Method for Estimation of Damage Grade and Damaged Paddy Field Areas Due to Salt Containing Sea Breeze with Typhoon Using Remote Sensing Satellite Imagery Data

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Abstract

Methods for estimation of damage grade and damaged paddy field areas due to salt containing sea breeze with typhoon using remote sensing satellite imagery data is proposed. Due to a fact that Near Infrared: NIR camera data is proportional to vitality of vegetation, it is possible to estimate damage grade and damaged paddy field areas due to salt containing sea breeze with typhoon using NIR channels of remote sensing satellite imagery data. Through regressive analysis between measured and estimated damage grade and damaged paddy field areas, it is found that there is a good correlation between both. Also it is found that there is a proportional relation between salt amount attached to the rice crop leaves and NIR reflectance measured with NIR channels of remote sensing satellite imagery data. Thus it is validated the proposed estimation method for damage grade and damaged paddy field areas due to salt containing sea breeze with typhoon using NIR channels of remote sensing satellite imagery data.

Keywords: Typhoon Disaster, NIR Radiometer Onboard Satellite, Damage Due to Salt Containing Sea Breeze.

1. INTRODUCTION

Vegetation vitality can be monitored with Near Infrared: NIR of spectral reflectance measured by ground based and satellite based instruments [1]. Also Normalized Difference Vegetation Index is very useful index for representing vegetation vitality [2]. For instance, NDVI can be calculated with the following simple equation, $NDVI=(IR-R)/(IR+R)$ where R denotes reflectance of vegetation in the red wavelength region while IR denotes reflectance in NIR region, respectively. NDVI was originally used as a measure of green biomass [3]. It got a solid theoretical basis as a measure of the solar photosynthetically active radiation absorbed by the canopy [4],[5]. Its application is limited, though, by a complexity of interacting factors involved in the formation of the reflectance response (see, for review [6]-[10]).

The method proposed here allows vegetation damage grade and damaged area estimations based on the NDVI as well as NIR reflectance. In particular, an estimation method of damage grade and damaged paddy field areas due to salt containing sea breeze with typhoon using NIR reflectance of remote sensing satellite imagery data is proposed. Also salt amount which is attached to the rice crop leaves is attempted for estimation. Through regressive analysis, a relation between NDVI and salt amount is clarified then a regressive equation which allows calculation of salt amount using NDVI is developed. The paper also describes trend analysis of the damage grade and damaged areas using satellite imagery data. Spatial distribution can be analyzed with satellite imagery data together with quantitative analysis. Also time series of analysis of damage grade and damaged area can be made with satellite imagery data.

The following section describes the detailed method for damage grade and damaged area estimation with satellite imagery data and time series analysis followed by examples of damage grade and damaged area estimation due to salt containing sea breeze caused by typhoon together with time series analysis. Finally, conclusions with some discussions are followed.

2. PROPOSED METHOD

2.1 Damaged Vegetated Area Estimation Due to Salt containing Sea Breeze With Vegetation Vitality Measurement

Damaged vegetated area due to salt containing sea breeze of typhoon can be estimated through a comparison of NDVI which is derived from two remote sensing satellite imagery data which are acquired on before and after the typhoon pass. Also damage grade can be estimated with NDVI as well. Because one of the greatest reason of damage is caused by sea salt which is contained in sea breeze caused by typhoon, so that the relation between attached salt amount to vegetation and damage grade has to be clarified. Due to the fact that vegetation vitality is getting worth in accordance with attached salt amount remarkably, it is considered that there is an exponential relation between both, not a proportional relation. Therefore exponential regressive analysis is proposed for representation of the relation between both.

2.2 Time Series Analysis

Even if the attached salt amount is same, vegetation damage grade will be increased for time being. By using NDVI derived from remote sensing satellite imagery data, damage grade is estimated. Then relation between vegetation damage grade and duration time is estimated with time series of remote sensing satellite imagery data. Such this trend analysis method is proposed for time series of vegetation damage grade analysis.

3. EXPERIMENTS

3.1 Example of Typhoon Which Hit the Northern Kyushu, Japan on 10 September 2006

The typhoon number 13 in 2006 was borne at the ocean in south eastern offshore of Philippine at around 21:00 local time on September 10. It grew up and moved to northwest direction. After the typhoon was passing through Ishigakijima Island, Japan on September 16 with atmospheric pressure of 919 hPa and maximum wind speed of 55 m /s then it changed its direction to northeast direction and finally reached to Kyushu Island, Japan. Then the typhoon landed on Sasebo city in Nagasaki prefecture, Kyushu, Japan at 18:00 local time on September 17 with maximum wind speed of 40 m/s. After that it moved to Genkainada offshore through Fukuoka city at 20:00 local time on that day. Figure 1 shows the typhoon track with the time duration.

Agricultural damage in Saga prefecture, for instance, was more than 12 billion Japanese Yen which was occurred in mainly rice crop and soybeans in the reclaimed farm lands near coastal regions. This was mainly caused by salt containing sea breeze. Severe storm of typhoon hit the Saga prefecture at the same time of high tide so that the coastal areas in the Chikushi plane in Kyushu Island was damaged by the typhoon 13 due to salt containing sea breeze. Furthermore, it was fine days after the typhoon hit so that damaged areas expanded to street tree areas and mountainous areas.

Approximately 80 percent of the rice crop farm area (23,400 ha) was damaged (Total rice crop farm area was 29,000 ha in 2006). The server damaged area, in particular, was 15,800 ha, about half of the total rice crop farm area. Figure 2 shows local government reported contour lines for more than 70 %, between 30-70%, less than 30% damaged areas borders.

Black colored contour line (more than 70% areas was damaged) is situated on the rout number 444. There are street trees along with the rout number 444 so that vegetation damage due to salt containing sea breeze at rear side of the street trees is quite different from the area which is situated on the other side, fore side of the street trees. This situation is same for the border line of rout number 207 and 264. There is the pink colored border line along with the routs. Then the red line is corresponding to the rout number 34.

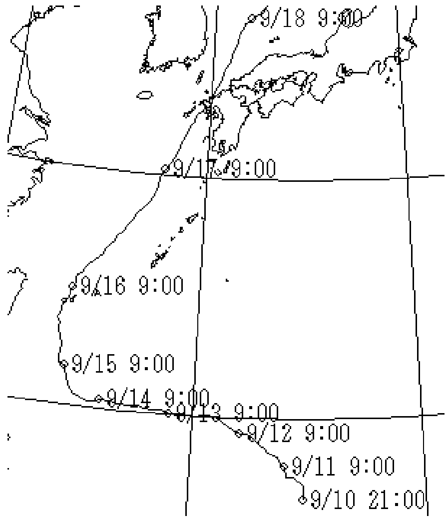

FIGURE 1: Typhoon track of the typhoon number 13 in 2006

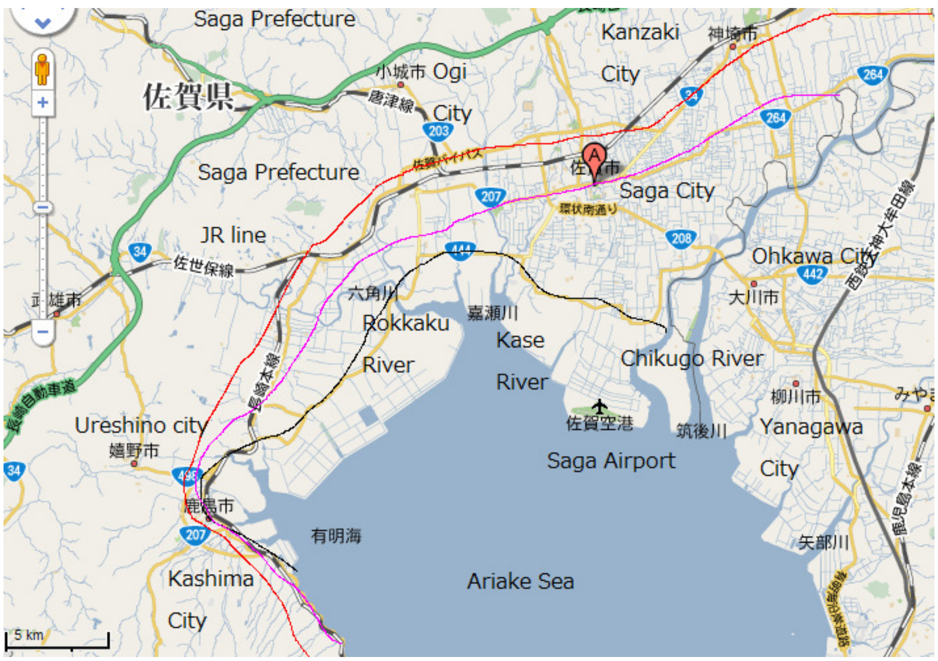

FIGURE 2: Contour lines of borders for Black line: more than 70 %, Pink line: between 30-70%, Red line: less than 30% damaged areas

3.2 Damaged Area Estimation With Remote Sensing Satellite Imagery Data

SPOT/HRV[1] imagery data which were acquired on August 25 (before the typhoon number 13 hit) and September 23 (just five days after the typhoon hit) are shown in Figure 3. Also spectral response of SPOT/HRV of multispectral bands is shown in Table 1.

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1 Spatial resolution of High Resolution Visible: HRV sensor onboard SOPT satellite developed by CNES (French Space Agency) and operated by SPOT Image Co., Ltd is 10 m for multi-spectral mode.

(a) August 25 **(b) September 23**

FIGURE 3 SPOT/HRV image which were acquired on August 25 and September 23 2006.

Mode	Band	Wavelength (μm)	Resolution (m)
Multispectral	XS1	0.50 - 0.59 (Green)	20
Multispectral	XS2	0.61 - 0.68 (Red)	20
multispectral	XS3	0.79 - 0.89 (Near IR)	20

TABLE 1: Spectral response of the SPOT/HRV of multispectral bands

Red colored areas show well vegetated areas while grey or blue colored areas show urbanized areas.. Almost farm areas in SPOT/HRV image of August 25 show vital and well vegetated areas while the portion of areas changed the colored from red (vital) to blue (week vegetation) in SPOT/HRV image of September 23.. These areas are damaged areas obviously due to salt containing sea breeze of typhoon number 13. By comparing both SPOT/HRV images, these areas are extracted. Figure 4 shows the extracted vegetation damaged areas.

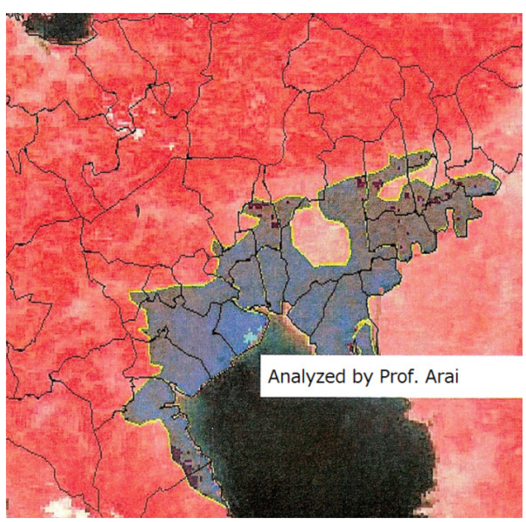


FIGURE 4: Vegetation damaged areas extracted through the comparison between SPOT/HRV images which were acquired on August 25 and September 23 2006.

One of insitu data of attched salt on the rice crop leaves (salt amount in unit of mg / leaf)is illustrated in Figure 5. Figure 5 also shows the contour lines for which salt amount a leaf is less than 0.5 mg/leaf, 0.5-1.0 mg/leaf, 1.0-1.5 mg/leaf, 1.5-2.0 mg/leaf and greater than 2.0 mg/leaf, respectively.

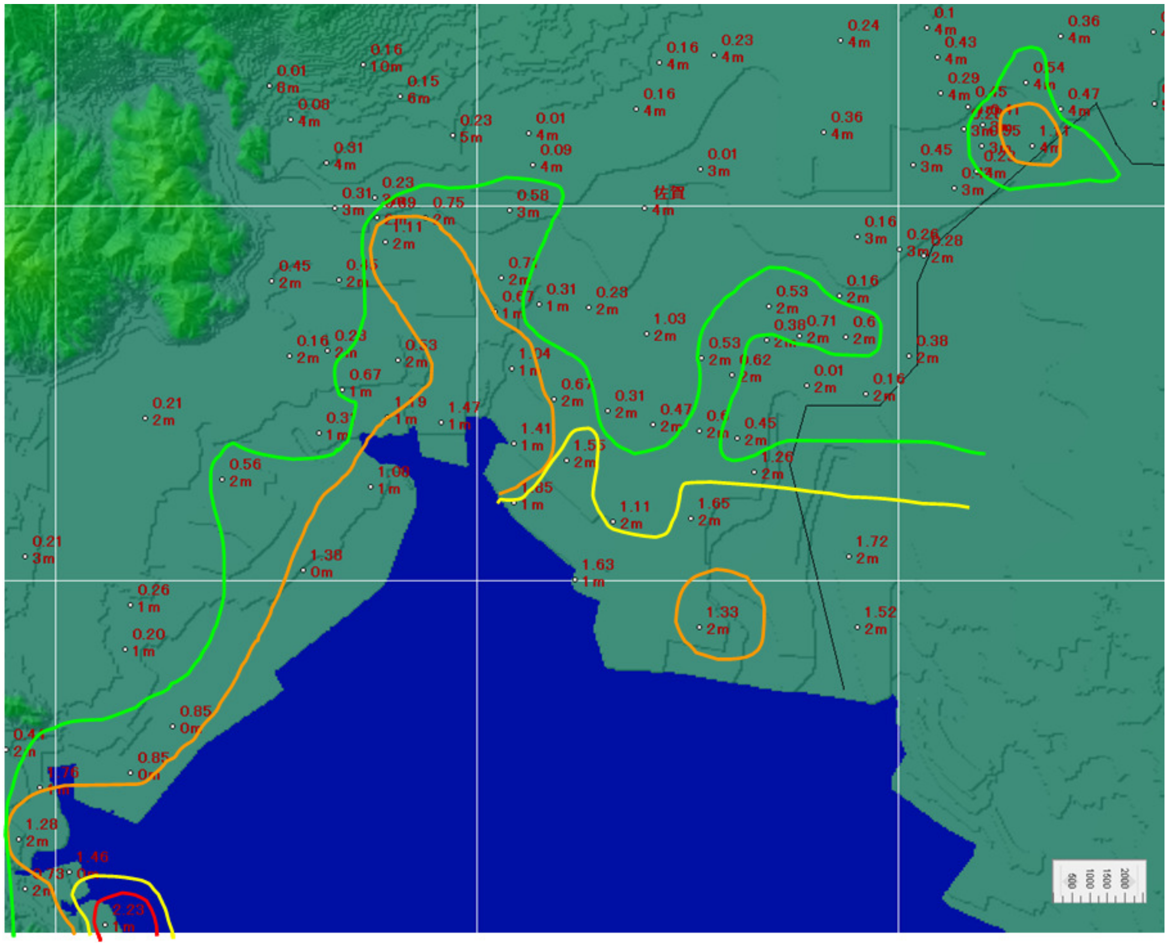


FIGURE 5: Attached salt amount to rice crop leaves (the top number) and elevation at that locations (the bottom number) as well as contour lines for which salt amount a leaf is less than 0.5 mg/leaf, 0.5-1.0 mg/leaf (green), 1.0-1.5 mg/leaf (orange), 1.5-2.0 mg/leaf (yellow) and greater than 2.0 mg/leaf (red), respectively.

One of the specific features of these contour lines is that attached salt amount rich areas area situated along with the rivers. This implies that salt containing sea breeze of typhoon blew from the south (the Ariake Sea) to the north (mountainous areas) along with the rivers. Therefore, attached salt amount is significant at the regions which are situated at the valley associated with the rivers even if the regions are situated far from the coastal region. Figure 4 and 5 show a coincidence in terms of damaged areas and the attached salt amount.

3.3 Regressive Analysis

As is shown in Figure 5, there is a relation between salt amount attached to the damaged rice crop leaves and vegetation vitality which is derived from satellite imagery data, NDVI. By using all the insitu data of salt amount and calculated NDVI with the corresponding pixel of the insitu data location, regressive analysis was conducted. By using SPOT/HRV imagery data, NDVI of corresponding to the insitu locations with 20m by 20m areas can be calculated. Figure 6 shows the relation between SPOT/HRV 20m derived NDVI and insitu data of salt amount attached to the rice crop leaves. Because the vegetation vitality is significantly decreased in accordance with increasing of salt amount, empirical equation of the relation would be a linear function. Then regressive analysis with a linear function is conducted with the equation (1).

$$S = a\,N + b \tag{1}$$

where S, N denote Salt amount (Salinity) attached to the rice crop leaves (mg/leaf), Normalized Difference Vegetation Index (NDVI) while a and b denote regressive coefficients. The results from the regressive analysis show a=0.0223, b=-1.789 and correlation coefficient R square value is 0.6. Although mean of the salt amount is 0.607, standard deviation of the salt amount is comparatively large, 0.505 while that of the NDVI is 17.51 (mean of the NDVI is 107.33). It is because that the location of insitu data of salt amount is not always the center of SPOT/HRV 20m pixel. Also situations of rice crops are different each other location. Namely, topological feature, shadow influences, illumination condition, soil condition, weather condition, etc. are different each other location.

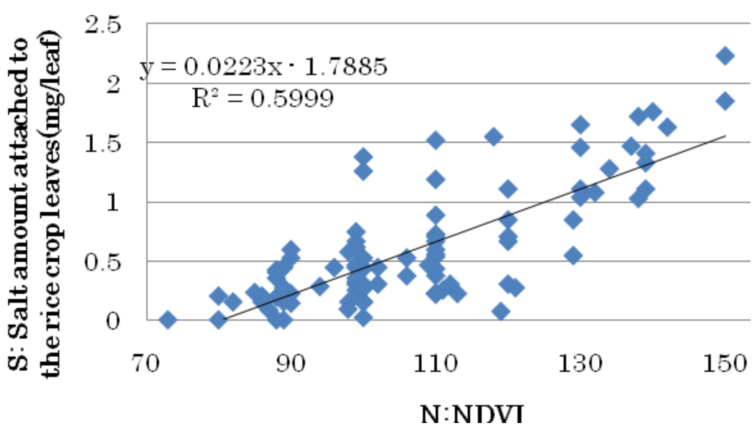


FIGURE 6 : Relation between NDVI derived from MODIS 250m and the correspoding location of insitu data of salt amount attached to the rice crop leaves.

3.4 Time Series Analysis

Two different spatial resolution of satellite imagery data are used for time series analysis. One is SPOT/HRV (High Resolution Visible) with 10m of spatial resolution and the other one is MODIS (Moderate Resolution of Imaging Spectrometer) on both satellites of Terra and Aqua with 250 m of spatial resolution. Characteristics of MODIS 250m of Leve-1B products are shown in Table 2.

Primary Use	Band	Bandwidth (nm)	Central Wavelength (nm)	Pixel Size (m)
Land/Cloud/Aerosols	1	620 - 670	645.5	250
Boundaries	2	841 - 876	856.5	250

TABLE 2: Characteristics of MODIS 250m of Level 1B data products

Acquisition dates are as follows,

SPOT/HRV: 25 August (Figure 3(a)), and Figure 7 of 20 September and 23 September (Off-nadir observation)
Terra/MODIS: Figure 8 of 24 August, 7 September, 20 September, 28 September, 19 October
Aqua/MODIS: 8 September, 26 September

The SPOT/HRV which was acquired on the closest time before the typhoon hit the Kyushu Island, Japan was acquired at 11:08 local time on 25 August while that of MODIS was acquired at 10:58 on 24 August 2006. Meanwhile, the SPOT/HRV which was acquired on the closest time after the typhoon hit the Kyushu Island, Japan was acquired at 11:18 local time on 20 September, just three days after the typhoon hit, while that of MODIS was acquired at 10:58 on 20 September 2006. By comparing the SPOT/HRV and MODIS imagery data which are acquired on the dates before and after the typhoon hit, damaged vegetation area and damage grade can be evaluated. Also once the regressive equation is created with the aforementioned SPOT/HRV and MODIS data together with the insitu data of attached salt on the vegetation, then trend analysis of damage grade can be done with the time series of the aforementioned MODIS data.

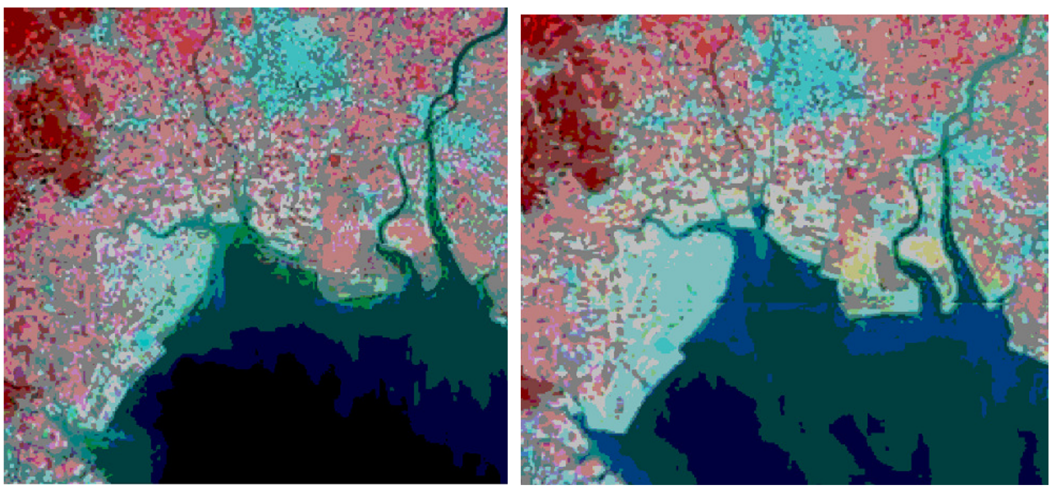
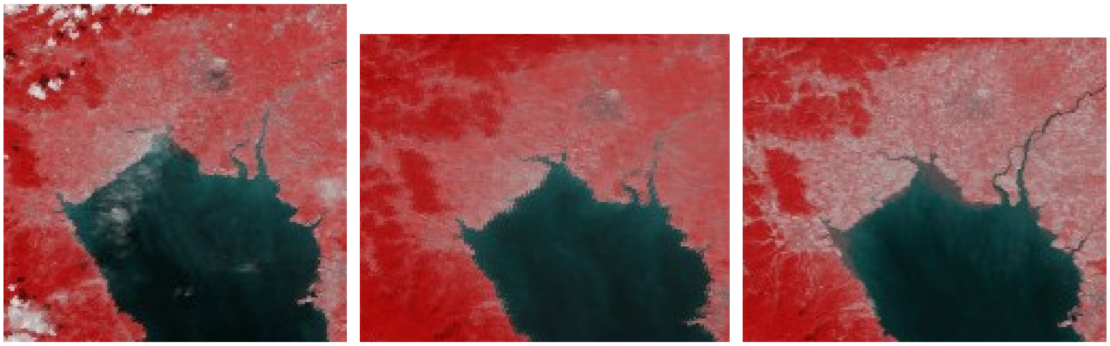


FIGURE 7 : Extracted and damaged area (light blue colored areas) with the enhanced SPOT/HRV images which were acquired on September of 20 (left) and 23 (right) 2006.

(a) August 25 **(b) September 7** **(c) September 20**



(d) September 26 (e) September 28 (f) October 19

FIGURE 8 Time series of MODIS data of Saga, Japan.

Fine days were continued a couple of weeks after the typhoon hit the Saga prefecture so that damaged areas was getting larger even for three days, as is shown in Figure 7. Damaged paddy field areas due to attached salt to the rice crop leaves got expanded around 34 % during three days, from September 20 to 23 2006 in comparison between two SPOT/HRV imagery data of September 20 and 23 2006 which is shown in Figure 7. Figure 8 shows the time series of MODIS images of southern portion of Saga prefecture which were acquired on August 25, September 7 (before the typhoon number 13 hit), September 20, 26, 28 (after the typhoon number 13 hit), and October 19 2006 (after harvest other crops). The first two images show almost same vegetation vitality. Within 13 days, from August 25 to September 7, all kinds of crops were grown-up so that vegetation vitality was increased a little bit. Turns out, MODIS image of September 20 shows remarkably changes in vegetation vitality, in particular, paddy fields which are situated in the coastal areas of Ariake Sea. Pink colored areas show degraded areas in vegetation vitality. The color of the paddy fields which are situated in the Ariake Sea coastal areas changed from red to pink. This implies that these areas were damaged by salt containing sea breeze from the typhoon number 13. Since then, the damaged area was getting larger by the time by time, September 26, 28 2006. After the remains of rice cop removals and harvesting other types of crops in the middle of October, vegetation vitality of all of the farm areas goes down sharply as is shown in Figure 8.

4. CONCLUSIONS

The proposed method for estimation of damage grade and damaged paddy field areas due to salt containing sea breeze with typhoon using remote sensing satellite imagery data is validated through experiments with SPOT/HRV of satellite imagery data and insitu salt amount attached to rice crop leaves. Equation which represents the relation between salt amounts attached to rice crop leaves and SPOT/HRV derived NDVI is created through linear regression with 0.6 of R square value. Also time series analysis method for damaged areas estimation due to attached salt is validated with MODIS 250m of level 1B data products.

5. REFERENCES

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