APPLICATION OF MODIS IMAGES TO MONITOR THE PROGRESS OF RICE SOWING AND CROPPING CALENDAR ASSISTING IN EARLY WARNING RICE BROWN HOPPER IN THE MEKONG DELTA, VIETNAM

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ABSTRACT

In Mekong Delta, total annual rice production is accounted for more than 53% of the total rice output and contribute 90% of the country's rice exports. However, the situation of rice pests and pest outbreaks have affected rice productivity and its production so that the monitoring and supervision in each locality as well as early forecasts on rice pest situation at each level management has been adopted management measures, protection of plants in each locality. With the advancement of remote sensing technology based on MODIS imagery to monitor the time of rice sowing/transplanting and the infected of rice hoppers distribuion simultaneously to forecast the development trends and possibilities of pest outbreaks in the Mekong Delta helping managers to propose management strategies and farmers to plan effective prevention of rice pest. GIS technique has been combined and linked to monitor and manage the disease situation, to solve challenges posed in monitoring and forecasting capabilities of rice disease appears that will form the basis for the monitoring and notice the appearing of rice pest disease and propose the trends for prevention in the near future.

1. INTRODUCTION

Nowadays, the rice cropping calendars in The Mekong Delta are very complicated, even in the same cropping season. Since it difficult to delineate the current state of rice-growing stages. Usually, the monitoring for cropping season mainly based on surveys, reports from local officers. Since, this does not guarantee the accuracy and require more time, funding, etc. The techniques using remote sensing images has been used to delineate the distribution of natural features in many countries around the world (Burrough, P. A, 1986). The results can be used to monitor the time of sowing progress and cropping calendar in the broad area, to propose the solutions for rice crop management, especialy in crop protection which can be used to predict the occurrence of Brown Plant Hopper on rice, based on the sensitive stages of rice with the attack of pest and desease.

The study mainly uses MODIS remote sensing images to monitor and delineate the rice crop progress and cropping calendars which was used to predict the occurence of Rice Brown Plant Hopper in the Mekong Delta from 2008 to 2009. The results were validated and correlated with official collected and reported data.

2. RESEARCH AREA

The Mekong delta located from $8^0$30'-11^0 North latitude and $104^0$30'-107^0 East longitude, including 13 provinces: LongAn, TienGiang, BenTre, DongThap, VinhLong, AnGiang, CanTho, HauGiang, SocTrang, CaMau, BacLieu, KienGiang and TraVinh (Le Sam, 1996).

3. METHOD

3.1. The images collection

The images were collected from NASA, code MOD13Q1, spatial resolution of 250m, and temporal resolution with 16-day period from 1st of January (2008) to 14th September (2009), 4800 x 4800 pixels/image, georectified. Total number of 82 images was collected. The NDVI images were calculated for rice showing stages and cropping calendar determination. Red and Near Infrared bands were used for calculation (Table 1).

Table 1: The spectral bands of MODIS sensors used in calculation of vegetation indices

MODIS band	Wavelength (μm)	Resolution (m)
1	0.620 to 0.670	250
2	0.841 to 0.876	250

3.2. Creating the Normalized Different Vegetation Index (NDVI)

Normalized Different Vegetation Index (NDVI) created from combination of spectrum band of visible, near infrared, infrared and red, from which intermediate evaluation can be differenciated the characteristics of the materials such as biomass, leaf area index, and photosynthetic capacity seasonally. Those characteristics are relevant and highly dependent on the type of plant cover and weather, physiological characteristics, biochemical and pests. (NDVI) is averaged in time series data is the basic tool to monitor changes in vegetation status, which can assist in understanding the impact of weather and climate to the biosphere. NDVI is calculated as follows:

$$NDVI = \frac{(NIR - R)}{(NIR + R)}$$

3.3. The relationship between NDVI values and rice growing stages

Table 2: Criteria used to classify land use (BR Parida et al, 2008)

NDVI ranges	Land uses
NDVI> 0.74	Forest
0.74 <NDVI> 0.46	Irrigated crops
0.46 <NDVI> 0.20	Rainfed crops
0.20 <NDVI> 0.15	Fallow land
0.15 <NDVI> 0.05	Bare Soils
0.05 <NDVI> 0.001	Salt pans
NDVI <-0.001	Water

Because NDVI value of crops changing in a certain situation (ex: each soil type has different properties). Generally its value changing in the same direction. Based on research results of Parida et al (2008) in India's Gujarat, the proposed NDVI values as shown in Table 2.

3.4. Monitoring the progress of rice sowing and delineating the rice cropping calendar

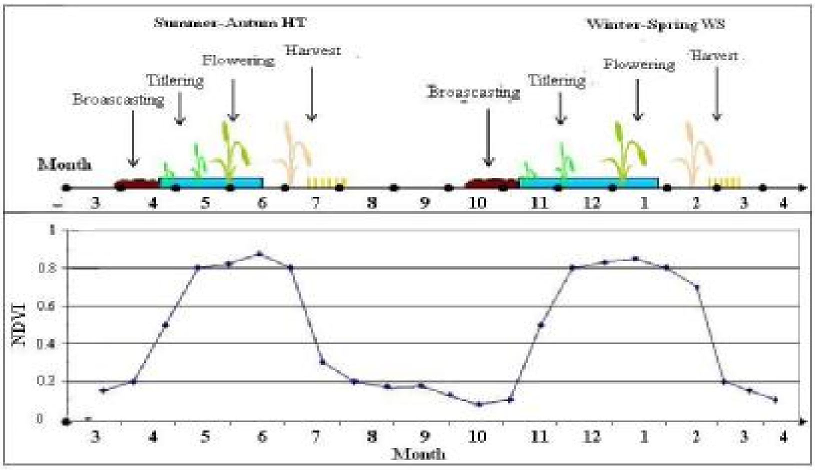


Figure 1: Changing of NDVI at different rice growing stages of Winter-Spring-Summer-Autumn cropping seasons

The time series NDVI values of the Mekong Delta were calculated and delineated, which combined with rice growing states to find out the relationship between NDVI indexes for rice growing stages. On the basis that low NDVI value at the early stage, then increased gradually and peaked at tilering stage, and decreased when rice began mature and harvested (Figure 1)

3.5. Simulating the distribution of pests

Collection of pest, brown plant hopper in 170 light traps, which GPS positioned, in the Mekong delta. Spatial analysis and interpolation technique were applied to simulate the spatial distribution of hopper from collected data, combined with rice growing stages distribution interpreted form MODIS images for predicting the occurrence of hopper on sensitive stages of rice. The results were correlated with the survey data.

4. RESULTS AND DISCUSSION

4.1. Temporal NDVI image interpretation

Each NDVI images allow to monitor changes in vegetation status, represented by the difference of NDVI index at a certain time, corresponding to level of low or high values. Through analysis of NDVI images in 2008, a few images where homogenous tone (light or dark) throughout the year, remaining changes over time. From first 6 months of 2008 showed that the coastal areas and Ca Mau peninsula have very low NDVI (brightness color) and not significantly changed during the year. In contrast, in AnGiang, DongThap, CanTho, HauGiang have high NDVI value in January, February and decreased in March, April, and increased in May, June. In last 6 months of 2008, in CaMau and the coastal area, the NDVI values colors tend to dark over time (decreasing of NDVI). In contrast, the NDVI value decreased in the September, October and November in AnGiang, DongThap and KienGiang provinces. The results in 2009 also showed similar variation.

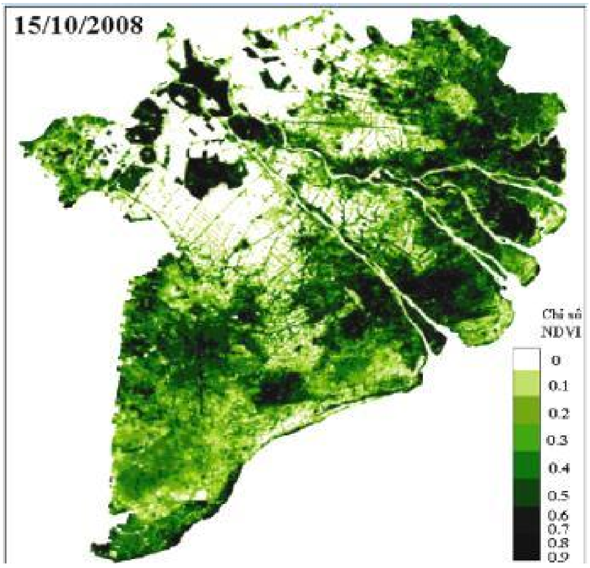


Figure 2: NDVI image day 15/10/2008

4.2 Analysis of variation in NDVI values

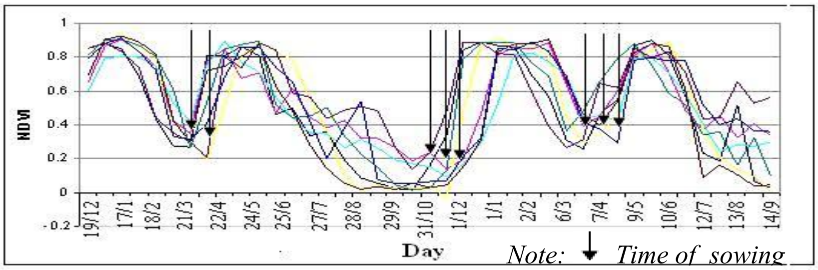


Figure 3: Example of changing of NDVI index for 2 crops areas (Main DX-Early HT)

Usually, if the NDVI index peaks (from 0.5 to 0.9) are the regions with well-developed, rice is in tilering/maturing/flowering or industrial crops/fruit trees/forests. If value < 0.5, there is no or poor plant growth, specialized areas such as shrimp, salt, water logging or sowing rice. The NDVI values of uncultivated or no crop are often stabilized throughout the year. The NDVI values of objects which not high fluctuations over time will be split into a separate object. For rice cultivation in the Mekong Delta region, according to figure 3, the changes in NDVI sinusoidal shape, reached maximum values at 0.8 to 1.0 corresponds to stage the maximum growing stage and decreased to about 0-0.4 when the season ends, this value continues to increase as a rule when starting a new season.

4.3 Time of rice sowing

Based on the temporal variation of NDVI values in the Mekong Delta, showing that the time of rice sowing of each rice crop as in table 3:

Table 3: Rice sowing area intepreted from MODIS images in May and June/ 2009 at different districts (ha)

From	To	AGiang	Lieu	BenTre	CaMau	Tho	DThap	HGiang
01/05	08/05	30,712	850	87	56	21,412	67,468	26,106
09/05	16/05	78,262	12,456	618	237	7,750	29,912	14,187
17/05	24/05	166,600	10,600	18,156	5,518	5,050	74,500	29,343
25/05	01/06	650	3,231	1,331	550	6,250	406	1,450
02/06	09/06	2,356	35,856	6,550	2,537	37	37	400
10/06	17/06		156					
18/06	25/06		4,131	68	9,431	400	4,012	168
26/06	03/07							

From	To	STrang	TGiang	TVinh	KGiang	Long An	V Long	Total
01/05	08/05	7,093	2,543	1,468	77,843	20,506	10,531	**14,543**
09/05	16/05	20,075	5,643	3,512	15,050	26,431	50	**9,206**
17/05	24/05	52,768	45,418	38,337	105,862	135,131	5,543	**8,930**
25/05	01/06	6,318	1,006	11,375	1,662	23,737	31	**12,412**
02/06	09/06	17,400	6,500	4,375	9,243	17,287	6	**10,881**
10/06	17/06	868						
18/06	25/06	39,868	1,106	943	18,625	225	175	**2,225**
26/06	03/07	243	206			25		**206**

4.4. Accuracy assessment:

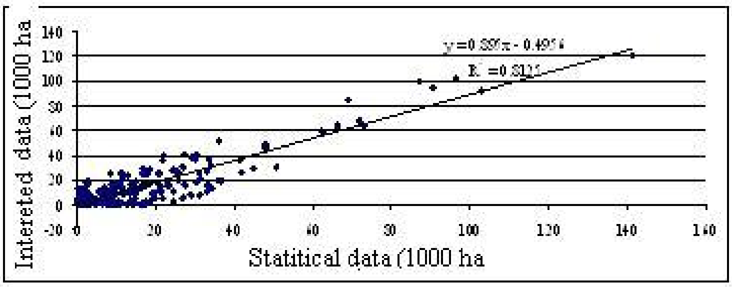


Figure 4: The correlation between the plated area in statistics and data interpretation.

The results was validated with official data (Southern Center for Crop protection, Ministry of Agricultural and Rural Development), which showed close correlation (r=0.752**, n=481, df=479). Then the results are quite reliable and can be used in monitoring the status of rice cropping stages (Figure 4).

4.5. Main rice cropping calendars in the Mekong Delta in 2008 - 2009

Based on the relationship between NDVI values with the rice cropping stages over time, determine the start time and end of each cropping season, which can assist in developing the major rice cropping calendars for the study area.

❖ *Mono rice crop (traditional rice)*

The Mono rice crops distributed along the coast from LongAn, BenTre, TraVinh and Soctrang, BacLieu and CaMau. Time of transplanting period ranging from August to middle of September (rice have been sown in June, July) (Figure 5).

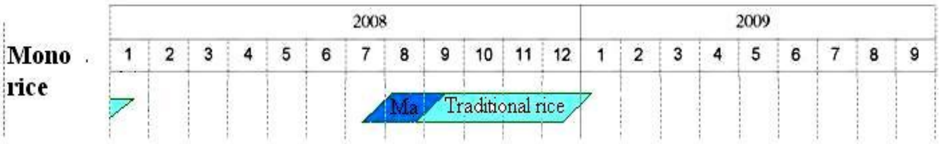
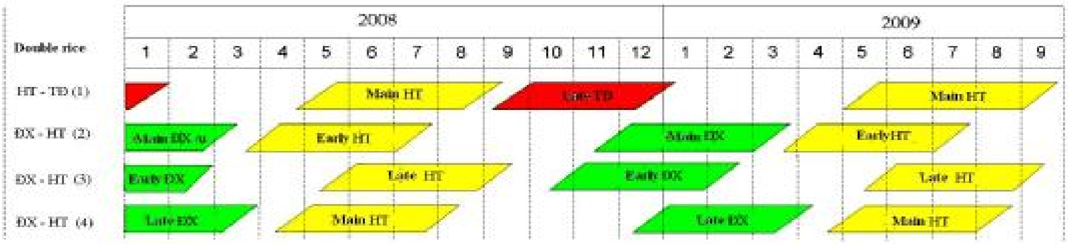


Figure 5: Typical mono rice cropping calendar

❖ *Double rice crops*



Notes: (1): Summer Autumn - Autumn Winter (2): Main Winter Spring - Early Summer Autumn (3): Early Winter Spring - late Summer Autumn (4): late Winter Spring - Main Summer Autumn

Figure 6: Some typical double rice cropping calendars

This rice cropping calendar is most popular in the Mekong Delta (in the freshwater and slightly saline areas). The image interpretation showing that NDVI index reached its maximum twice a year at different intervals depending on the time of sowing (see figure 6).

- Summer Autumn- Autumn Winter: The cropping calendar is scattered in the coastal areas. The Autumn-Winter starting date of rice sowing around middle of September of previous year (2007) and ended at end of January of year after (2008). Then, soil will be fallowed for 3 months (due to salinity or flooding) and start sowing Summer-Autumn rice crop in May. Then it starts for next rotation. Which populated in GiaRai (BacLieu); Thanhtri, MyXuyen and LongPhu (SocTrang).

- Main Winter Spring - Early Summer-Autumn: Winter-Spring cropping season started in November of previous year, after harvested, it starts sowing for next cropping season from 21/3 to 6/4. Then this cropping season soil is left fallow from early of August to end of October, and will begin Winter Spring cropping season for next rotation of 2009. Populated mainly in CanTho, DongThap, AnGiang, VinhLong, and scattered in KienGiang provinces.

- Early Winter Spring - Late Summer-Autumn: The Winter Spring starting date of rice sowing is within October. Soil will be fallowed after this cropping season for two months before starting of Summer-Autumn cropping season (from 8/5 to 24/5). After harvested, soil will be fallowed for one month then it starts Winter-Spring cropping season of 2009. Which populated in the coastal of TraVinh, KienGiang, CaMau, BacLieu provinces.

- Late Winter Spring – Main Summer-Autumn of services: The starting time of rice sowing for Winter Spring (2008) within December; and The Main Summer Autumn starting from 21/3-6/4. In 2009, the Summer Autumn rice sowing relatively later than in 2008 (middle to end of April). Most populated in HonDat, TanHiep, RachGia (KienGiang).

❖ *Triple rice crops*

Triple rice cropping season is most popular and almost year round in freshwater alluvial soil ecosystem. Based on the time of rice sowing calendar, it is divided into Early Winter-Spring, Main Winter-Spring and Late Winter Spring rice cropping (see Figure 7).

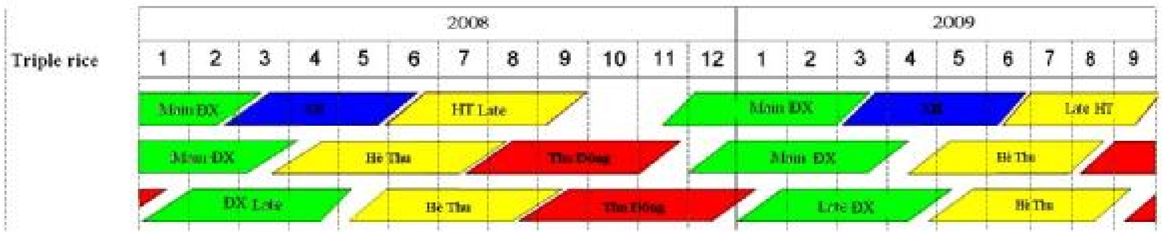


Figure 7: Some of triple rice cropping calendars

Winter Spring - Spring Summer – Late Summer Autumn: At the end of Summer-Autumn crop, soil is left fallow for 1 or 2 months before starting Winter-Spring rice crop of next year. Sowing time for the three cropping season can be as : Winter Spring - starting from end of november to beginning of December, second rice crop starting from middle of March, third rice crop starting from beginning of June. This cropping calendar most populated in CaiBe, CaiLay (Tiengiang), ThapMuoi (DongThap).

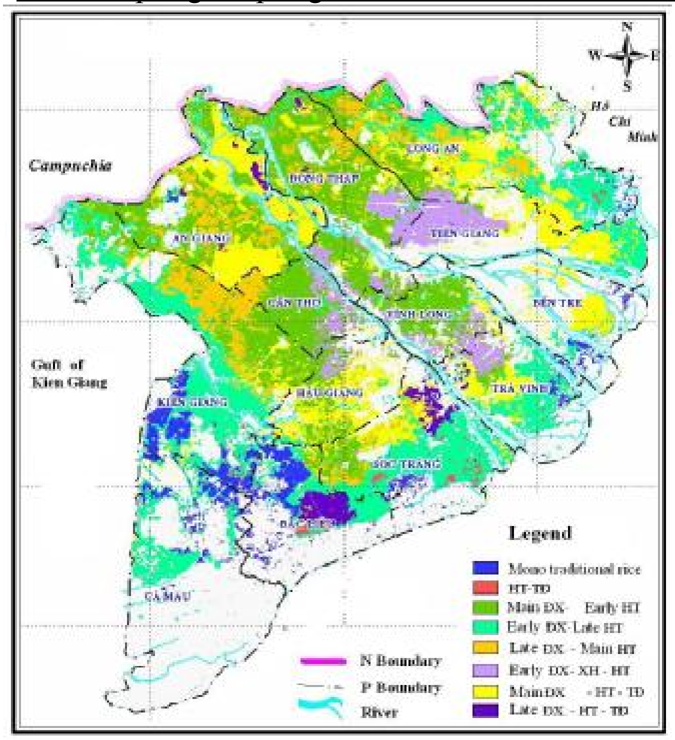


Figure 8: Distribution of rice cropping seasons and time of rice sowing in the Mekong delta in 2008-2009

Note: ĐX: Đông Xuân (Winter-Spring); XH: Xuân Hè (Spring-Summer); HT: Hè Thu (Summer-Autumn); TĐ: Thu Đông (Autumn-Spring) : N National ; P Provincial

Main Winter Spring – Summer Autumn - Autumn Winter: Winter Spring crop sowing time starting at beginning of December, the Summer-Autumn starting from 6th/April to 22nd/April, Autumn-Winter sowing from end of July to first half of August. When Autumn Winter rice crop harvested in 2008, soil is fallowed for a month before starting of Winter-Spring crop of 2009, which populated in AnGiang, HauGiang, BenTre, LongAn provinces

Late Winter Spring - Summer Autumn- Autumn Winter: Winter-Spring crop sowing from end of January to beginning of February, the Summer Autumn crop starts in end of May, and Autumn Winter starting from middle of September (Figure 8). Which populated in HongDan, GiaRai, PhuocLong (BacLieu); and in KeSach, MyTu, LongPhu, (SocTrang). Figure 8 shows that the double rice crops is dominated (> 63.8%) followed by tripple rice crop (30.7%) and finally mono rice crop (5.5%). In which Early Winter Spring–Summer Autumn cropping season populated (>27.9%), followed by the main Spring Summer–Early Summer Autumn (> 25.5%). Thirdly is Main Winter Spring–Summer Autumn–Autumn Winter (22.0%). Lowest is double rice crops of Summer Autumn–Autumn Winter (0.6%).

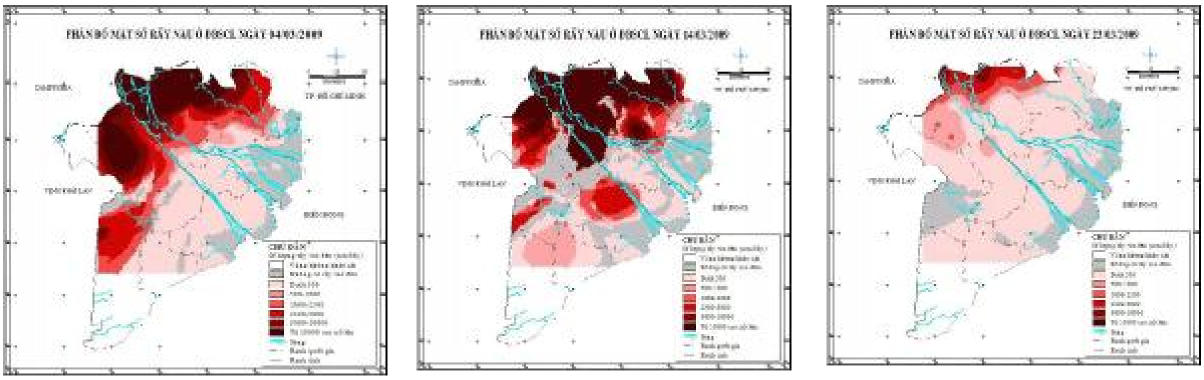
Although a total of eight major rice cropping calendar representing in the Mekong Delta but the double and triple rice crops dominated, which account for three quarters of total area. The remaining rice cropping calendar occupy negligible.

4.6. Predicting the damage of rice from occurrence of Brown Plant Hopper

4.6.1. Spatial delineation the density of Brown Plant hopper

In order to delineate the distribution of Brown plant hopper in the Mekong Delta from the collected data of hopper density in light traps, which geopositioned. The delinetion of hopper fluctuations using krigging spatial interpolation techniques. The spatial variation model is also tested for accuracy assessment. The figure below shows the distribution density of pests in light traps at stage 1 from March 3rd to 9th (Figure 9a), stage 2 from March 10th to 16th (Figure 9b) and stage 3 from March 17th to 23th (Figure 9c).

The results showed that the interpolation technique have the ability to delineate the distribution of the density of brown plant hopper from point data.

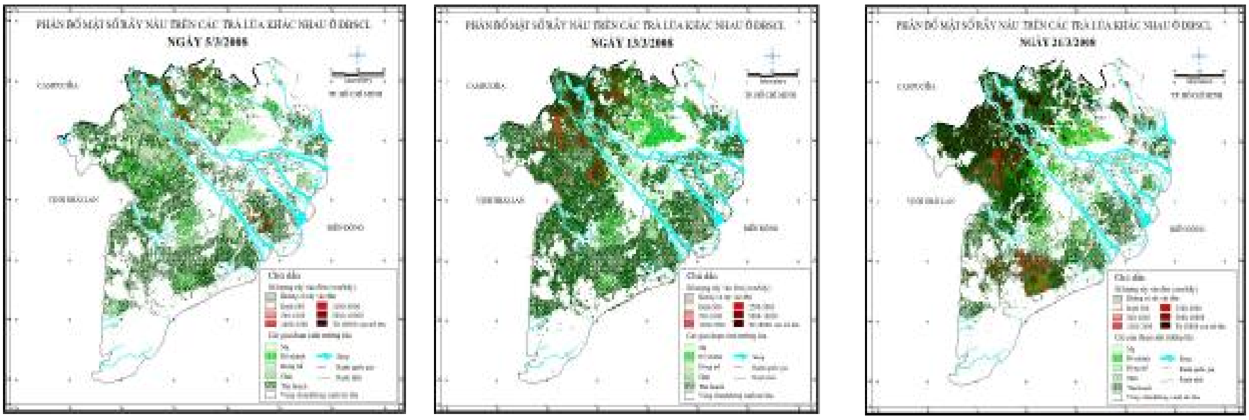


(A) (B) (C)

Figure 9: The distribution of pest density in light traps in the Mekong Delta at 3 time observations (A) stage 1 from March 3rd to 9th, (B) stage 2 from March 10th to 16th, and stage 3 from March 17th to 23th (Using the Kriging method).

4.6.2. Distribution of Brown Plant hopper at difference rice growing stages

The result of interpolation above was used to combined with rice crop growing stages for identifying the sensitive stages with Brown plant hopper, which will help to predict the ability of Brown Plant Hopper can damage for rice.



(A) (B) (C)

Figure 10: Distribution of BRH at diffence rice growing stages
(A) Stage 1 from March 4th to 10th; (B) Stage 2 from March 11^{h} to 17th; and (C) Stage 2 from March 18th to 24th.

The above results show that at each rice growing stage, we can know the occurrence and amount Brown plant hopper, which can predict the ability of rice damaged by Brown Plant Hopper. Then the agriculturalist can developt the strategies in rice crop protection to prevent the attack of pest and diseases.

5. CONCLUSION

Monitoring the date of starting rice sowing based on temporal variation of NDVI is very effective, and useful, for determining the current state of rice evolution and rice sowing stages then rice cropping calendar, which did not depend on human subjectivity.
GIS interpolation technique can be used to simulate the spatial distribution of pests from light traps pest collection, which can combine with rice crop growing stages interpreted from MODIS images for early warning the occurrence of pest which damage for rice crop.
Multispectral and Temporal Remote Sensing Data, MODIS most suitable for research at regional or national level. Which can provide quick and low cost information for managers and decision maker to select the suitable best strategies for crop management.
Cloud and low spatial resolution impaired the accuracy of the results, since it needs for further studies and more fields validation is also needs to enhance the accuracy.

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