ESTIMATION OF ABOVE GROUND BIOMASS IN RESTORED JUVENILE MANGROVE STANDS:
EVALUATION OF SPECTRAL AND IMAGE DOMAIN OPERATORS UTILIZING AIRBORNE HYPERSPECTRAL DATASETS

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FOREST DEPARTMENT SARAWAK
(Geospatial Initiative)

(VISION)
To be an agency of excellence:
• management
• conservation and
• protection of tropical forests.

Adoption of technology (geospatial) into daily operations to increase efficiency and effectiveness.
www.forestry.sarawak.gov.my
AIRBORNE HYPERSPECTRAL IMAGING SYSTEM (AHIS)
HYPERSPECTRAL IMAGING COMPONENTS

Sensor Head: AISA Eagle-II
IMU: Oxford-RT GPS/INS
Stabilized Platform: SOMAG 3000 Gyro
AERIAL ENFORCEMENT AND MONITORING SYSTEM

Operator Display & Controls

Mobile Navigation & Pilot Display

Hyperspectral Imaging System & Gimbal Component fitted onboard Bell 206L4
RESTORATION OF MANGROVE FORESTS AND COASTAL ECOSYSTEM

• Rehabilitation of degraded coastal forests (9th-10th Malaysia Plan Development Project: 2006-2015)

• Objectives:
  – coastal protection
  – soil stabilization
  – marine/wildlife habitat
  – REDD+ initiative*

* Work-in progress to develop a tool for remotely estimating biomass of juvenile stands as an application for the mangrove rehabilitation project.
CHARACTERISTICS OF PLANTED MANGROVE STANDS

• Varying growth rates:
  – Species
  – Spatial position in the stand
  – Competition
  – Vigor
  – Age.

• In the Matang Mangrove Forest Reserve in Malaysia, Putz and Chan (1986) reported that diameter growth rates of *R. apiculata* trees were 0.24–0.29 cm (0.09–0.11 in) for diameter size classes from 10 to 60 cm (4–24 in).

• Watson (1928) estimated that under Malaysian conditions mean annual increment (MAI) of stilt mangroves culminated at around *10.6 m³/ha/yr* (152 ft³/ac/yr) at 39–40 years.
Characteristics of Stilt Mangroves

(R.apiculata)

- **Habitat:** Intertidal wetland zone (0-6m) between mean sea level and highest tide.

- **Standing Biomass:** 136-299 mt/ha

- **Main products:** Timber (poles, stilts), fuelwood, charcoal, medicine

Source: Duke, N.C
REFORESTATION EFFORTS

Issues/constrain:

• Site suitability (wave energy; driftwood; soil substrate)

• Slow growth rate as compared to other types of introduced tree plantings such as Acacia (3.3 cm/yr)

• Shortage of planting stock (other suitable species – Avicennia; Sonneratia)

• Planting generalized using R.apiculata seedlings (varying success rate)
MANGROVE RESTORATION
(MONITORING AND MEASURING)

• Monitor forest cover change of areas under mangrove/previously mangrove cover.
  – Total area under forest
  – Changes to forest cover/land-use

• Measuring productivity of mangrove stands
  – Old growth natural mangrove stand
  – Juvenile planted mangrove stands*
MONITORING MANGROVE
REFORESTATION ACTIVITIES

• Monitoring systems should provide estimates that are transparent and consistent, as far as possible accurate, and that reduce uncertainties, and results are available and suitable for review as agreed by the COP.
  (COP 15 Decision on Methodological Guidance-support of REDD activities)

• Remote sensing role:
  – Consistent reporting through development of standardized protocol (tool) for processing and analyzing data to final information product.
DEVELOPMENT OF A SPECIFIC TOOL FOR REMOTELY MONITORING JUVENILE MANGROVE STANDS

• Management requirements:-
  – Project worth @ value
  – Applicability (National operations)

• Type of information:-
  – Planting progress (size of area planted, species composition, no. of saplings planted and mortality).
  – Productivity (Above Ground Biomass) of planted stands ~ REDD+ initiative.
  – Standardization and simplification of workflow
• Constrain of current remote sensing capabilities:
  - High spatial resolution but low spectral capabilities to discriminate between mangrove canopies with other vegetation and reduce background influence.
  - High spectral resolution but coarse spatial details resulting in mixed response of target materials with background.

Spectral un-mixing would not resolve detail structural properties of single crowns.
MONITORING MANGROVE
REFORESTATION ACTIVITIES

• High fidelity imaging systems:
  – Spectral capability to distinguish between target and other background materials.
  – High geometric detail to effectively resolve single canopies of small statured (dwarf) stands.
  – Derive biophysical variables (crown area; crown volume) to better estimate stand productivity (biomass).
DERIVATION OF ABOVE GROUND BIOMASS (AGB)

Calibration of Airborne Dataset with Field Sampling

• Develop Biomass regression (single tree) based upon relationship between **crown structural characteristics** (as observed from image datasets) and **biomass components** (trunk, branch, prop-root, leaf and total above-ground biomass).

• Aboveground Biomass estimates based on:
  - **Field measurements (components)**
  - **Allometric equation:**
    - Calibration of field measurement with Final Vector Product of the airborne hyperspectral dataset (Biomass Estimation Tool).
    - Compare with existing allometric equations: 
      \[
      \text{AGB} = 0.0509 \times (\rho \cdot \text{DBH}^2 \cdot H) \quad \text{Chave et.al} \ (2005)
      \]
DERIVATION OF BIOMASS ESTIMATES
(High Resolution Image Datasets)

• Emphasis placed on:

  – **Sensor band placement** and **bandwidth** to optimise separability between target classes.

  – **Spectral enhancement** to detect salient features in dataset and suppress background influence.

  – **Enhancement of canopy geometric features** such as to coincide with the purpose of being able to delineate individual tree crowns from imagery.
SPECTRAL ENHANCEMENT

– Derivative transformation (IDL’s DERIV function – David Gorodetzky):

\[ 1-D\lambda(i) = \frac{(R\lambda(j+1) - R\lambda(j))}{\Delta \lambda} \]

– No need for equally spaced band positions as function adopts Langrangian interpolation.

– Use only 1\textsuperscript{st} order to minimise noise amplification at higher order
• Spatial Derivative (Edge Enhancement)
  – Based on neighbourhood functions (convolution mask) on image datasets.
  – Spatial derivative transformation on original image to find changes in pixel brightness gradient in horizontal (Gx) and Vertical (Gy) direction:

  **Roberts Operator (2x2 gradient)**

  \[ G[f(i, j)] = [f(i, j) - f(i + 1, j + 1)] + [f(i + 1, j) - f(i, j + 1)] \]

  \[
  \begin{array}{cc}
  1 & 0 \\
  0 & -1 \\
  \end{array}
  \quad \quad \quad
  \begin{array}{cc}
  0 & 1 \\
  -1 & 0 \\
  \end{array}
  \]

  **Sobel Operator (3x3)**

  \[
  G_x = [f(i-1, j-1) + 2f(i-1, j) + f(i, j+1)] - [f(i+1, j-1) + 2f(i+1, j) + f(i, j+1)]
  \]
  \[
  + \quad \quad \quad
  G_y = [f(i-1, j-1) + 2f(i, j-1) + f(i+1, j-1)] - [f(i-1, j+1) + 2f(i, j+1) + f(i+1, j+1)]
  \]

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STUDY SITE
HYPERSPECTRAL IMAGE DATASET

(TRUE COLOR COMPOSITE 3 FLIGHT LINES ACQUIRED ON 8TH MAY 2012)
CHANGES IN LUFC AT STUDY SITE
(2001 – 2012)

Image courtesy of: Digital Globe
COLLECTION OF FIELD DATA
ABOVE GROUND BIOMASS COMPONENTS
(LEAVES; BRANCH; TRUNK; PROP-ROOTS)
# CONDITIONS OF PLANTED MANGROVE STANDS

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<th>Diam. (cm)</th>
<th>Tinggi (cm)</th>
<th>Kanopi (cm)</th>
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SPECTRAL RESPONSE
(MANGROVE VEGETATION AND SOIL BACKGROUND)
SPECTRAL VARIATIONS
(CANOPY CLASSES)
INDIVIDUAL CROWN DELINEATION
(20m X 20m SUB-PLOT)
INDIVIDUAL CROWN DELINEATION
(1 HECTARE PLOT)
BIOMASS Estimation Tool

(Phase-1)
ACKNOWLEDGEMENT

• Ministry of Natural Resource and Environment, Malaysia for funding project (10th Malaysia Plan P2309900007003)

• Technical comments ITT-VIS regional office in Japan (Bernard Lawes)