# MGF 2014

# Performances of UAV and WorldView-2 Images for Individual Canopy Delineation in Tropical Forest

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*Malaysia Geospatial Forum (MGF 2014)*
*Sutera Harbour, Kota Kinabalu Sabah, March 11-12, 2014*

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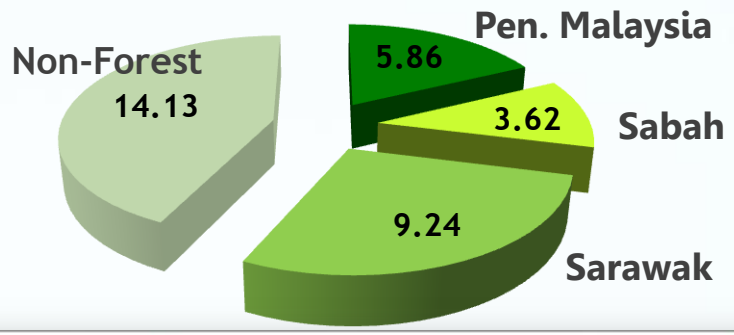
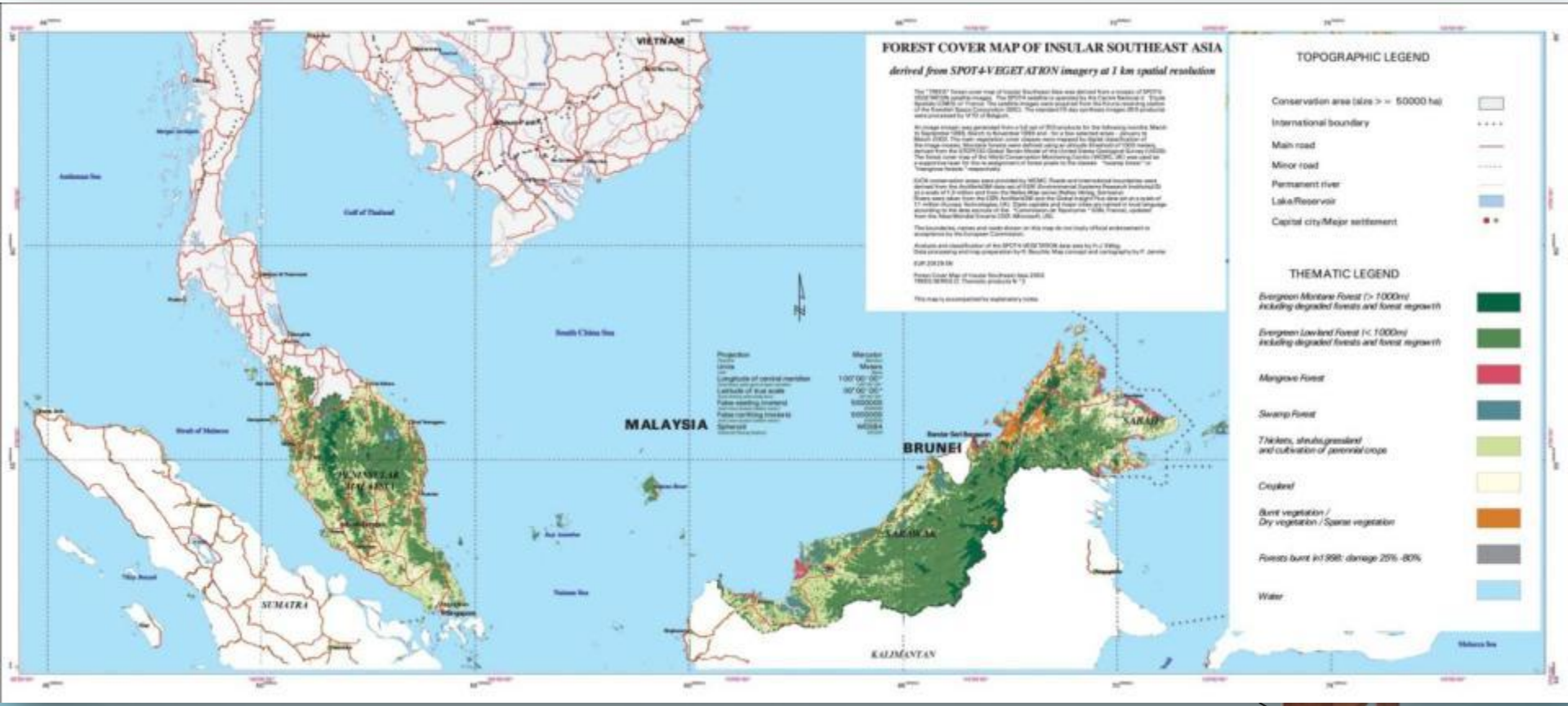
# Presentation Outline

- Forests in Malaysia
- Introduction
- Materials & Methods
- Results & Discussion
- Conclusion

# Forest in Malaysia

('000,000 ha)



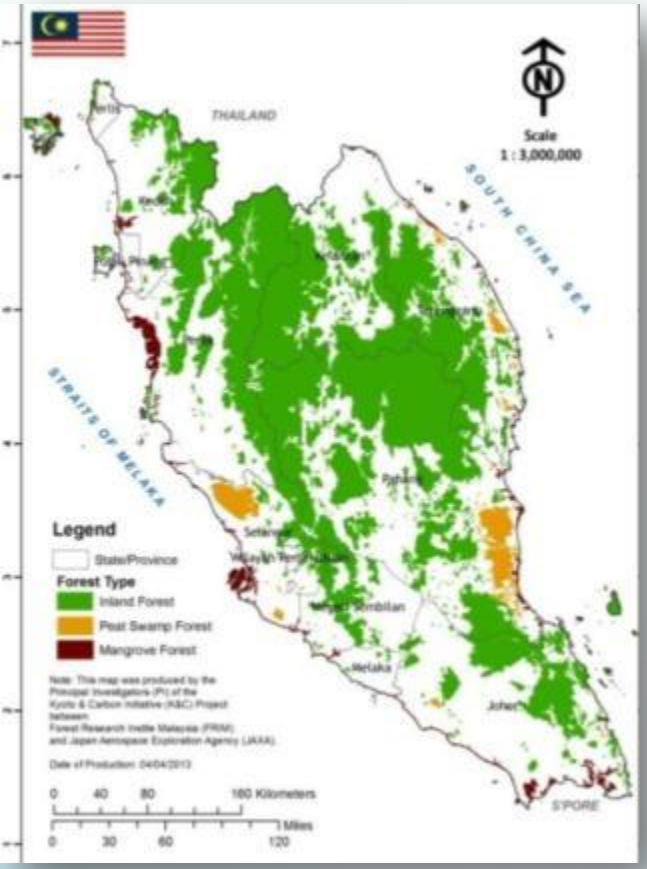
# Permanent Reserved Forest in Malaysia, 2010 ('000,000 ha)

| Study Area | Protection Forest | Production Forest | Total PRFs |
|---|---|---|---|
| **Pen. M'sia** | 1.98 | 2.82 | 4.80 |
| **Percentage** | 41.25 | 58.75 | 100 |

Comprises mainly **Lowland** and **Hill Dipterocarp** Forests (with minor portions of Peat swamp and Mangrove forests)

***Sources:*** *Forestry Department Peninsular Malaysia (2011)*

# Forests in Peninsular Malaysia




| Forest Type | Extents (ha) | Percentage (%) |
|---|---|---|
| Inland Forest* | 5,690,815.57 | 93.3 |
| Peat Swamp Forest** | 290,038.47 | 4.8 |
| Mangrove Forest*** | 115,180.60 | 1.9 |
| **Total** | **6,096,034.64#** | **100.0** |

**Including forest plantation.*
***Including fresh water swamp and Melaleuca cajuputi forests.*
****From Hamdan et al. (2012).*
*#Figure is not final and not to be quoted.*

# Introduction

- Recent developments in high spatial resolution remote sensing have created a wide array of potential new forestry applications.
- High spatial resolution imagery allows a tree-scale of analysis, in which individual trees and their attributes are the focus of interest.
- Currently, there are many airborne and space borne sensors that offer high spatial resolution images.
- Along with the advancements in remote sensing technology, various methods have been developed to delineate individual tree canopy in different type of vegetation and ecosystems.

Focus article

# UAV IN FORESTRY: THE TRIALS

The GateWing X100 equipment

Aerial photograph over FRIM campus captured by GateWing X100

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**Dr Khali Aziz Hamzah**

**Remote sensing instruments are now smaller and cheaper. The Unmanned Aerial Vehicle (UAV) for instance, looks like a miniature aircraft but its contribution to remote sensing activities is invaluable.**

In September 2013, Forest Research Institute Malaysia (FRIM) and Geospatial Solution Sdn Bhd flew the GateWing X100 over FRIM campus. GateWing X100 is a Belgium-made UAV system which weighs 2.2 kg with wings measuring only 100 cm. It carries a payload of about 800 kg including a battery (500 g) and a compact digital camera (300 g) that are mounted on the aircraft to capture aerial photographs.

The aerial photography over FRIM area of 544.3 ha took three days and six flights to complete, in which the duration was largely determined by weather condition. The miniature aircraft flew at an altitude of 500 m above sea level and captured digital aerial photographs with a pixel resolution of 12 cm.

The successful UAV flight over FRIM showed the capability of the system in studying forest canopy structure and other biophysical characteristics. The advantage of using lightweight UAVs for vegetational dynamics research is primarily in capturing individual plants spatially. Individual plants can be mapped provided flight paths are at a sufficient low altitude and revisit times can be optimised according to the phenological cycle of the target species. In addition, the UAVs should allow fitting of a miniature narrowband and hyperspectral radiometers, or thermal cameras to capture patterns in biophysical variables. As opposed to satellite, this system is able to provide cloud-free images.

Previously, spatial forestry research was severely hampered by the difficulties in obtaining the appropriate data. Now, it is possible to capture data in the form of fine spatial and temporal resolutions, over prolonged period of time and at a reasonable cost. The use of UAVs is a major step towards more effective and efficient operational monitoring and management of natural resources. By flying slow and low, and being comparatively affordable, UAVs offer scientists new opportunities for scale-appropriate measurement of ecological phenomena. Data in the form of fine spatial resolution can now be captured at a user-controlled revisit periods.

## ABOUT THE MAIN AUTHOR

Hamdan Omar is a Research Officer at the Geoinformation Programme, Forestry and Environment Division, FRIM. He is currently active in a number of research projects relating to the carbon stock assessments in Malaysia's forest ecosystems by using spatial technologies, in addition to forests roles in combating climate change. He is also pursuing his PhD in the field of forest engineering and operations at Universiti Putra Malaysia (UPM). His work is mostly concentrated on the use of remotely sensed data in assessing forests biomass and carbon stock.



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Design & Printing : Concept Press Sdn Bhd

*Aerial photograph over Forest Research Institute Malaysia (FRIM) campus captured using the Unmanned Aerial Vehicle Technology (Photograph credit: Hamdan Omar)*




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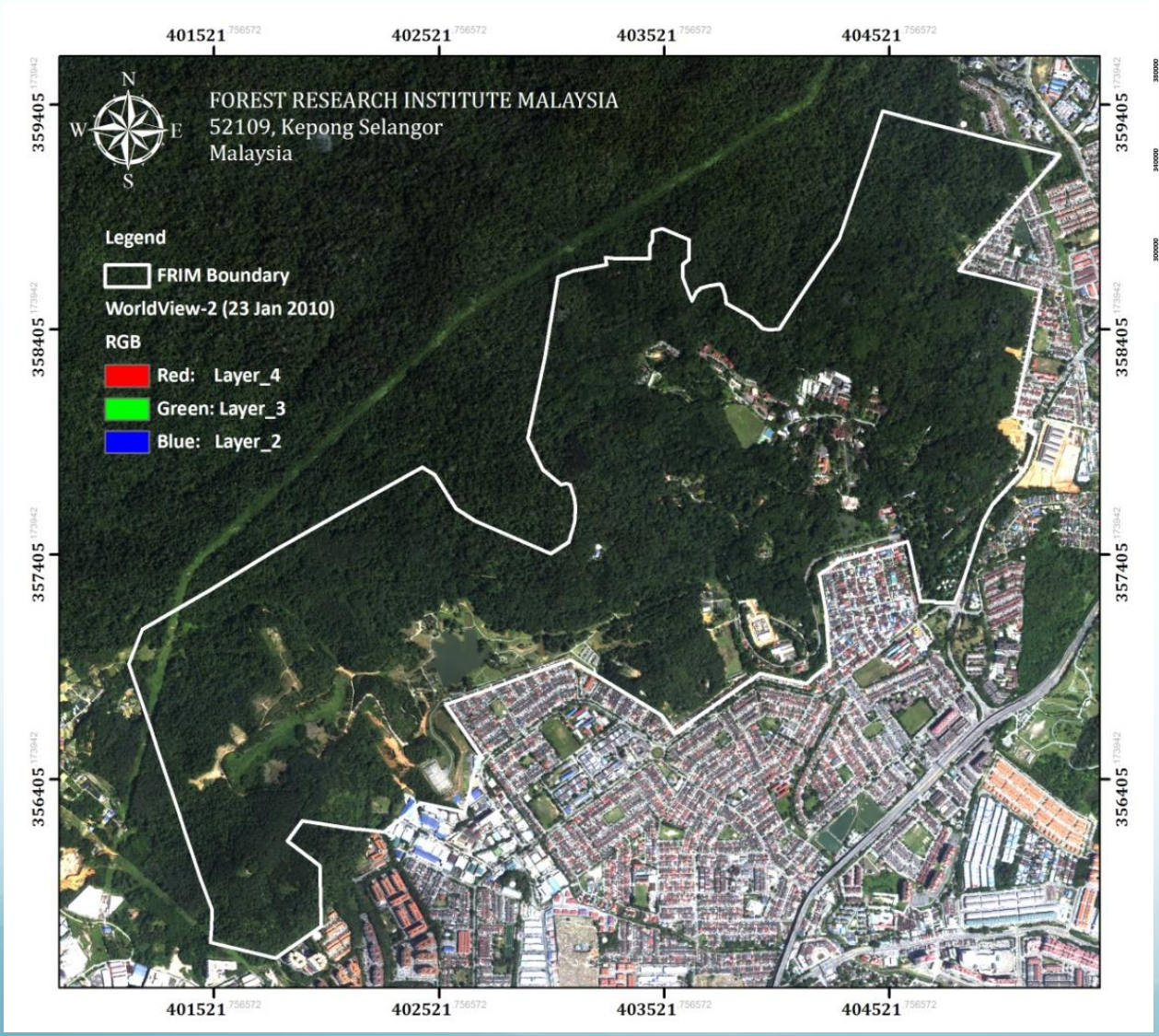
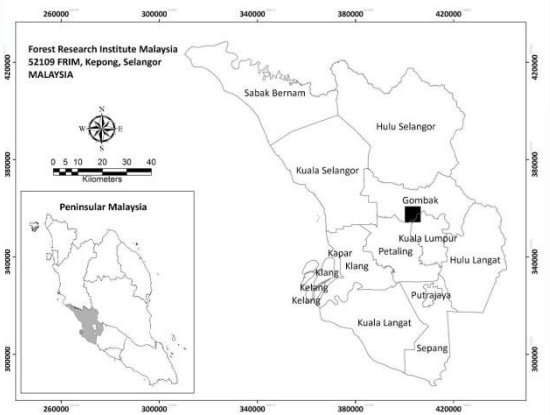
# The study area




Total Area: 544 ha

Forested area: 473 ha

- 90.4% are planted forest
- 9.6% natural forest

Non-forest: 71 ha

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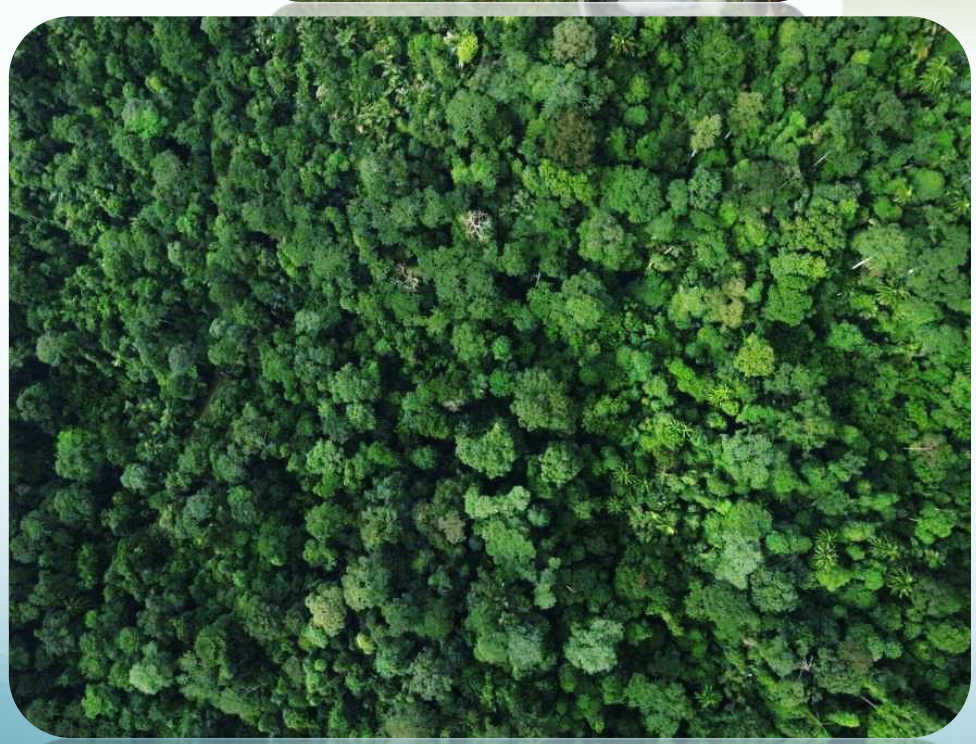
# Methodology

1. Image preparation: WorldView-2 & UAV aerial photo
2. Image segmentation: Object based classification and canopy delineation
3. Canopy counting: Vector shapefile
4. Validation: The results were validated by using information collected on the ground



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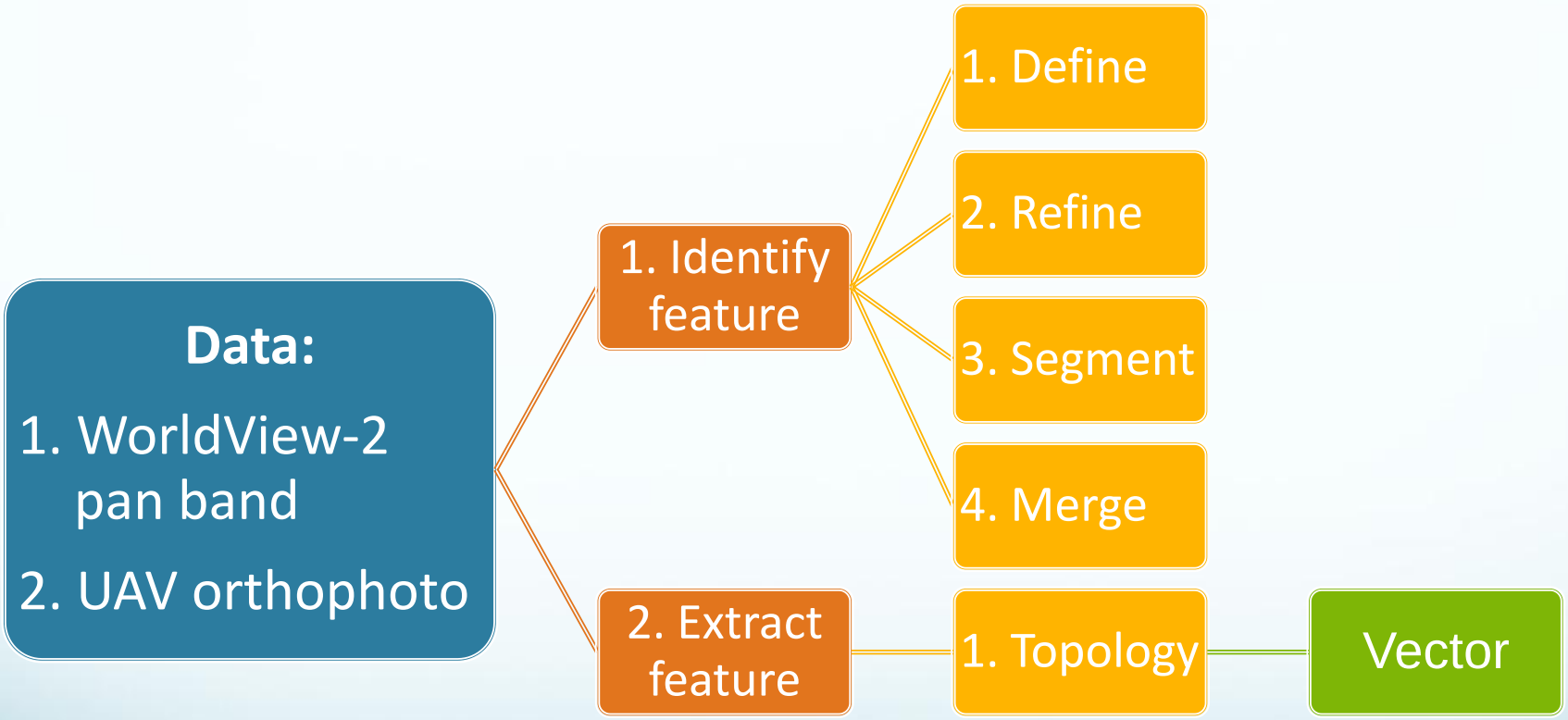
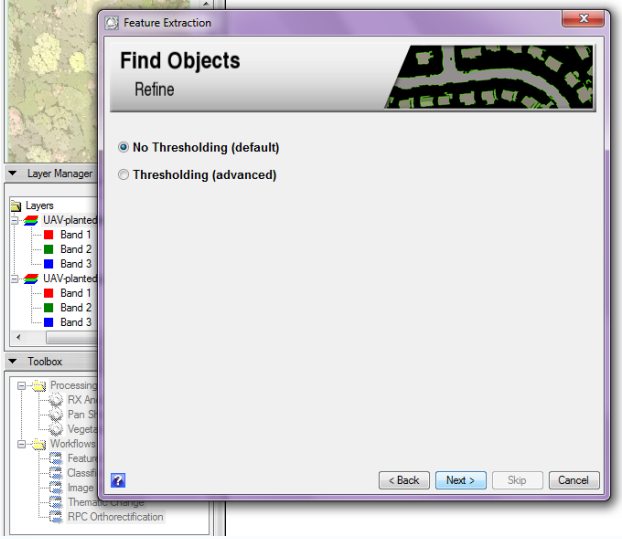
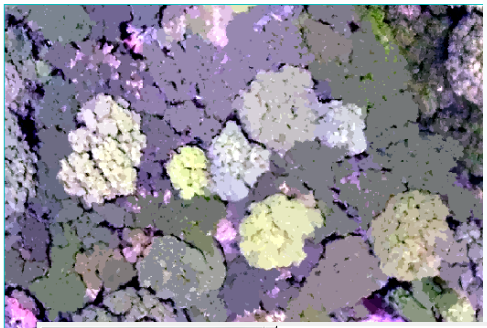
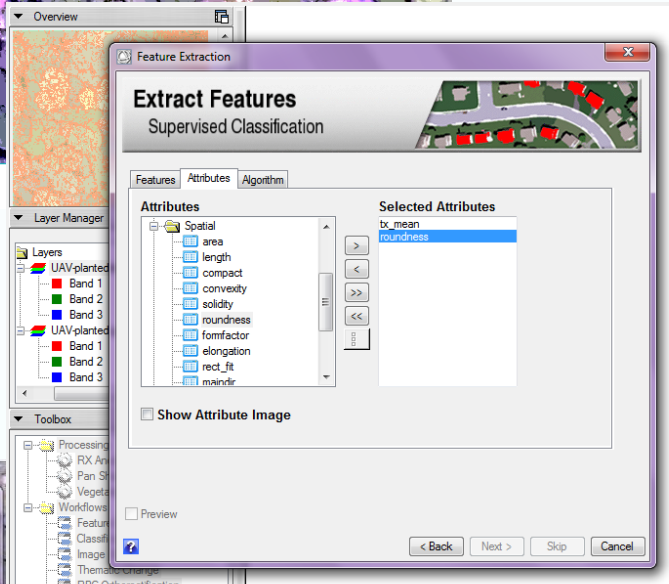
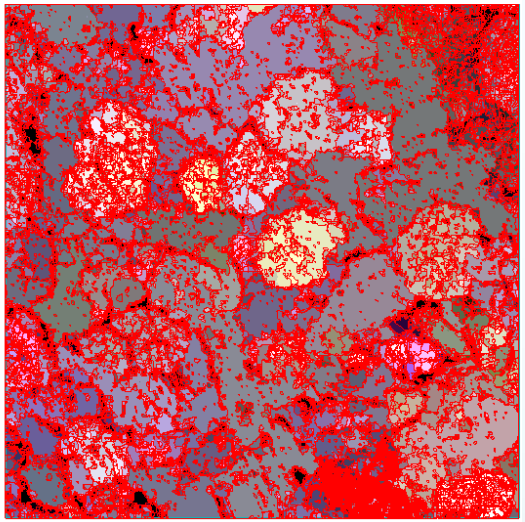
# Segmentation Processes



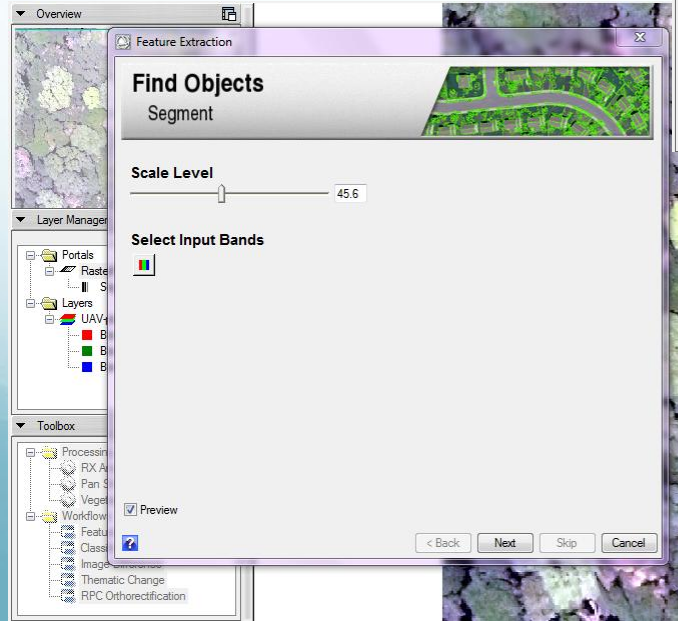




# 1. Object /Feature identification




# 2. Feature delineation

# Feature definition

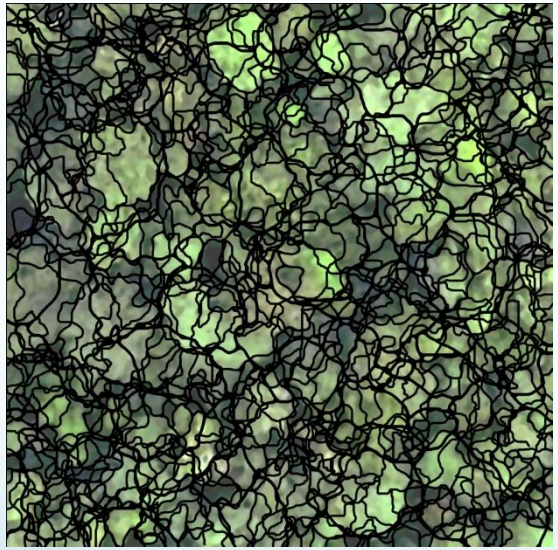
| Attribute | Description |
|---|---|
| AREA | Total area of the polygon, minus the area of the holes. Values are in map units. |
| LENGTH | The combined length of all boundaries of the polygon, including the boundaries of the holes. This is different than the MAXAXISLEN attribute. Values are in map units. |
| COMPACT | A shape measure that indicates the compactness of the polygon. A circle is the most compact shape with a value of 1 / pi. The compactness value of a square is 1 / 2(sqrt(pi)).<br><br>COMPACT = Sqrt (4 * AREA / pi) / outer contour length |
| CONVEXITY | Polygons are either convex or concave. This attribute measures the convexity of the polygon. The convexity value for a convex polygon with no holes is 1.0, while the value for a concave polygon is less than 1.0.<br><br>CONVEXITY = length of convex hull / LENGTH |
| SOLIDITY | A shape measure that compares the area of the polygon to the area of a convex hull surrounding the polygon. The solidity value for a convex polygon with no holes is 1.0, and the value for a concave polygon is less than 1.0.<br><br>SOLIDITY = AREA / area of convex hull |
| ROUNDNESS | **A shape measure that compares the area of the polygon to the square of the maximum diameter of the polygon. The "maximum diameter" is the length of the major axis of an oriented bounding box enclosing the polygon. The roundness value for a circle is 1, and the value for a square is 4 / pi.**<br><br>**ROUNDNESS = 4 * (AREA) / (pi * MAXAXISLEN$^2$)** |

| Attribute | Description |
|---|---|
| FORMFACTOR | A shape measure that compares the area of the polygon to the square of the total perimeter. The form factor value of a circle is 1, and the value of a square is pi / 4.<br><br>FORMFACTOR = 4 * pi * (AREA) / (total perimeter)$^2$ |
| ELONGATION | A shape measure that indicates the ratio of the major axis of the polygon to the minor axis of the polygon. The major and minor axes are derived from an oriented bounding box containing the polygon. The elongation value for a square is 1.0, and the value for a rectangle is greater than 1.0.<br><br>ELONGATION = MAXAXISLEN / MINAXISLEN |
| RECT_FIT | A shape measure that indicates how well the shape is described by a rectangle. This attribute compares the area of the polygon to the area of the oriented bounding box enclosing the polygon. The rectangular fit value for a rectangle is 1.0, and the value for a non-rectangular shape is less than 1.0.<br><br>RECT_FIT = AREA / (MAXAXISLEN * MINAXISLEN) |
| MAINDIR | The angle subtended by the major axis of the polygon and the x-axis in degrees. The main direction value ranges from 0 to 180 degrees. 90 degrees is North/South, and 0 to 180 degrees is East/West. |
| MAJAXISLEN | The length of the major axis of an oriented bounding box enclosing the polygon. Values are map units of the pixel size. If the image is not georeferenced A defined location in physical space in map projections or coordinate systems., then pixel units are reported. |
| MINAXISLEN | The length of the minor axis of an oriented bounding box enclosing the polygon. Values are map units of the pixel size. If the image is not georeferenced A defined location in physical space in map projections or coordinate systems., then pixel units are reported. |
| NUMHOLES | The number of holes in the polygon. Integer value. |
| HOLESOLRAT | The ratio of the total area of the polygon to the area of the outer contour of the polygon. The hole solid ratio value for a polygon with no holes is 1.0.<br><br>HOLESOLRAT = AREA / outer contour area |

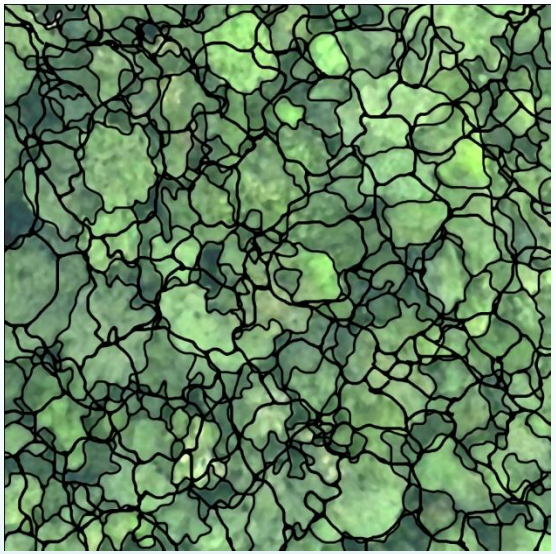
# Results

## Scale Levels

Too many details

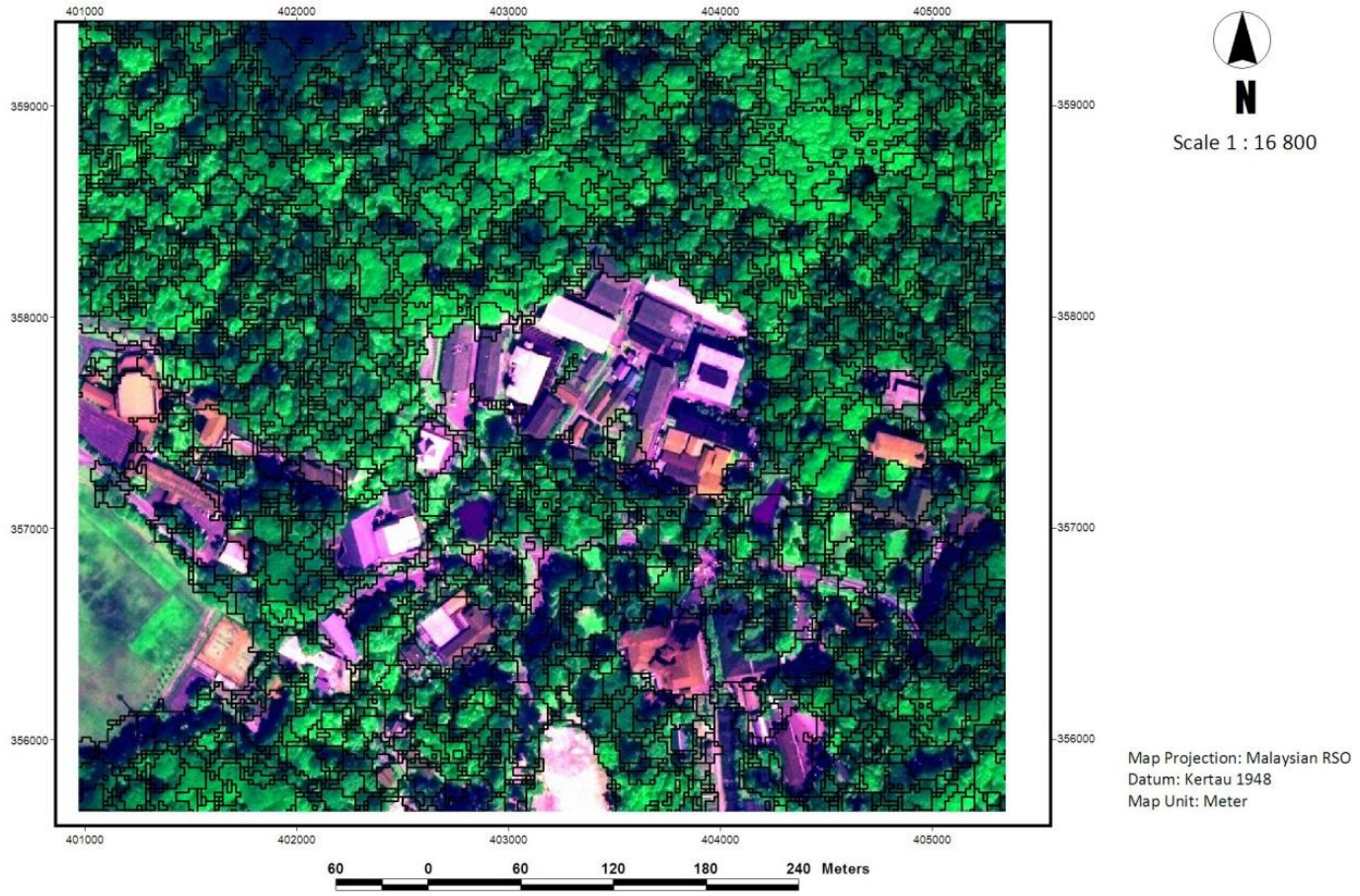


Medium details



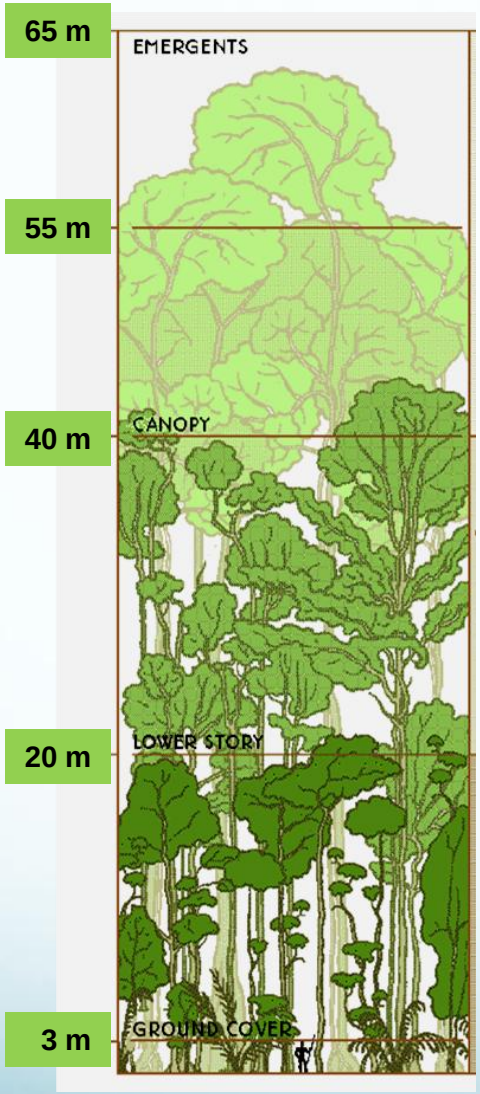
Ideal details

## Segmented Trees Canopy around FRIM Campus

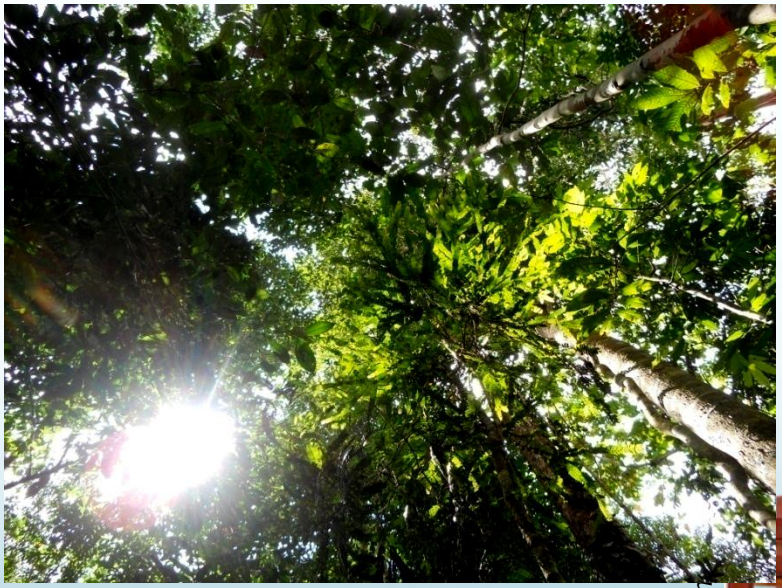



| Data source | Min. crown diameter (m) | Max. crown diameter (m) | Average count (trees/ha) | Total count (Trees) |
|---|---|---|---|---|
| WorldView-2 | 3.84 | 42.65 | 122.9 | 66,848 |
| UAV | 2.79 | 21.76 | 133.4 | 72,586 |

# Forest Strata

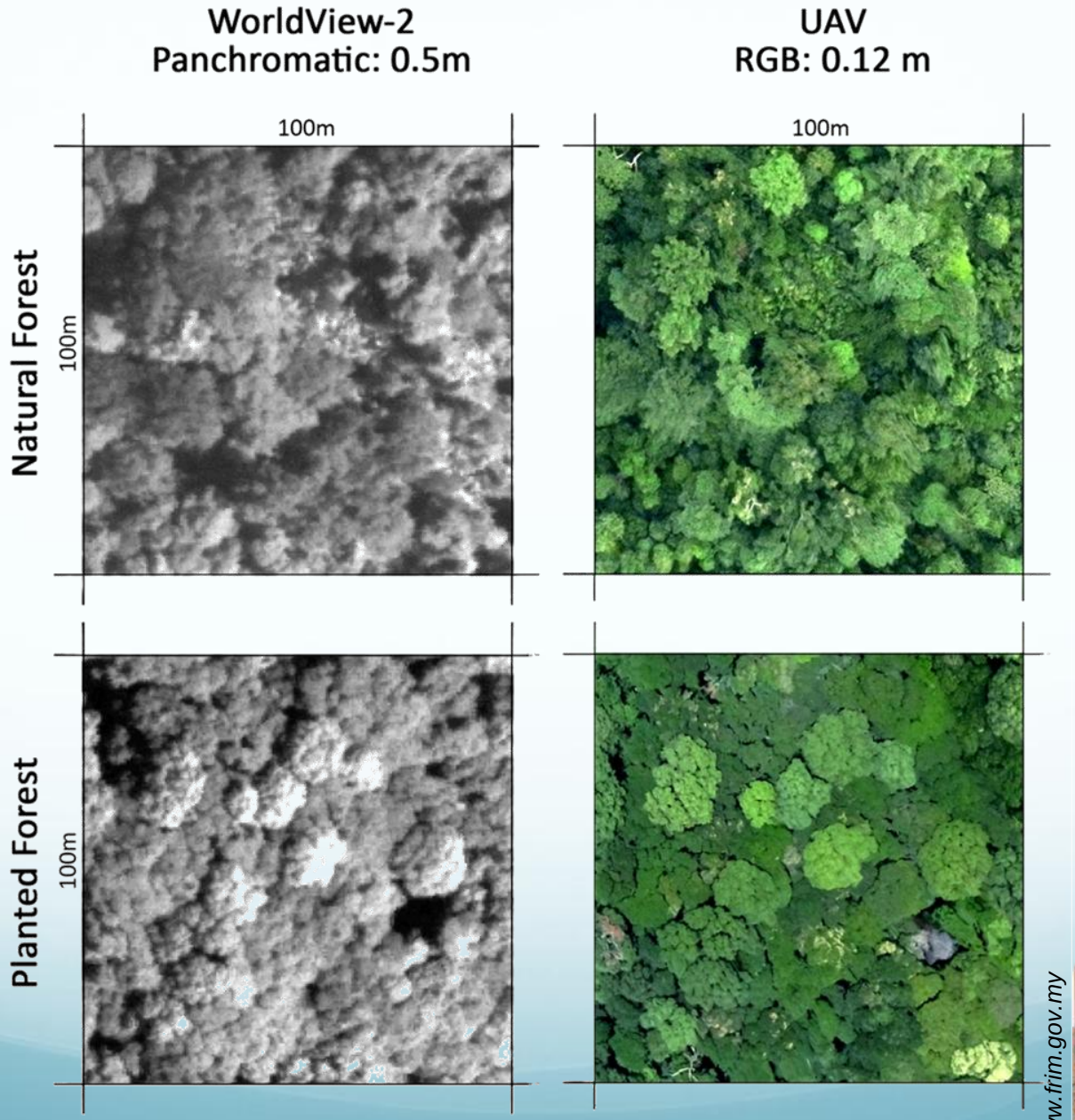


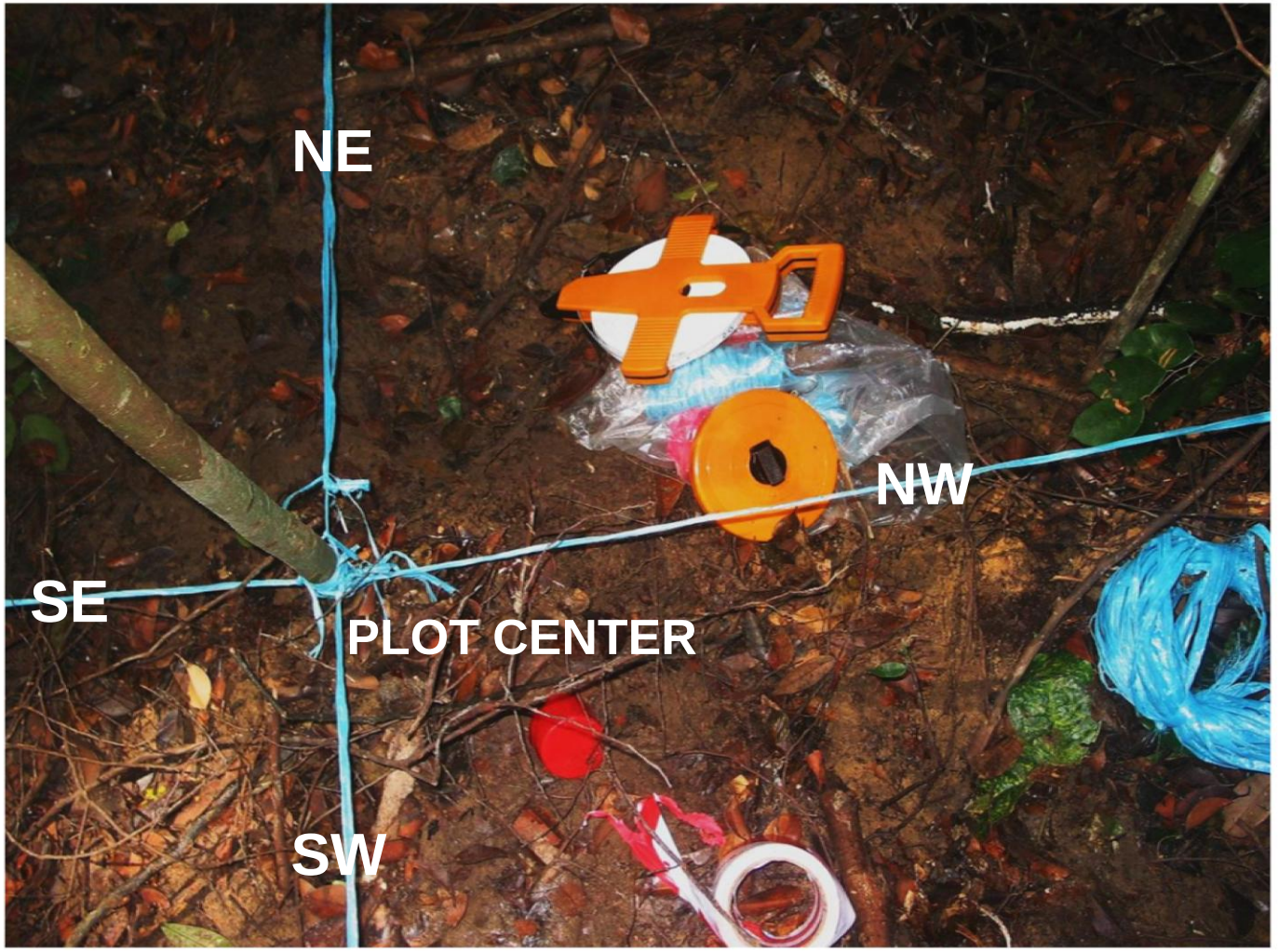

Planted forest



Natural forest

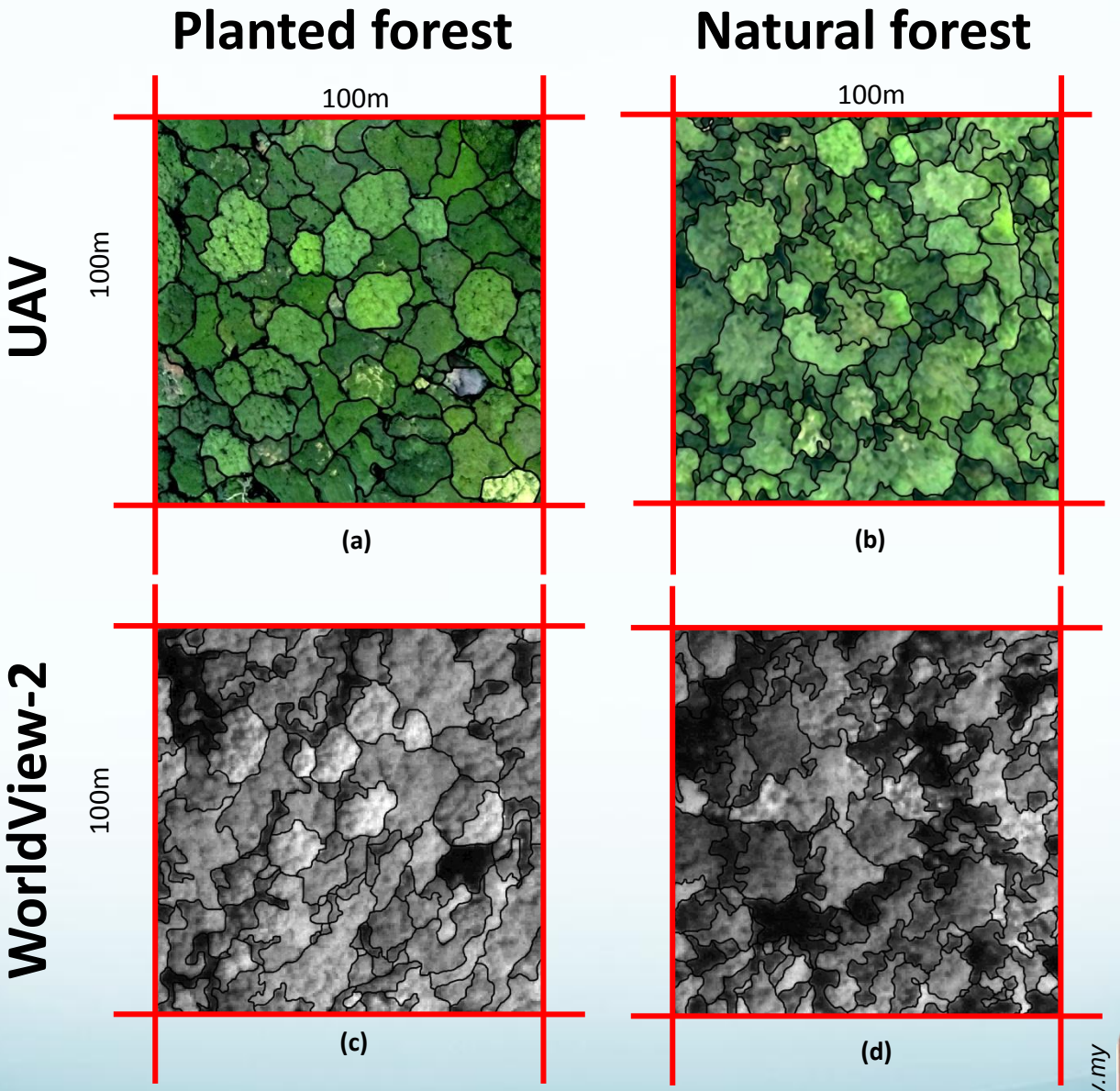
# Validation



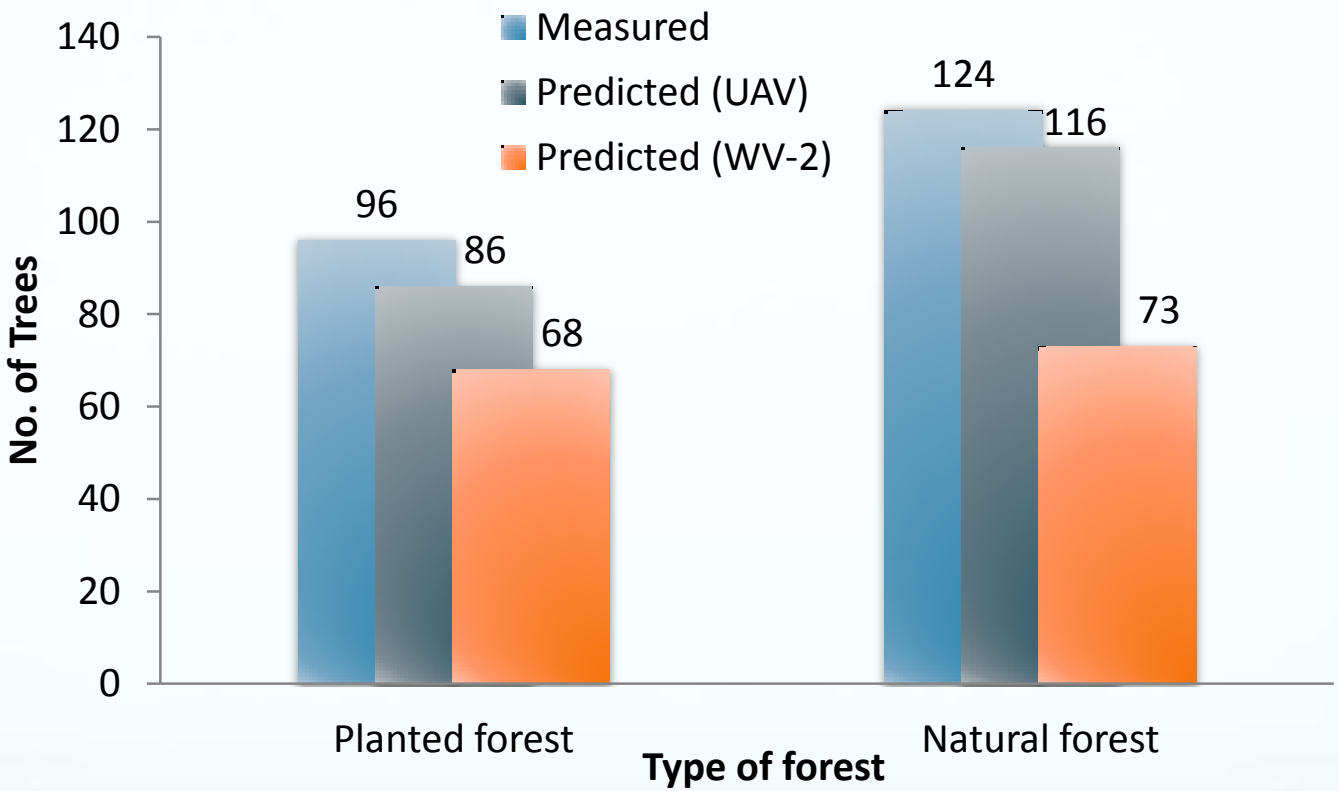



Validation plots: 100 x 100 m

# Ground data collection


Planted forest
Natural forest
UAV
WorldView-2
100m
100m
100m
100m
(a)
(b)
(c)
(d)

# Data from validation plots




| Data source | Measured canopy | Predicted canopy | | | Stem diameter (dbh) | Canopy height (m) |
|---|---|---|---|---|---|---|
| | | Planted | Natural | Accuracy | | |
| WV-2 | 96 | 68 | 73 | 65 | 25.0 - 78.5 | 35 - 42 |
| UAV | 124 | 86 | 116 | 92 | 25.0 - 81.4 | 20 - 38 |

## Performance of WV-2 and UAV in forest canopy delineation

| Performance aspect | WorldView-2 | UAV |
|---|---|---|
| Accuracy (%) | ~65 | ~90 |
| Processing time (sec/ha) | 49.2 | 172.4 |
| Spatial resolution (m) | 0.46 | 0.12 |
| Storage (Mb/band/ha) | ~1.4 | ~3.6 |
| Cost (RM/ha) | 5.88 | 22.06 |

# Conclusion

- In native multi-layered mixed species forests in Malaysia, the diversity of canopy sizes and forms complicate the delineation processes.
- The accuracies are typically higher in the mono-species stands and declined with stand density because of the obscuration of many smaller trees (understory) by the taller trees and the presence of intermingled canopies.
- It was obvious that UAV data was sufficient to cater information on canopy coverage and it is found that segmentation technique is most suitable for crown delineation in forest areas.

- Canopy-mix is a major problem found in natural forest conditions. A segment can represent 2 or 3 canopies and one canopy can be represented by 2 or 3 segments. These circumstances have produced under estimate or over estimate of the counted trees.

- The information obtained from this study is becoming crucial for modern forest administration, loggers to estimate profit in the meantime to well manage/control logging activities in timber industry.

- The study is useful and become more important in forest resources assessment in-line with Sustainable Forest Management. It is also an emerging technology in precision forestry, where more biophysical properties of a forest can be accessed through remotely sensed data.

# Thank you

Terima kasih