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PEST ATTACK DETERMINATION IN PADDY AREAS USING MULTISPECTRAL REMOTE SENSING IMAGES

FARANAK GHOBADIFAR

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By

Faranak Ghobadifar

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Doctor of Philosophy

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DEDICATION

Every challenging work needs self-efforts as well as guidance of elders especially those who were very close to our heart.

This is dedicated to:

My love, REZA, who has been a great source of motivation and inspiration

And also to:

My parents for their endless love, support and encouragement

Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy.

PEST ATTACK DETERMINATION IN PADDY AREAS USING MULTISPECTRAL REMOTE SENSING IMAGES

By

FARANAK GHOBADIFAR

February 2015

Chairman: Aimrun Wayayok, PhD

Faculty: Engineering

Infestation of rice plant-hopper is one of the most notable risks in rice yield in tropical areas especially in Asia. Early recognition of pest infestation by means of remote sensing will support precision farming practices. Farmers cannot determine the location of spread and apply pesticide at the right place within their farms. Under particular conducive environment such as high temperature and humidity, pest population will increase. The damage caused by the pest to crop is well known. The major aspects of satellite remote sensing are timely estimates of agriculture crop yield and prediction of pests and disease infestation. On-farm pest management and crop protection strongly depend on diagnosis of crop stress in the fields. The main purpose of this research was to determinate pest attack in paddy field using remote sensing by assessing weather data and their effect on the pests infestation.

To address this issue, detection of sheath blight in rice farming was examined by using SPOT-5 images for discriminating healthy parts from unhealthy ones. Specific image indices such as Normalized Difference Vegetation Index (NDVI), Standard difference indices (SDI) and Ratio Vegetation Index (RVI) were used, for analyses using ENVI
4.8, SPSS and ArcGIS software. Also, this research presents the extraction of weather data such as temperature and relative humidity (RH) derived from Landsat images by investigating and comparing with the pest infestation during special time. The data set satisfied several quality criteria and was used for extracting temperature (T), Normalize Difference Vegetation Index (NDVI), Relative Humidity (RH) and Extraterrestrial radiation (R_a) from Landsat images.

Results showed that all the indices to recognize infected plants from uninfected ones are significant at $\alpha = 0.01$. It showed that the indices can be good indicators for pest discrimination in the paddy areas. Examination of the association between

the disease indices indicated that band 3 (near infrared) and band 4 (mid infrared) in SPOT-5 images have a relatively high correlation. Image investigations revealed that pest were existing at the higher limits of tolerable temperatures when at nymph's stage. By this means, models for each date were created, consequently, based on the model and analysis it can be concluded that pest can be alive at the higher limits of acceptable temperatures and RH. Therefore, it states that between tillering to flowering stage of paddy which encounter with March while the plants are between 70 and 90 days of the growth stage, high temperature up to 32°C and also RH up to 85% cause increases in distribution and survival of pest. Transferring from one growth stage to the other for pest was caused by temperature. Based on the models temperature and RH are two significant factors which can affect pest infestation in the field. On the other hand, indices like NDVI, SDI and RVI stated differences between infected parts from healthy plants. Consequently, it can be concluded that it is better to use any method for preventing from pest attack at early March.

Abstrak tesis yang dikemukakan kedapa Senati Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENENTUAN KAWASAN SERANGAN SERANGGA PEROSAK DALAM PENANAMAN PADI MENGGUNAKAN TEKNOLOGI PENDERIAAN JAUH MULTISPECTRAL

Oleh

FARANAK GHOBADIFAR

Februari 2015

Pengerusi: Aimrun Wayayok, PhD

Fakulti: kejuruteraan

Serangan serangga terhadap padi seperti Bena Perang (BPH) (*Nilaparvata lugens*) merupakan salah satu risiko yang paling ketara bagi hasil padi di kawasan tropika terutamanya di Asia. Pemastian awal serangan perosak melalui penderiaan jauh akan menyokong amalan pertanian presis iaitu petani boleh menentukan lokasi pertaburan dan mereka boleh memberi racun perosak di tempat yang betul di dalam ladang mereka. Di bawah persekitaran yang kondusif tertentu seperti suhu yang tinggi dan hujan lebat, bilangan BPH akan meningkat. Kerosakan yang disebabkan oleh perosak ini terhadap tanaman telah diketahui. Aspek utama penderiaan jauh adalah menganggar hasil pertanian yang tepat pada masanya dan meramalkan perosak. Pengurusan perosak diperingkat ladang dan perlindungan tanaman sangat bergantung kepada diagnosis penyakit tanaman di ladang. Tujuan utama kajian ini adalah untuk mewujudkan sistem amaran awal untuk mengesan BPH dalam penanaman padi menggunakan teknologi penderiaan jauh untuk menilai data cuaca. Untuk menangani isu ini, kekeringan daun yang rosak bagi tanaman padi telah diperiksa dengan menggunakan imej SPOT-5. Indeks imej tertentu seperti Indeks Perbezaan Normal Tumbuhan (NDVI), Indeks Perbezaan Standard (SDI) dan Indeks Nisbah Tumbuhan (RVI) telah digunakan, untuk analisis menggunakan ENVI 4.8, SPSS dan perisian ArcGIS. Juga, kajian ini membentangkan pengekstrakan data cuaca berasasuan imej Landsat dan dibandingkan bersama serangan BPH. Data yang diekstrak daripada imej dengan menggunakan ENVI 4.8 telah dianalisis perhubungan mengguna perisian SPSS. Set data memuaskan beberapa kriteria kualiti dan telah digunakan untuk mengeluarkan nilai suhu (T), Indeks Perbezaan Normal Tumbuhan (NDVI), Kelembapan Relatif (RH) dan radiasi ruang angkasa (Ra) dari imej Landsat. Keputusan menunjukkan bahawa semua indeks untuk mengenali tumbuh-tumbuhan yang dijangkiti adalah signifikan pada $\alpha = 0.01$. Pemeriksaan hubungkait antara indeks penyakit menunjukkan bahawa band 3 (berhampiran inframerah) dan band 4 (inframerah pertengahan) dalam imej SPOT-5 mempunyai korelasi yang agak tinggi. Indeks yang dipilih dianggapkan mempunyai hubungkait yang lebih baik bagi mengesan kawasan yang mempunyai tumbuhan yang sihat berbanding kawasan yang berpenyakit. Siasatan imej meunjukkan bahawa BPH mampu berada pada had suhu yang lebih tinggi apabila

ia diperingkat nymphs. Melalui sistem amaran awal yang mencipta model untuk setiap tarikh, akibatnya, ia menyatakan bahawa dengan pengetahuan bahawa dipenghujung peringkat pertumbuhan mempunyai serangan BPH yang lebih teruk, dan keputusan menyatakan bahawa wabak BPH amat jelas di sudut Utara Barat dan tengah dalam peta kawasan kajian dan ia adalah lebih cenderung untuk berlaku dalam julat suhu dan RH tertentu, iaitu 29°C <T <32°C dan 88% <RH <93%. Apabila suhu dan RH menjadi lebih tinggi daripada tarikh lain seperti dalam bulan Mac, serangan BPH akan meningkat. Dengan cara ini, ia boleh membuat kesimpulan bahawa suhu dan RH adalan dua parameter yang efektif dan penting untuk serangan perosak ini.

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At the end I want to confess that I will truly cherish the past three years at UPM for the rest of my life.

APRROVAL

I certify that a Thesis Examination Committee has met on 13 February 2015 to conduct the final examination of Faranak Ghobadifar on her thesis in title" PEST ATTACK DETERMINATION IN PADDY AREAS USING MULTISPECTRAL REMOTE SENSING IMAGES" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U. (A) 106] 15 March 1998. The committee recommends that the student be awarded the Doctor of Philosophy.

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University of Florida.
(External Examiner)

Prof. Ir. Dr. Desa Ahmad
Professor
Faculty of Biological and Agricultural
Universiti Putra Malaysia
(Chairman)

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Professor
Faculty of Biological and Agricultural
Universiti Putra Malaysia
(Internal Examiner)

Assoc. Professor Dr. Abdul Rashid bin Mohamed Sharif
Associate Professor
Faculty of Biological and Agricultural
Universiti Putra Malaysia
(Internal Examiner)

Zulkarnain Zainal., PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follow:

Aimrun Wayayok
PhD
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Shattri Bin Mansor
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Helmi Zulhaidi Bin Mohd Shafri
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

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Name of
Member of
Supervisory
Committee _____

Signature: _____
Name of
Member of
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Committee _____

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LIST OF ABBREVIATIONS

BIO - Percentage Biomass

BPH - Brown Planthopper

˚C - Degrees Celsius

DN - Digital Number

FAO - Food and Agricultural Organization

FR- False rate

GIS - Geographic Information Systems

IPM - Integrated Pest Management

K - Degrees Kelvin

LST - Land Surface Temperature

LAI - Leaf Area Index

L - Spectral Radiance Range

LR- logistic regression

MIR - Mid Infrared

MODIS- Moderate-resolution Imaging Spectroradiometer

NDVI - Normalized Difference Vegetation Index

NIR - Near Infrared

NRSA - National Remote Sensing Agency

PAR- Photosynthetically active radiation

PH - Plant Height

R^2 - Coefficient of Determination

Ra - Extraterrestrial radiation

RH - Relative Humidity

RSI - Ratio Significance Index

RVI- Ratio Vegetation Index

SDI - Standard Difference Indices

SM - Soil Moisture

SPOT - Satellite Pour l'Observation de la Terre

SSEB- Simplified Surface Energy Balance

T - Temperature

TC - Total Chlorophyll

T_{dew} - Dew Point Temperature

VRT - Variable Rate Technology

ʎ - Wavelength

µm - Micrometer

CHAPTER 1

INTRODUCTION

1.1 Background

Rice is considered as an important crop globally when more than half of the world's population depends on it for supplying food. There are many parameters that can affect sustainable farming of rice, including timely and appropriate pest control to maintain the crop. The potential of remote sensing makes it useful as a proficient and low-priced system to recognize unhealthy plants in a ground scale, primarily for the reason that infected plants contain various spectral reactions in comparison to healthy ones (Zhang et al., 2002).

Between fifteen species of leafhoppers and planthoppers known to attack rice in tropical regions, whitebacked planthopper (WBPH), brown planthopper (BPH), Nilaparvata lugens; Sogatella furcifera, and green leafhopper (GLH), Nephotettix viruses are the great dangerous ones.

Figure 1.1. Rice plants affected by pest

Since the green revolution began a variety of thoroughly correlated Delphacid planthoppers have caused remarkable problems for rice farmers in Asia. These consist of the brown planthopper (*Nilaparvata lugens*), the small brown plant hopper (*Laodelphax striatellus*) and the white-backed planthopper (*Sogatella furcifera*). Absolutely these sort of species were observed at low levels in tropical rice paddies previous to the arrival of high-input farming apparently by natural enemies, when blown northwards by converging winds only

causing damage in northern Asia as well (China, Korea and Japan) (Shepard et al., 1991; Otuka et al., 2009). The relationship between the developing pest position of planthoppers and agricultural strengthening in the 1960s and 70s were pointed to the effects of current farm management performs in supporting build-up of hopper populations and eventual harms in tropical rice (Shepard et al., 1991).

The eggs of BPH hatches in 4-8 days. Colors of nymphs are creamy white with a light brown tinge, which becoming dark brown. They live for four to five mouth and adults are brownish black with a yellowish-brown body.

Figure 1.1. BPH in adult form

The appearance of the winged form started infestations, then create wingless categories. When numbers become high the winged form mature; males are about 4.5 mm and females are 4 mm; wingless forms are slighter. The planthoppers transfer to grasses after harvest, or blow-out to new crops of rice. The life of Brown planthoppers are up to 20 days.

The eggs are pushing in a straightforward line commonly beside the mid-region of the leaf sheath and they flyblow in about six to nine days.

In general, planthoppers generally remain confined to plant stems and leaf sheaths while leafhoppers occur on plant foliage. Due to this habit, planthoppers are over- looked by farmers until appearance of 'hopperburn' symptoms in which crop starts drying and lodging. However, during outbreaks, planthoppers can be witnessed in abundance on leaves also.

1.2 Statement of the Problems

Based on previous researches the damage caused by the pest to crop is well known. Rice farming managers cannot prepare a good prediction of how their farms are in the risk due to attack of pest. So pest detection in rice is critical and early warning sȳstem for pest detection is not available in farms during rice growing. Currently, farmers apply the pesticide or insecticide for the pests in their farms based on farming schedule i.e. age of the rice, without having a precise information on the existence of the pest or insect, because there is a limitation of the available information about it. In result, pest prevention method is the costly act and on the other hand, using inappropriate content of pesticide has many harmful consequences on paddy, particularly, when it use in inappropriate time. So, there is a need to create an early warning map or schedule based on different factors such as weather factor and age of paddy which are attributing to pest population growth for the farmers to know about the time of attack and infestation. Finally, make a decision for having some prevention methods.

Regarding to the high usage, insecticide persistence go to be a significant problem. Farm managers or farmers reacted by rising dosages or by incorporating various chemicals in toxic combinations. In conclusion, even many useful and natural predators were murdered, insecticide persistence made up was advanced, and the environment and human health were moreover threatened (George W, 2010).

The major aspects of remote sensing in agriculture are timely estimates of agriculture crop yield and prediction of pests and diseases. There are few investigations on remote sensing applications to pests of rice (Zhang et al., 2003). Probability for methods of sensing to worldwide problems has long been argued (Cline, 1970). Basically planning application to verify the associate variable and process for existing epidemiological claim remote sensing can be exposed remotely (Hay, 1997).

The main purpose of this research was investigating significant pest and diseases in paddy fields by using multispectral RS data instead of very high resolution ones, on the other hand, several weather parameters which can effect on their infestation were examined for making precise schedule for the farmer to prevent in the proper time with proper method.

1.3 Objectives of the study

On-farm pest management and crop protection strongly depend on diagnosis of crop stress in the fields. Initial recognition of pest infestation by means of remote sensing will decrease food production lose, limit environmental hazards and enhance natural pest control before the problem spread.

The main purpose of this research was to create an early warning schedule for pest infestation in rice farming using remote sensing by assessing weather data and also:

1. To discriminate healthy plant from unhealthy ones in the rice farming using RS

2. To determine the conducive environment for spread of pest in paddy fields i.e. temperature and RH for determining the attractive environmental parameters using RS data such as Landsat 7 and Landsat 8/thermal bands

3. To establish an early warning technique for pest and diseases in rice farming by weather data extraction and their influence on pest infestation. Utilizing the data acquired by remote sensing to develop as a tool for an early warning system to the farmers to prevent from the widespread attack by pests in appropriate time.

1.4 Scope and limitations

Various factors such as intensive cultivation, mono cropping, changing weather conditions and indiscriminate use of pesticides have resulted in frequent outbreaks of crop pests and diseases causing huge crop losses.

By use of early warning system, the facts that, weather conditions such as temperature, humidity (moisture) and heavy rainfall play major influence on the densities of pest population were detected in this investigation.

The scope of this research was to evaluate the potential application of new images to detect ground surface changes and also for weather condition which promoted change detection and threshold methods on the images. For discriminating the special spectral contrast and recognize the diseased plants or patches in the field by using remote sensing.

The limitation of using RS in the agricultural investigation especially in this examination are:

1.4 RS images are not available in all the time for every research and purpose, especially in the research area.
1.4.2 Weather data from station do not cover all parameters and the date for all parameters was limited, etc.
1.4.3 The absence of imagery with optimal spatial and spectral resolutions and a critical revisit time for most crop stress-detection applications are two acute limitations for using current satellite sensors in real- time crop management.
1.4.4 Just Block C was available for research and it does not cover wide area to investigate more.
1.4.5 Cloudy and unstable weather condition and cloudy images in the area.

1.5 Thesis Layout

Pests and diseases in rice farming could have major undesirable effects on the production everywhere in the world. In both spatial and temporal scales there is a necessity for organization and exhibiting the features and mutability of crop pests and diseases for an agricultural district. Hence, to consider this subject, the existing investigation will scheme and fulfil a pests and diseases database for rice in Malaysia using remote sensing analysis, database administration and network knowledge.

The main intention of this examination is to evaluate the effectiveness of integrated pest management on environmental and weather foundations for generating a proposal and awareness for agriculturalists about rice pests. Furthermore, to produce an early warning system for BPH detection in rice farming by means of remote sensing to assess chlorophyll content and weather data.

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