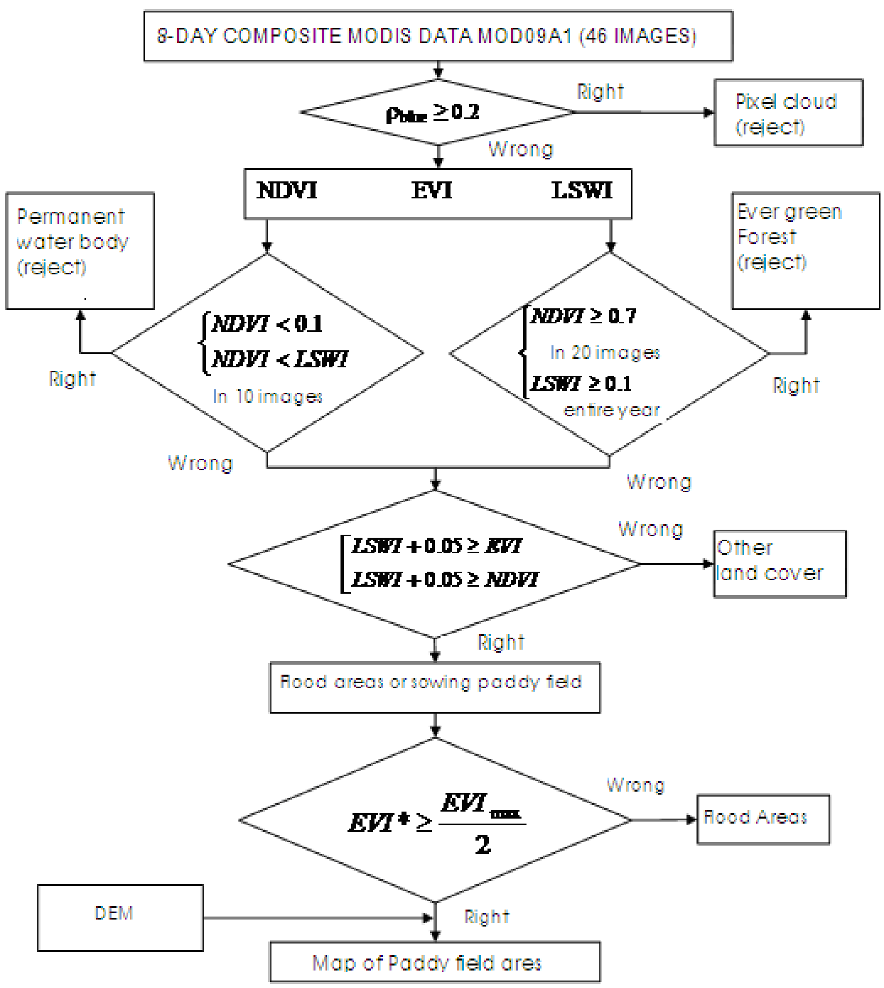
To detect paddy rice field areas by 8-day composite MODIS data, the authors used a detection algorithm paddy land through analysis dynamics of the time LSWI index, NDVI and EVI [4]. Index normalized difference vegetation index NDVI is a plant very common use in monitoring the plant status changes, reflecting the level of green plants. Vegetation index EVI enhanced sensitivity higher NDVI index in areas with high biomass (Huete et al, 2002) [6]. EVI is often used to evaluate the development of plants with large amplitude fluctuations, such as rice growing areas, in addition, EVI closer to reality than on the NDVI in vegetation monitoring when high humidity. Remaining surface water LSWI index denotes the level of water content changes of surface coatings, one of the indicators to assess the drought of vegetation cover in general and in particular crops. The indicators above are as follows:

$$NDVI = \frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + \rho_{red}} \quad (1)$$

$$EVI = 2.5 \times \frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + 6 \times \rho_{red} - 7.5 \times \rho_{blue} + 1} \quad (2)$$

$$LSWI = \frac{\rho_{nir} - \rho_{swir}}{\rho_{nir} + \rho_{swir}} \quad (3)$$

Where: ρ_{NIR}, ρ_{red}, ρ_{blue}, ρ_{swir} turn is the reflection coefficient of the near-infrared channel, red channel, the channel positive and mid-infrared channels.



*Notes: mark { is equivalent function" and"; mark [is equivalent function "or" EVI * is EVI in day after the date of sowing, transplanting 40 days (5 composite images) EVI_{max} is max value of EVI in the current crop.*

Figure 3. The flowchart of detecting paddy field ares algorithm.

Detecting algorithm focus areas for rice cultivation period through flooded paddy field in time of sowing and rapid growth of rice in the dawn of the next season when fully mature leaves. When surface water LSWI index reached higher values of vegetation indices NDVI and EVI, which is the hallmark of rice land under water at sowing transplant period. Based on the results of previous studies and field studies, pixel threshold wetlands in this study is $LSWI + 0.05 \geq EVI$ or $LSWI + 0.05 \geq NDVI$. After classification of wetlands, the next step of the study was to determine whether it is the will or just sowing in flooded areas or waters as often as ponds, lakes, rivers and streams. The author used the assumption that the index value of 5 photos combined EVI 8 days after sowing transplant period (40 days) to reach half the maximum value of the EVI index is paddy land. This assumption is established from distinct physiological characteristics of rice plants after sowing transplant period, rice growing and leaf area index reached a maximum within 2 months. The steps of the algorithm are specified in figure 3 above.

4. Results and discussion

Map of the area of rice from data analyzed MODIS

When performing the detailed steps in the research process has developed, need careful consideration and evaluation of various factors that influence the external environment (Figure 3). First, always causing factors influence the optical remote sensing data is cloudy, it should be removed first. Waters frequently and evergreen forest areas are also confusing objects with the land and planted rice grown on rice, two factors are detected and eliminated by the multi-period conditions. Finally, the rice-growing areas are considered to match the digital elevation model DEM to remove the rice area is analyzed on the height and slope irrelevant, unrealistic. The end result is to map the rice crop in 2009 is shown in Figure 4.

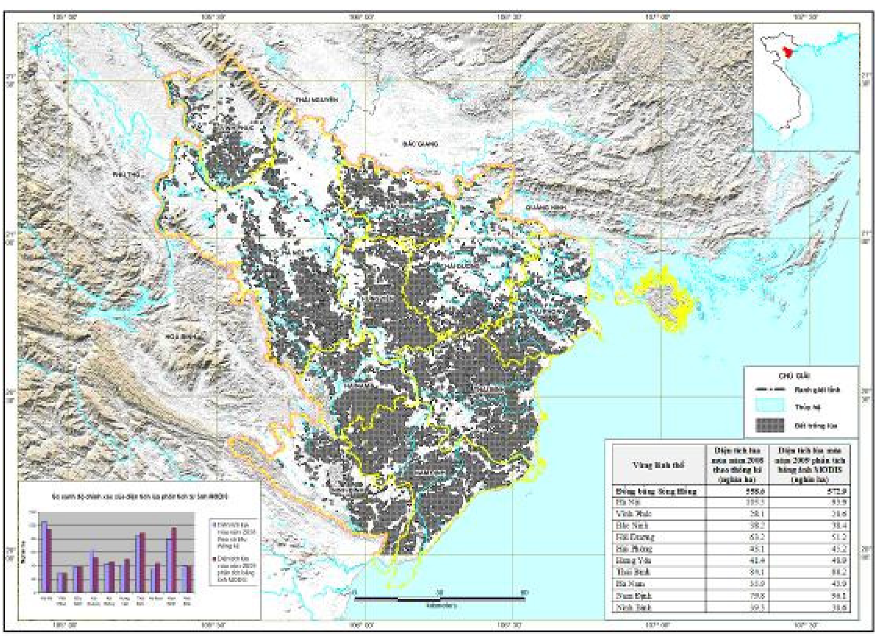


Figure 4. Map of paddy field ares in the Red River Delta derived from MODIS data.

Compared to statistical data, the area of rice cultivation area of the Red River Delta with the sequence analysis of MODIS data in 2009 an area of 572.9 thousand ha, according to statistics in 2008 reached 558.6 thousand ha. Thus, the error compared to the statistics of the total rice area of the Red River Delta is only at 2.6%. For provinces in the study area, but also a few provinces have considerable value as disparities in Nam Dinh, Ha Noi, Hai Duong (comparison table in Figure 4), rice area from image analysis is generally quite accordance with provincial statistics, a symbol in the chart showing the correlation of the two sources of data of 10 provinces, squared correlation coefficient reaches a high value $R^2 = 0.8911$.

5. Conclusion

Research has confirmed the ability of MODIS data and multi-period detection algorithm rice planting areas in the establishment of distribution maps of paddy land. With the advantage of resolution and time updates, MODIS data suitable for the overall assessment of regional rice area.

Detection algorithm based on the rice physical changes of paddy land, and focus on the detection time of sowing through a temporary increase of the spectral index is sensitive to water (LSWI). This algorithm is a very objective and can be extended another year to apply for, or applied research for other crops.

Although there are many sources of error affecting the usual optical remote sensing of clouds as noise, effects of topography, resolution limited space but generally results from analysis of rice maps are similar MODIS with statistics, in accordance with the terms of the actual spatial distribution and area measurements.

References

[1] FAOSTAT, *Statistical Database of the Food and Agricultural Organization of the United Nations,* 2001.

[2] Prather & Ehhalt, *Atmospheric chemistry and greenhouse gases. Climate change 2001: The scientific basis,* Cambridge University Press (2001), UK. Pp 239–287.

[3] Xiangming Xiao, et al, Observation of flooding and rice transplanting of paddy rice fields at the site to landscape scales in China using VEGETATION sensor data. *International Journal of Remote Sensing* (2002), 23, Elsevier-USA, pp 3009– 3022.

[4] Xiangming Xiao, Stephen Boles, et al, Mapping paddy rice agriculture in South and Southeast Asia using multi-temporal MODIS images. *Remote Sensing of Environment* (2006), 100, Elsevier-USA, pp 95 – 113.

[5] Le Toan, T., Ribbes, F., et al, Rice crop mapping and monitoring using ERS-1 data based on experiment and modeling results. *IEEE Transactions on Geoscience and Remote Sensing* (1997), 1, IEEE-USA, pp 41–56.

[6] Huete, A., et al, Overview of the radiometric and biophysical performance of the MODIS vegetation indices. *Remote Sensing of Environment* (2002), 83, Elsevier-USA, pp 195– 213.