

High Spatial Resolution RGB and NIR UAV Based Imagery for Detection of Ganoderma Disease in Oil Palm

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Introduction

- Oil palm (*Elaeis guineensis* Jacq.) the most important agriculture sector in Malaysia.
- Damage and loss due to pests and diseases are considered serious problems and can reduce the profitability of the business and jeopardise the growth of the industry over time.
- Three major oil palm threats for the crop losses can be classified into insects, vertebrates and diseases.
- Monitoring agricultural areas are time and labour consuming – dealing with large area of homogenous crop.

Introduction

- Remote sensing technology - synoptic view of the large plantation area - possibility to monitor the state of vigorousness and stress due to disease, pest and nutrient deficiency.
- The use of remote sensing technology in detection and monitoring of existing infected area with *Ganoderma* BSR is possible and opens new horizon in *Ganoderma* BSR study.
- Disease and pest detection and control are important phases in agricultural management. Cultural practices combined with biological and chemical control have been considered as the best approach for controlling diseases and pests. Remote sensing provides a possible solution to the intensive sampling required for site-specific pest management.

Research Timeline - *Ganoderma* Detection Using Remote Sensing Technology

- 2008 – Baseline study using handheld spectroradiometer (seedlings, young and mature palm).
- 2010 – Hyperspectral data acquisition using airborne carrier (over ground thruthed area for young and mature palm).
- 2013 – UAV (RGB/NIR) data acquisition over ground thruthed mature palm)
- 201? – Baseline study using RADAR technology.
- 201? – Hyperspectral data acquisition using UAV (over ground thruthed data for young and mature palm).

Ganoderma BSR

- Basal Stem Rot (BSR) caused by fungi - *Ganoderma* (wood decaying fungi). Fatal disease – most serious disease of oil palm in Malaysia for over 80 years and has caused severe economic loss in Malaysia.
- The soil-borne fungi attack the oil palm tree from the roots and progressively spread to the stem and bole system.
- The disease causes root rot, which prevents water and nutrient uptake by the plant. This results in foliar symptoms and gradually affects the growth and yield, eventually leading to the death of the palm
- Vegetation loss after repeated planting cycles.



Pathological Symptom



Detection of *Ganoderma* BSR

- Visual interpretation - detect the mortality towards BSR, middle or late stages of disease pathology. Stress diagnoses based on plant sampling and physiochemical analysis using traditional methods are commonly time-consuming, destructive and expensive.
- Early detection / aerial detection – enable treatment at the early stage of the infection and avoid more extensive damage and losses.
- Detection of subclinical symptom of *Ganoderma* could be achieved through GSM test, PCR-DNA molecular, ELISA-polyclonal antibody and GanoScan1 tomography (Idris, 2009).

Disease Severity Index (DSI)

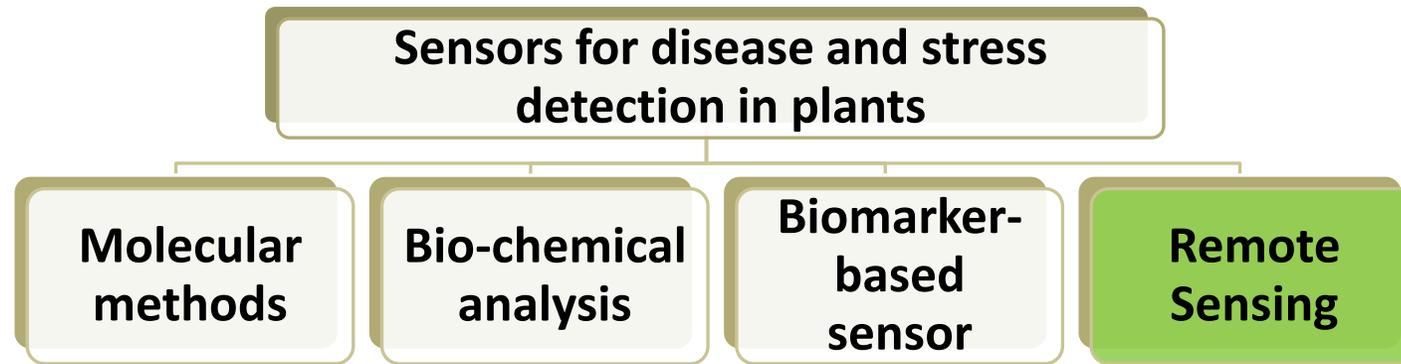
T0 Healthy palm	T1 Mild infected palm	T2 Moderate infected palm	T3 Severe infected palm
No fruiting body, foliar symptom and stem rotting	Presence of fruiting body. No foliar symptoms and no stem rotting	Presence of fruiting body. Foliar symptoms (<50%) and slightly stem rotting (<30%)	Presence of fruiting body. Severely foliar symptom (>50%) and stem rotting (>30%)
			

Why Remote Sensing?

Ganoderma Workshop 2014 (MPOB and Oil Palm Stakeholders) :

- Early detection tools – more sensitive, precise and localize
- Standardize the methods and classification – visualize
- Faster, cheaper and precise remote sensing and GIS
- Aerial detection – need estimation for the statistical analysis using hyperspectral remote sensing.
- Estate experience 1 UAV for 500 ha per day, depend on certain limitation

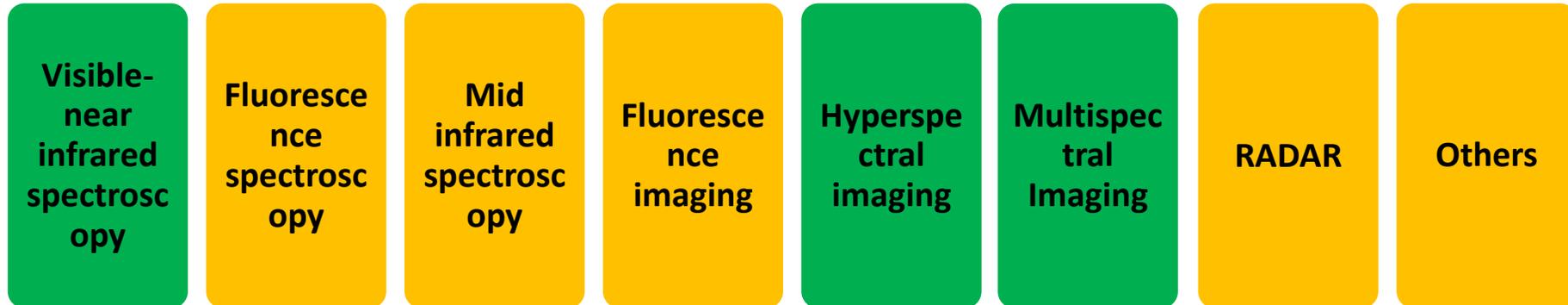
Satellite, Airborne RS has been and always will continue to be a very important factor in the improvement of the present systems of acquiring and generating agricultural and resources data.



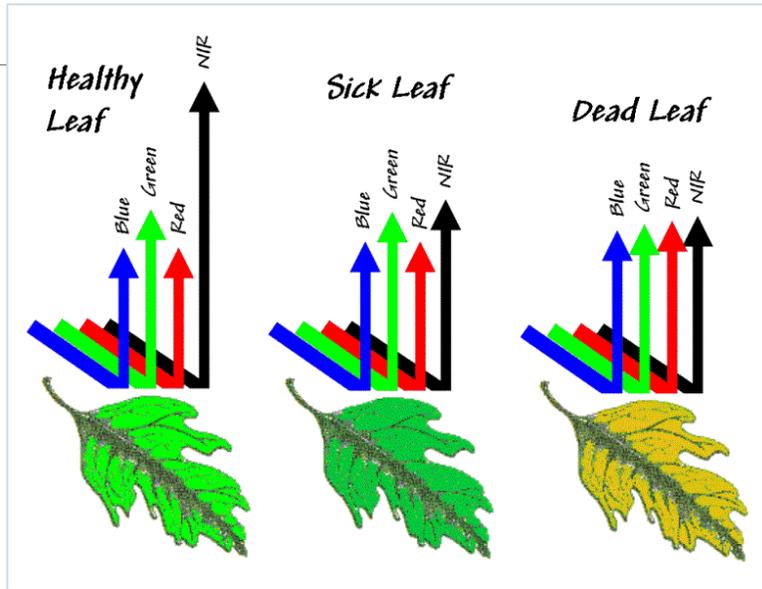
Remote Sensing

Spectroscopic Techniques

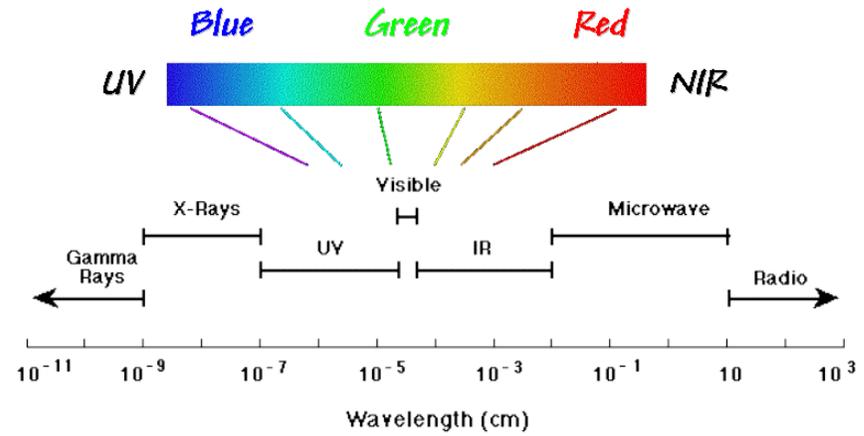
Imaging Techniques



Remote Sensing Properties of Plant

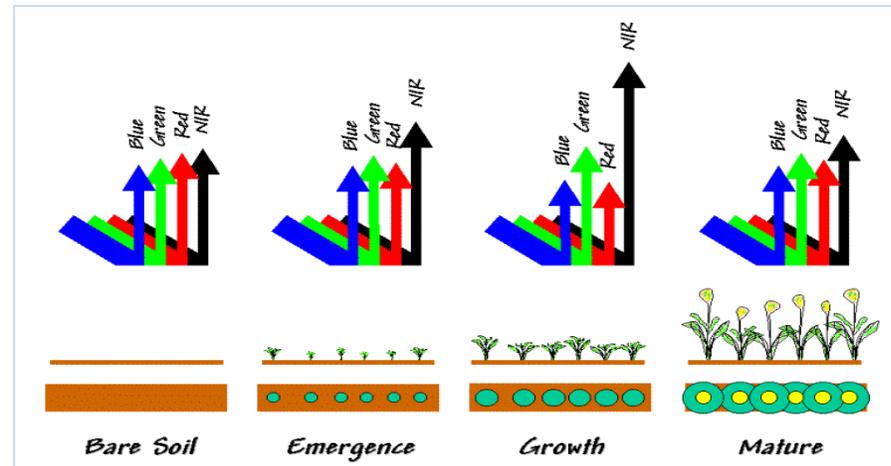
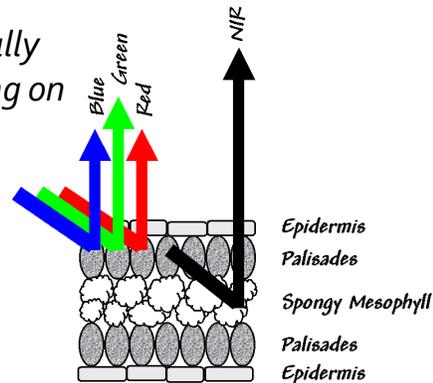


...Electromagnetic Spectrum (Light+)

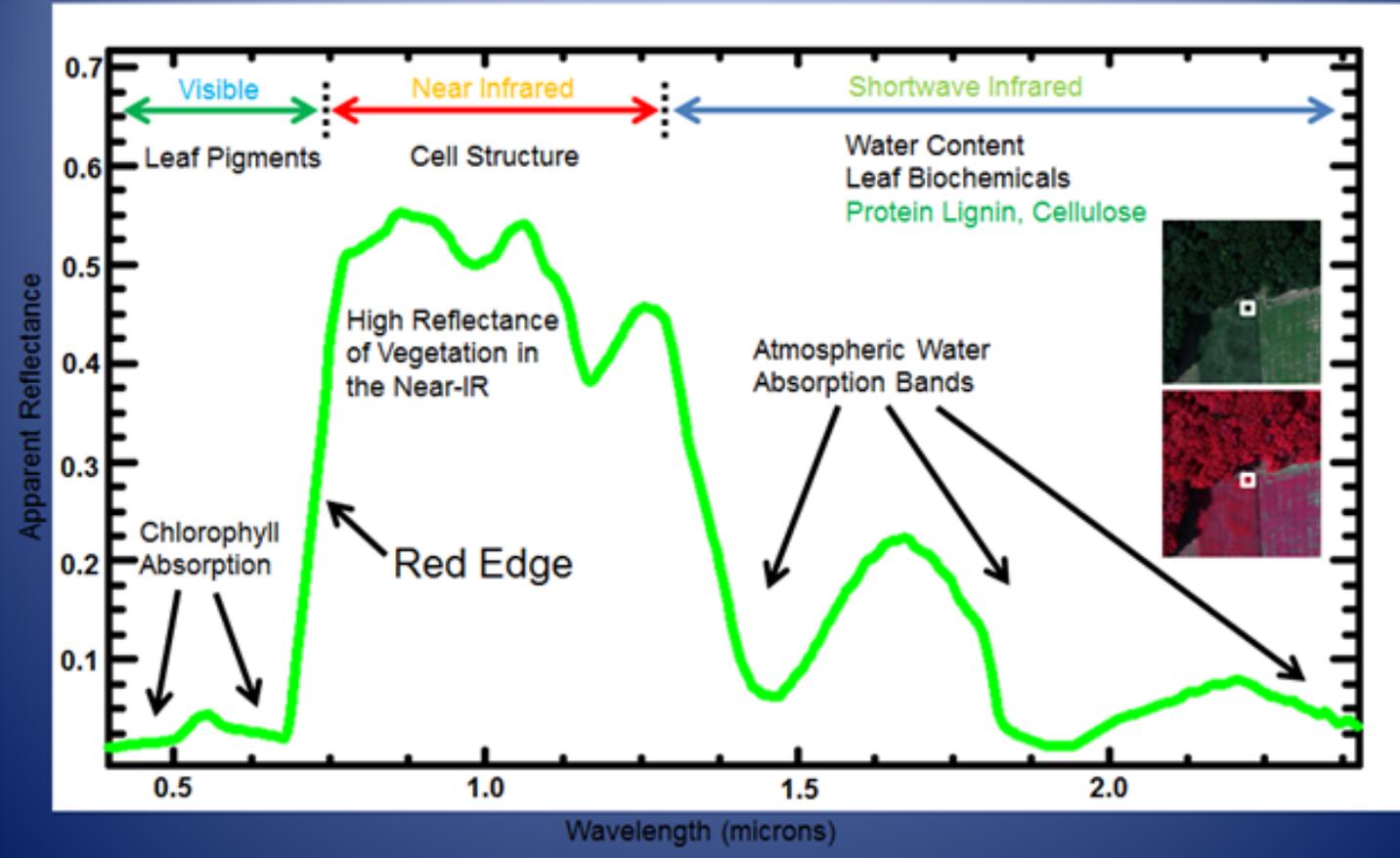


...incoming light is preferentially absorbed (reflected) depending on plant physiology

- Species
- Photosynthesis
- Water Content

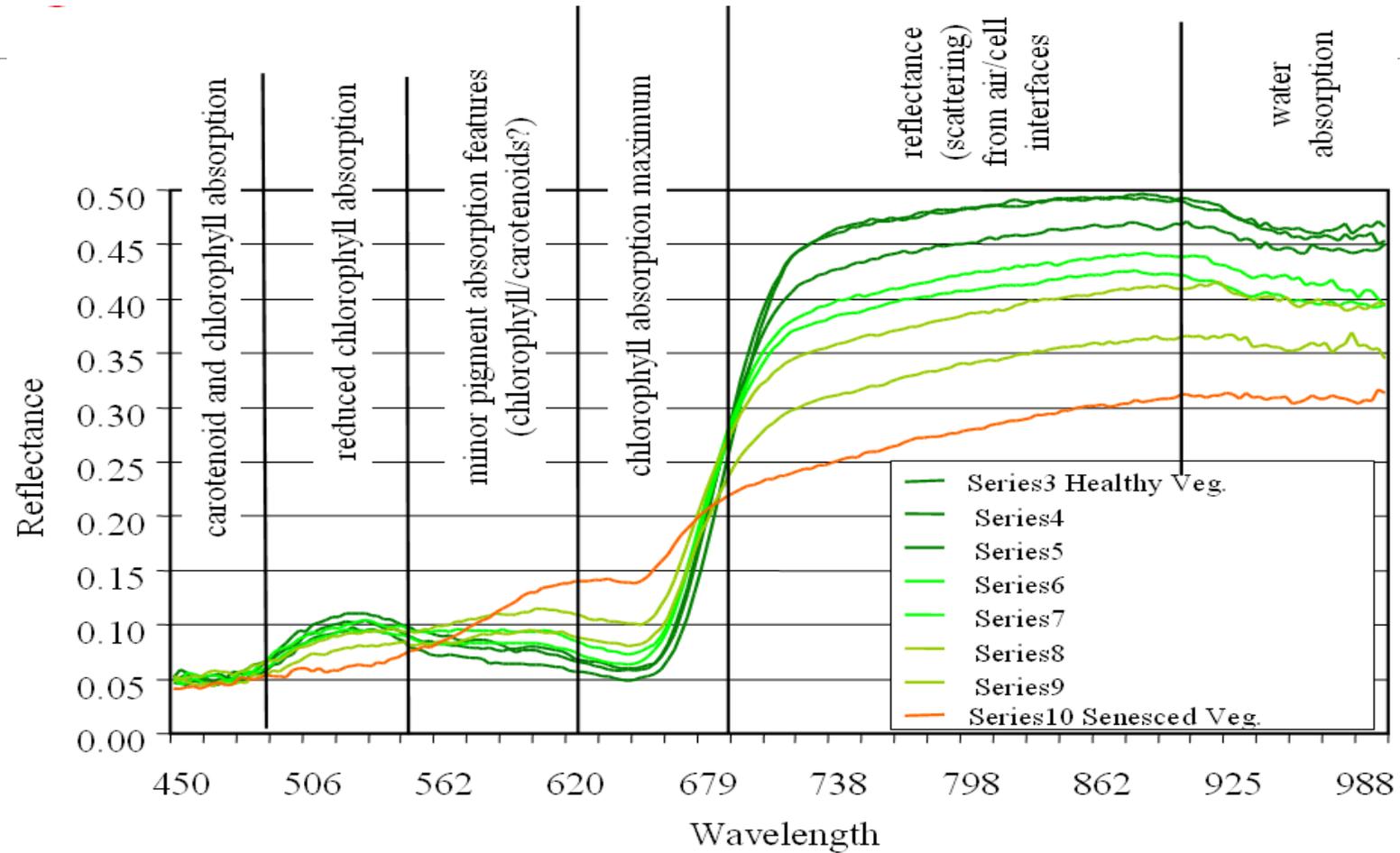


The Vegetation Spectrum in Detail



Elowitz (2013) @ <http://www.markelowitz.com/Hyperspectral.html>

Biochemical Response of Leaves



Remote Sensing Research on *Ganoderma*

Spectroradiometer (Baseline Study - GER1500)

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graph TD; A[Spectroradiometer (Baseline Study - GER1500)] --> B[Hyperspectral (AISA DUAL)]; B --> C[Multispectral (UAV Swinglet - Canon IXUS)]; C --> D[RADAR (Baseline Study)]; D --> E[Hyperspectral UAV (Verification)];
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Hyperspectral (AISA DUAL)

Multispectral (UAV Swinglet – Canon IXUS)

RADAR (Baseline Study)

Hyperspectral UAV (Verification)

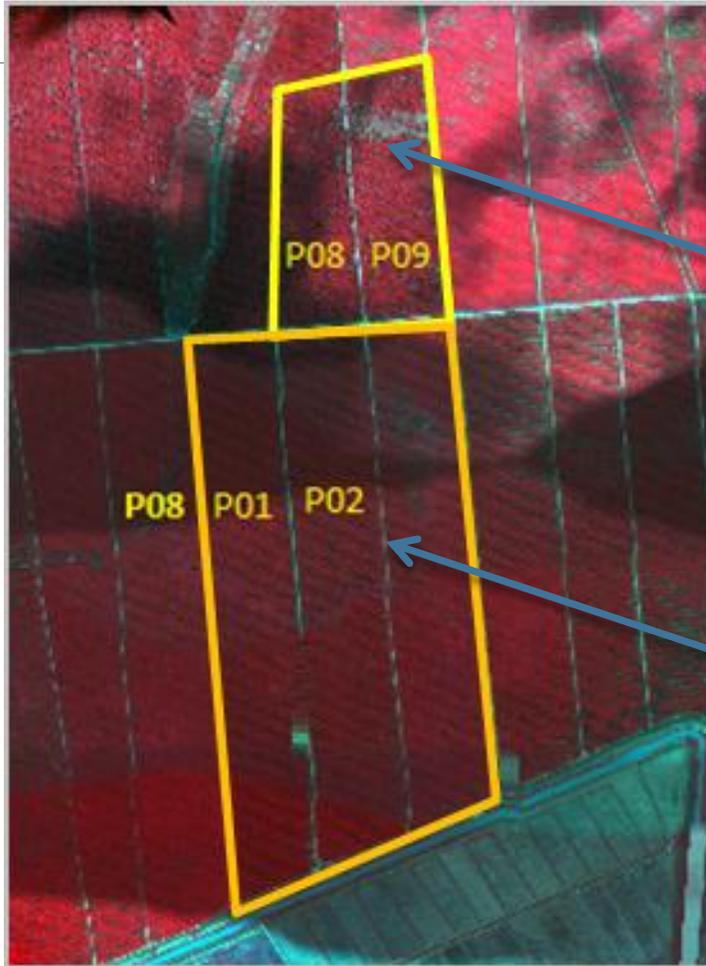
Data Acquisition & Equipment



Data Acquisition and Equipment



Study Area – Planted Palm / Airborne AISA Dual Hyperspectral Sensor

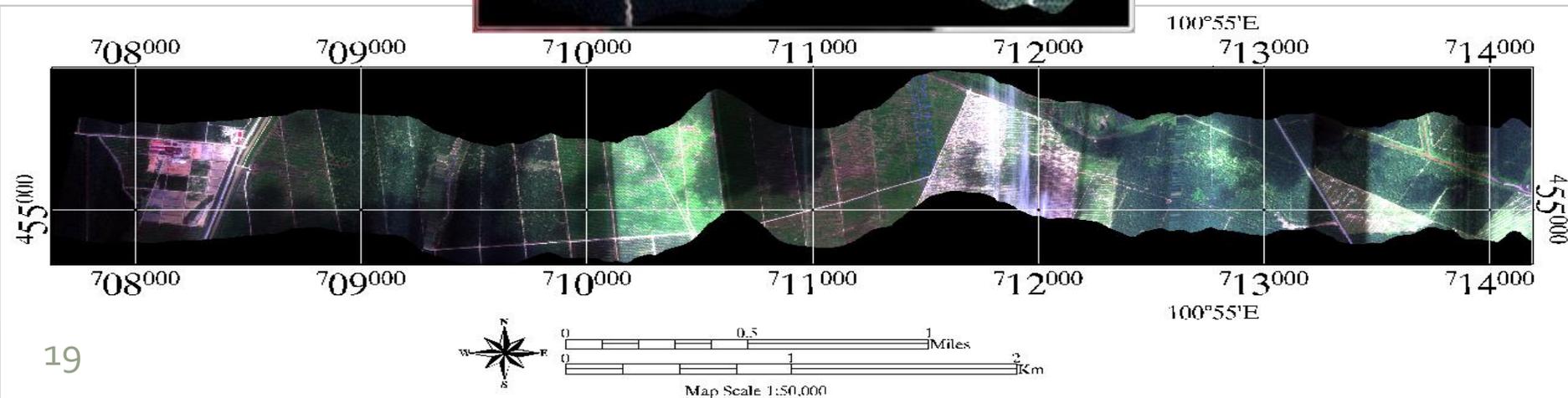
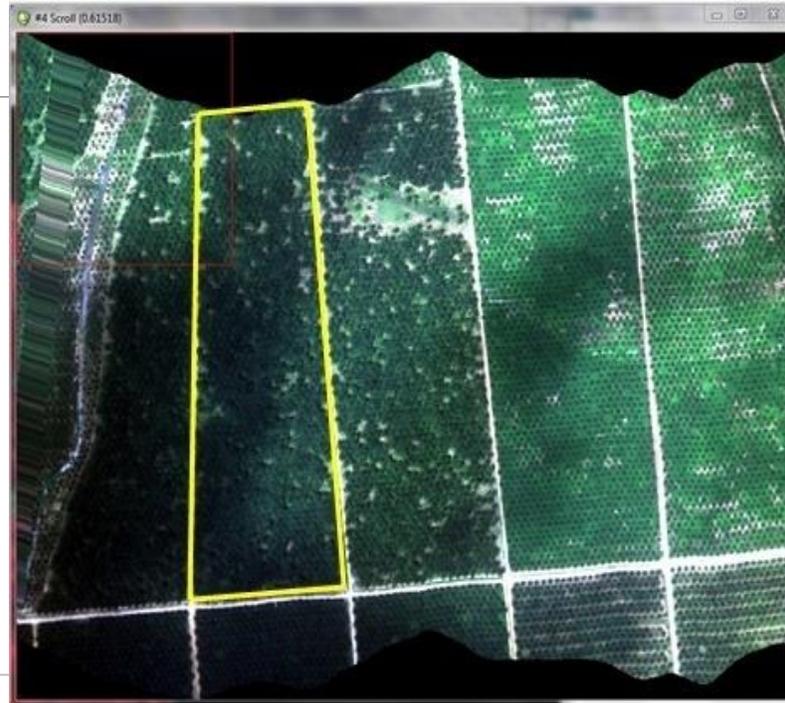


- Oil palm plantation in Seberang Perak, Perak, Malaysia ($4^{\circ} 6' N$ $100^{\circ} 53' E$).

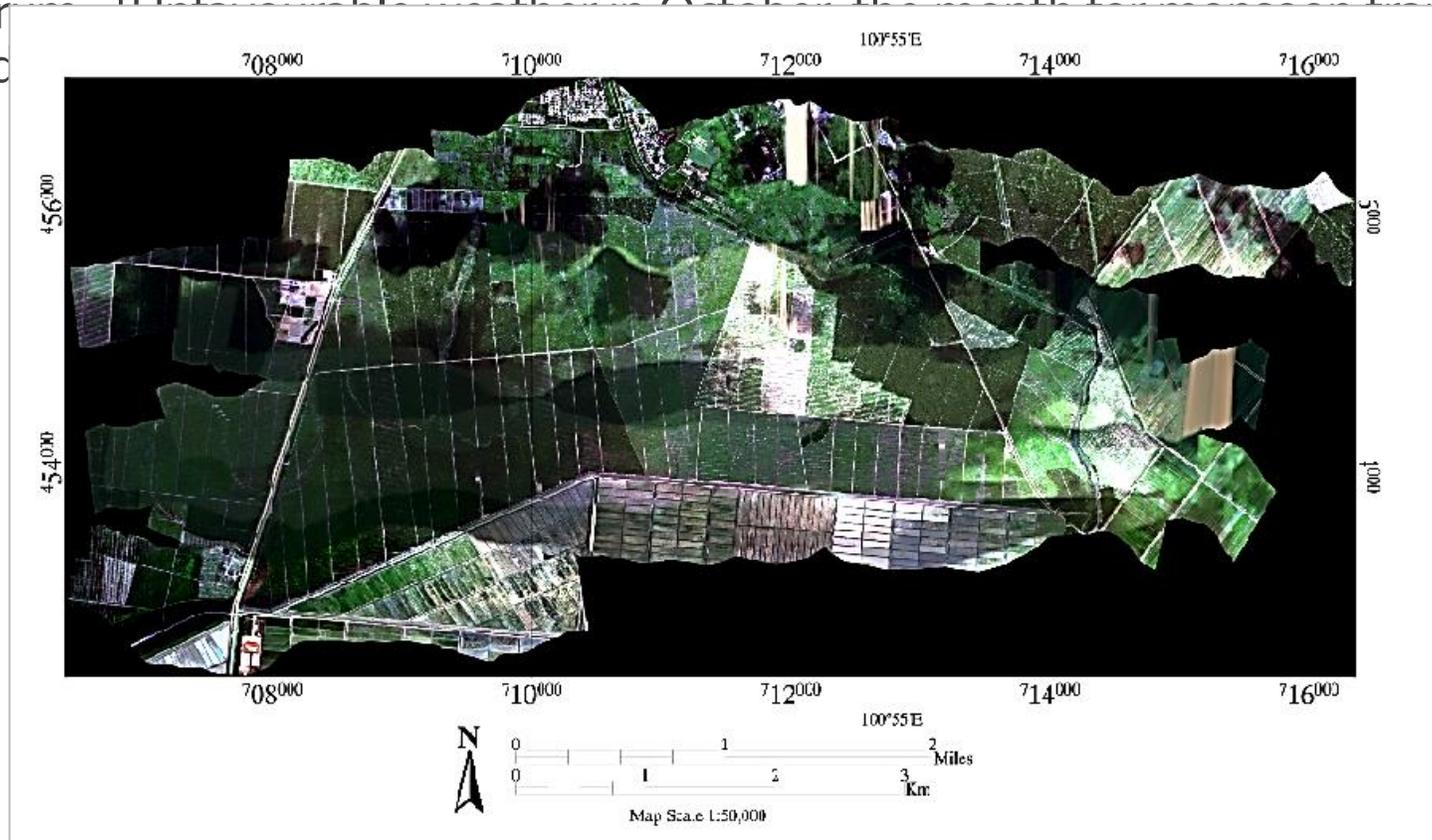
Mature palm 17 years old

Young palm 5 years old

AISA Hyperspectral Image



The hyperspectral image acquired on 20 October 2008, showing the effect of fluctuations in solar illumination during flight. However only two plots were selected from the image and fortunately the selected ground areas have minimal cloud coverage. Cloud cover significantly impacts the optical parts of the spectral period



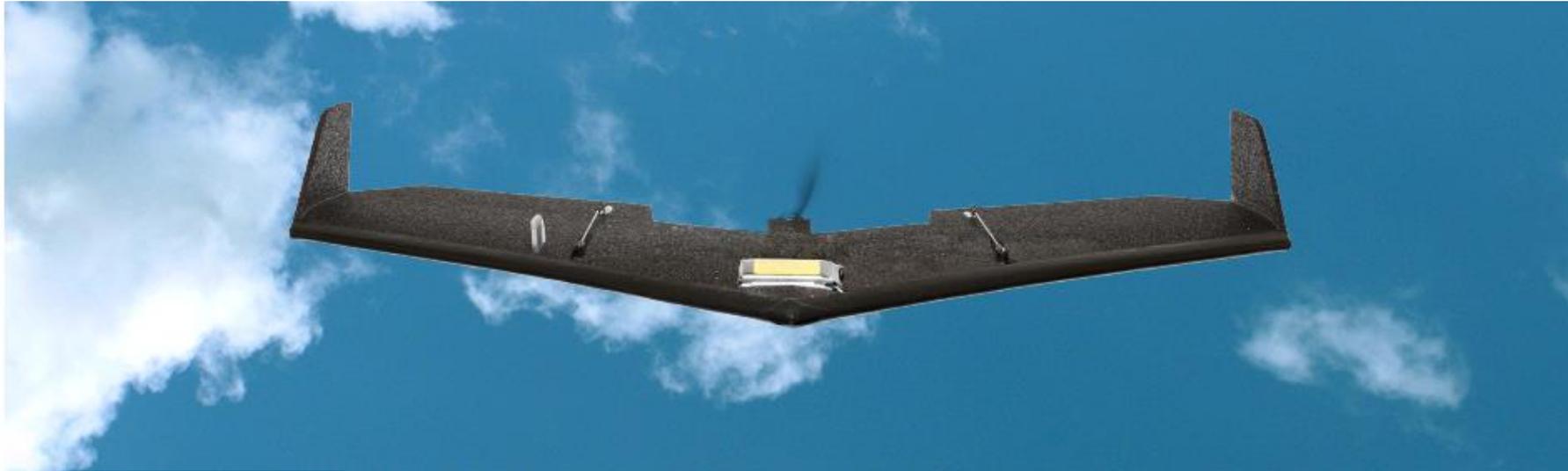
Unmanned Aerial Vehicle (UAV)

- The advancement of remote sensing technology in providing a **synoptic view** – provides possibility to monitor a large plantation state of vigorousness and stress due to disease, pest and nutrient deficiency.
- UAV has become commercially available nowadays – have the **advantages of high spatial and temporal resolution** characteristics compared to airborne and satellite platforms. Many interest due to the simplicity of the system.
- UAV promotes the remote sensing technology in **detection and monitoring** of existing plot infected with *Ganoderma* BSR.
- The foliar symptoms of *Ganoderma* BSR are prominent and visible at certain levels of infection and can be discerned through the human eyes.

Unmanned Aerial Vehicle (UAV)

- Same visual detection concept is applied to the RGB image; since it corresponds to the optical concept of a human's eye.
- The use of NIR cameras in the UAV is additional whereby it implies the high reflectance of vegetation in the NIR region invisible to the human eye to demonstrate the health of the plant.
- The RGB and NIR images are coupled with GIS analysis to achieve the aim to monitor *Ganoderma* BSR in oil palm plantation.

Data Acquisition and Equipment



Flight Planning

The screenshot displays a flight planning application window titled "e-mo-tion - [Map]". The interface includes a menu bar (File, Map, Window, swingle_t_cam_0), a toolbar with navigation icons, and a zoom control. The main map area shows a satellite view of a field with a red circular boundary and a "CONNECTION NOT AVAILABLE." warning. A red diagram of a quadcopter is overlaid on the map, with the text "274m274m274m" below it. The left sidebar contains various status indicators and controls, including buttons for "GO TO HOME WAYPOINT", "INITIATE LANDING", "GO TO NEXT WAYPOINT", and "ABORT LANDING". It also displays flight data such as "WIND 1.5 m/s", "GROUND SPD 0.0 m/s", "DIST. TO HOME 15.1 m", "ALT AMSL 18.7 m", "TIME IN FLIGHT 24:44.3", "THRUST 0%", "REMOTE CTRL NO LINK", and "CONTROL AUTO". The bottom status bar shows the time "10:27:29".

	ACT	NXT	CUR	HGT	RAD	DIR
H	<input checked="" type="checkbox"/>	N/A	<input checked="" type="checkbox"/>	75	20	<input type="checkbox"/> CW
0	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	100	30	<input type="checkbox"/> CW
1	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	274	80	<input type="checkbox"/> CW
2	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	274	80	<input type="checkbox"/> CW
3	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	274	80	<input checked="" type="checkbox"/> CW
4	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	274	80	<input type="checkbox"/> CW
5	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	274	80	<input checked="" type="checkbox"/> CW
6	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	274	80	<input type="checkbox"/> CW
7	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	274	80	<input type="checkbox"/> CW
8	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	100	30	<input type="checkbox"/> CW
9	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	100	30	<input type="checkbox"/> CW
10	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	100	30	<input type="checkbox"/> CW
11	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	100	30	<input type="checkbox"/> CW
12	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	100	30	<input type="checkbox"/> CW
13	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	100	30	<input type="checkbox"/> CW
14	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	100	30	<input type="checkbox"/> CW
15	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	100	30	<input type="checkbox"/> CW
16	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	100	30	<input type="checkbox"/> CW
17	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	100	30	<input type="checkbox"/> CW
18	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	100	30	<input type="checkbox"/> CW
19	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	100	30	<input type="checkbox"/> CW

Selected waypoint
 Action: None
 LAT: 4.0991594 LON: 100.8859153
 Place on map Reset
 All waypoints
 Refresh all Save to autopilot
 Export... Import...
 ON LATITUDE LONGITUDE
 A 0.0000000 0.0000000
 B 0.0000000 0.0000000
 C 0.0000000 0.0000000
 D 0.0000000 0.0000000
 E 0.0000000 0.0000000
 Place on map Refresh all

UAV Flight Mission

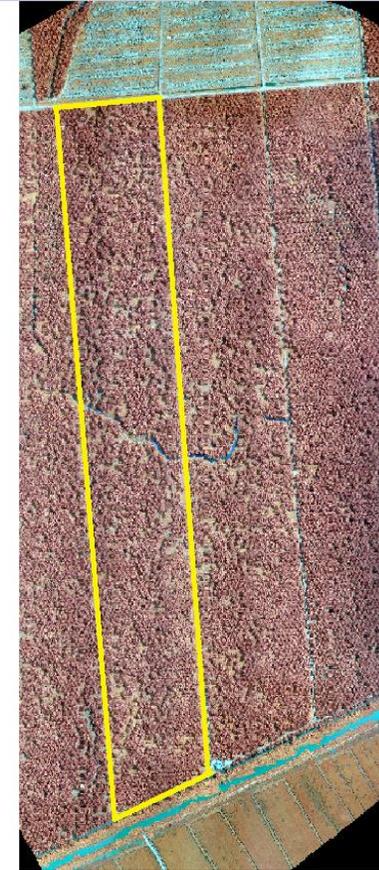


Image Acquired From UAV

<i>Band</i>	<i>Resolution</i>	
	<i>Spectral (nm)</i>	<i>Spatial (cm)</i>
RGB	400-750	10
NIR	760-900	4



RGB



NIR

Ground Truth

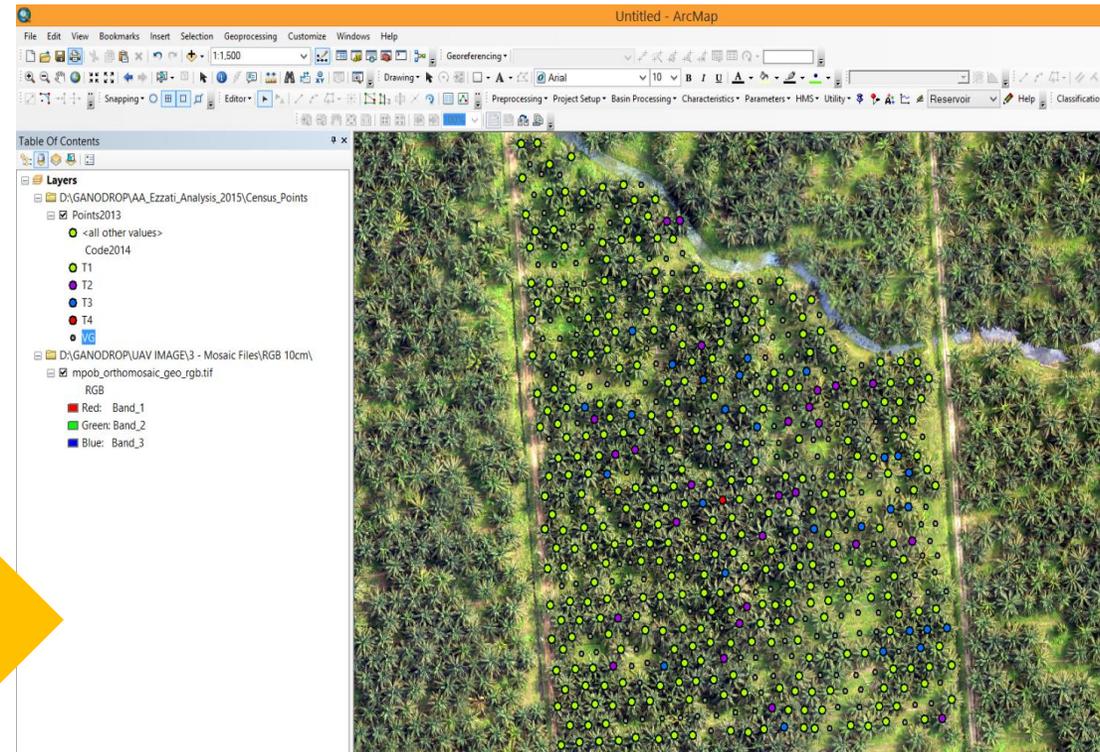
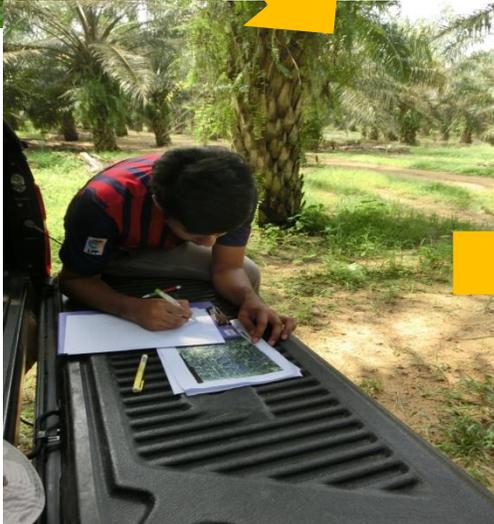
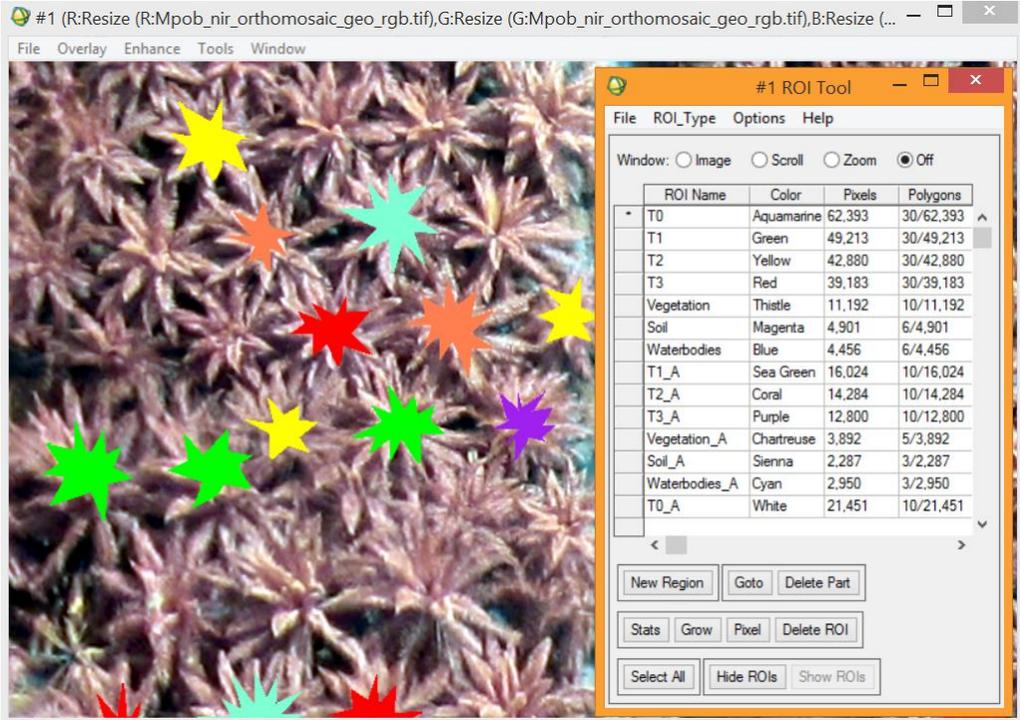


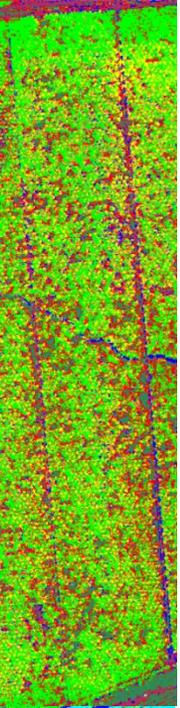
Image Analysis

DSI	RGB Image	NIR Image
T0		
T1		
T2		
T3		



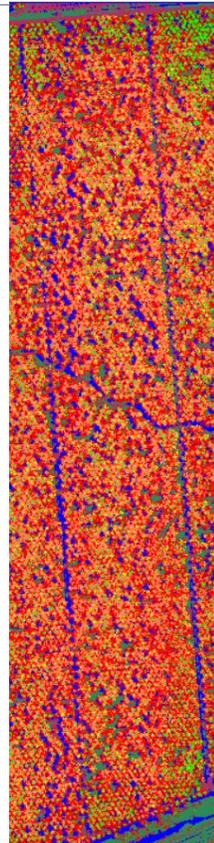
Analysis on Severity Index - suggested that both RGB and NIR images give significant difference ($p < 0.05$) between all indicated DSIs of BSR disease.

Image Analysis

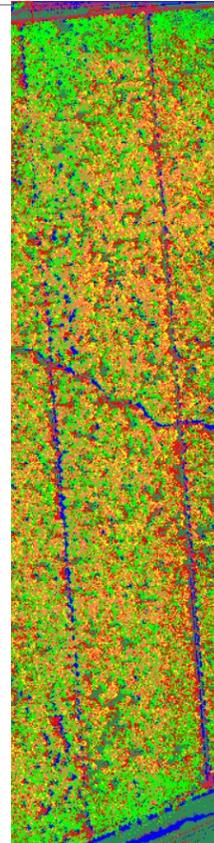


Results using Adaptive Filtering (7x7) and Supervised Classification for NIR (a) ML - Enhanced Frost (b) MD - Frost (c) NN - Local Sigma; dan RGB (a) ML- Enhanced Lee (e) NN - Frost (f) MD - Enhanced Lee.

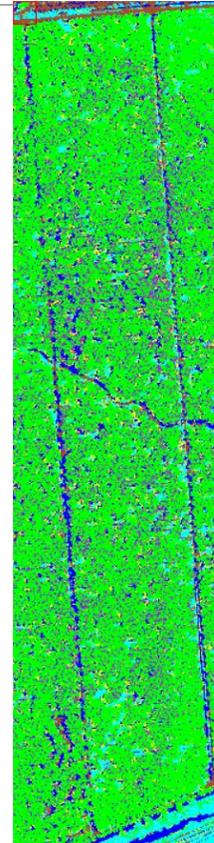
- The adaptive filtering increased the accuracy of classification to up to 8%, with average 42% accuracy.



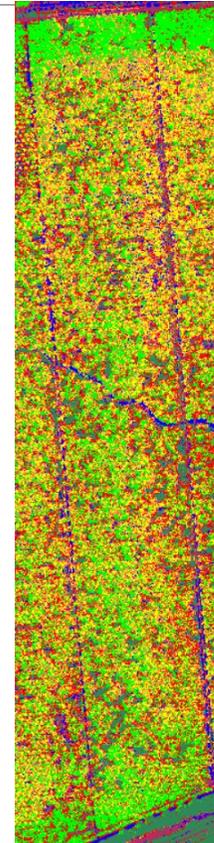
(a)



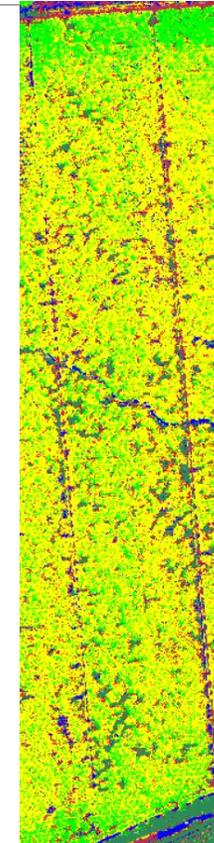
(b)



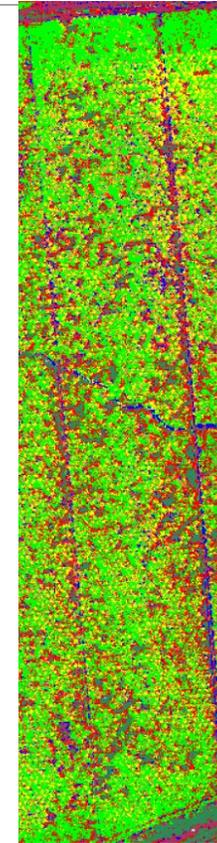
(c)



(d)

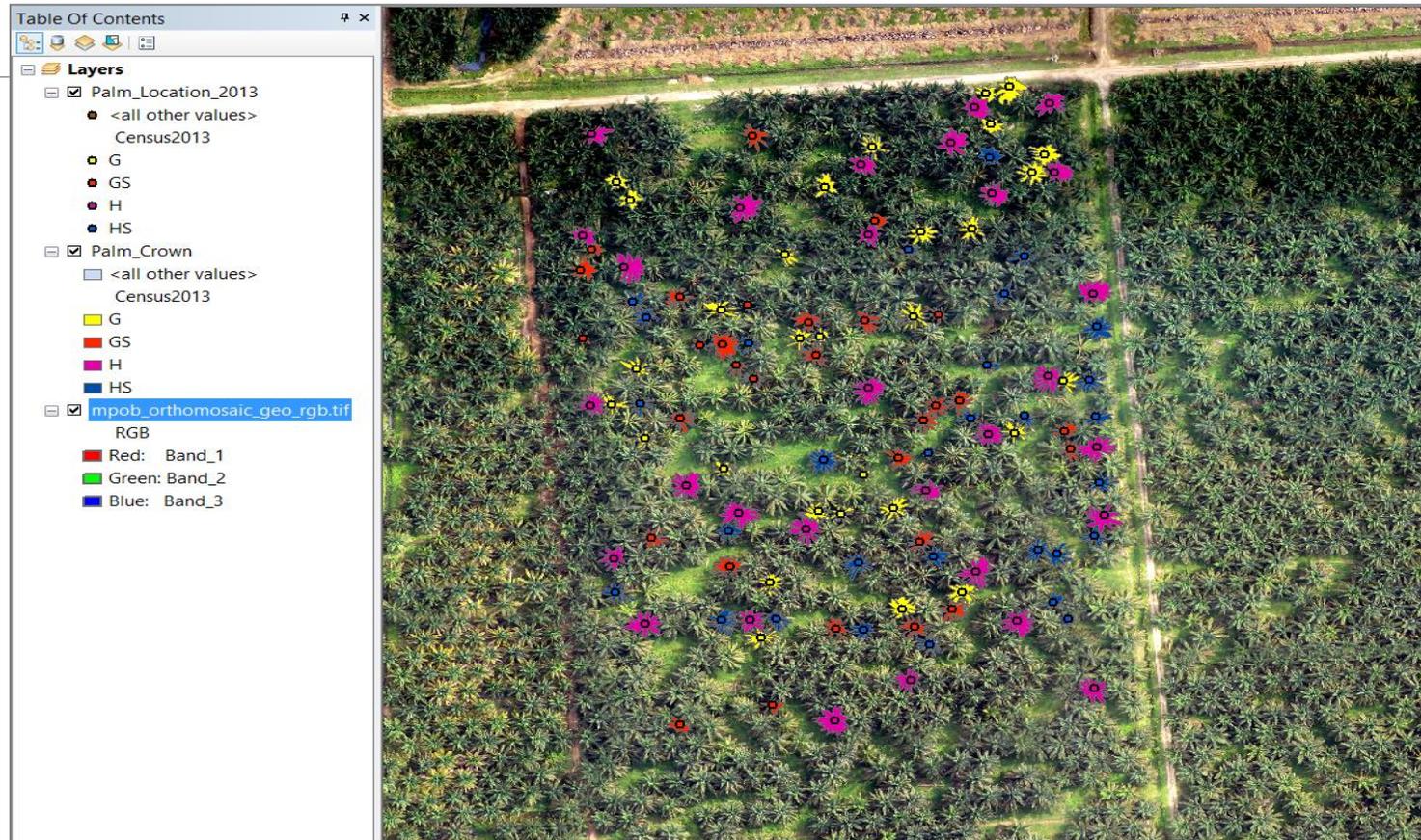


(e)



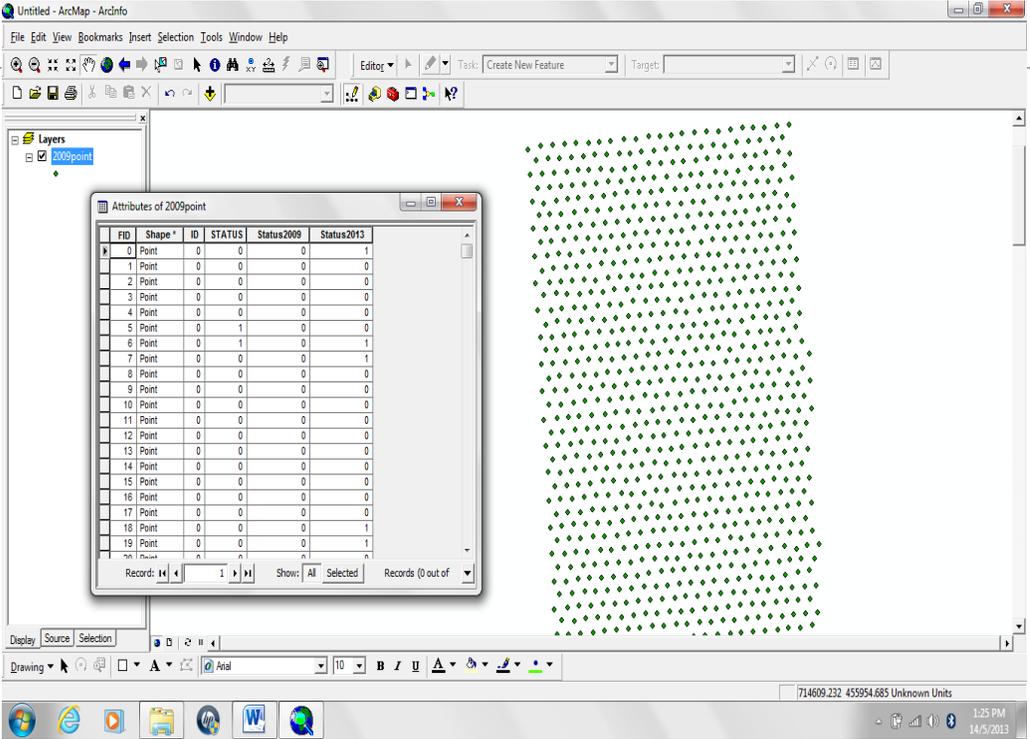
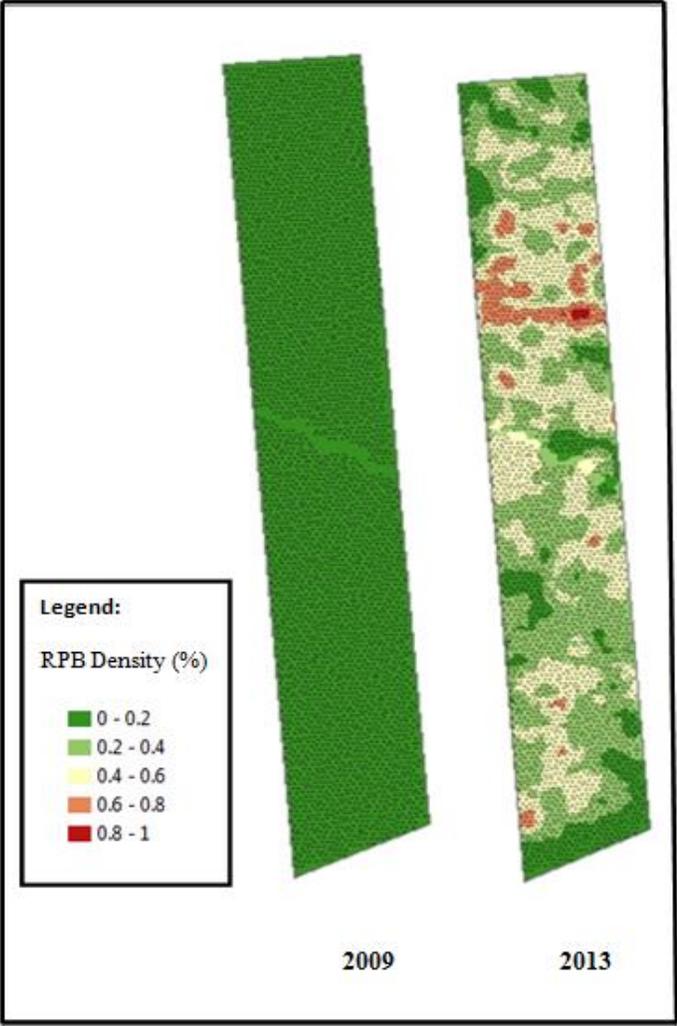
(f)

GIS and Remote Sensing



Identification and digitizing of polygon on the selected palms which has been categorized into four states of palm health known as H, HS, G and GS.

GIS Spatial - Temporal Analysis



To incorporate all data collected by remote sensing with the census to develop a time series of disease spread over time. Multi sensor and multi temporal.

Future Developments

- Development of **vegetation indices** for oil palm for stress detection – based on band selection. Verification of index.
- **Modeling** on the relationship of *Ganoderma* disease with factors such as soil type, moisture content, nutrient.
- Areal detection based on percentage of disease based on **pixel based analysis**.
- **Index mapping** of *Ganoderma* disease for areal based identification for management and planning purposes.
- UAV hyperspectral system – a compact and, lightweight sensor can be fitted in UAV. Max sensor plus IMU – 3 kg.
- GIS mapping, hotspots and prediction of disease dispersion.
- RADAR (Radio Detection and Ranging) fusion with hyperspectral imagery.

Conclusion and Recommendation

- The detection (based on area – not on individual trees – percentage over total area) and assessment of the disease symptoms, especially early detection of the disease is **vital for profitable agriculture business**.
- In view of plantation management, early identification of stress and diseases are decisive and could **ameliorate on plan and strategy** to overcome the problem in a cost effective manner.
- Expands the *Ganoderma* BSR detection survey options available to plantation managers and a **viable data source** for detecting and monitoring damage due to pest and disease in oil palm plantation.

Conclusion

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Thank You

