Case Study – Resource Inventory Assessment

A Multi-faceted approach for ‘whole of forest’ inventory.

(LiDAR, Digital Multispectral Imagery, Ground Sampling)

presented by:

Troy Sawyer, Manager Southern Plantations, FPC WA
Ross Lewin, Director, Outline Global Pty Ltd

Presentation Outline

• Project Overview
• Data specification,
• Acquisition, processing
• Data modelling and statistical results
• Summary
Project Overview

- The Forest Products Commission (FPC) is a Government Trading Enterprise established to develop and market Western Australia’s renewable timber resources.
- FPC resource level inventory of plantation *Pinus radiata* estate (43,000ha) in South West WA.
- Underpin development of long term wood flow models – satisfy supply contract arrangements.
- Sought to acquire precise estimates of plantation characteristics for sub region (Blackwood Valley Estate).
- Technologies chosen included a combination of:
  - Airborne LiDAR scanning
  - Airborne Digital Multispectral Imagery
  - Ground Sample Plot survey
- Total planted area of sub-region: 13,050ha
  - LiDAR and 4-band imagery captured for this complete area
  - Specific area of interest - 1983 to 2003 plantings: 5,050ha
Project Schedule

• Primary Components
  • Procurement
  • Planning
  • Data Capture – DMSI, LiDAR, Sample Plots
  • Data Analysis
  • Statistical modelling
Project Gantt

~ 5 Month Project Duration

Data Acquisition

- LiDAR:
  - High accuracy LiDAR survey of Blackwood Valley plantations
  - Full waveform LiDAR captured at min 2pts/sqm using IGI Litemapper 5600 LiDAR system
  - End Specification
    - 1m Digital Terrain Model (DTM)
    - Specification 1m used 0.5 m Digital Surface Model (DSM) for determination of Canopy Height Model (CHM)
Key LiDAR Terminology

- DSM
- DTM
- CHM (DSM-DTM)
Data Acquisition

- Digital Multispectral Imagery (DMSI):
  - Outline 4-band (RGB/NIR) Imagery acquired at 50cm GSD resolution
  - Derived NDVI and Forest stratification
- Plantation health/stratification
- Project planning
  - GIS boundary validation
  - Plantation status – burned areas
  - Recently harvested areas
  - Plant health, stratification
  - ‘Visual’ guide to sample plot planation survey
Data Acquisition

- Sample Plots:
  - 30m x 30m grid placed over LiDAR data and LiDAR metrics applied to each square
    - mean height of first return (primary predictor variable)
    - % points reaching ground (% zero)
  - Mean Height LiDAR variable mapped and categorised into 70 equal classifications (‘bins’) – excl returns less than 4m

Sample Plot Location

120 random samples
distribution vs stand height metric
Data Acquisition

- Sample Plots:
  - 30m x 30m grid placed over LiDAR data and LiDAR metrics applied to each square
    - mean height of first return (primary predictor variable)
    - % points reaching ground (% zero)
  - Mean Height LiDAR variable mapped and categorised into 70 equal classifications ('bins') – excl returns less than 4m
  - Sample plot design established using a 'hybrid' approach:
    - 120 samples placed using a random systematic approach
    - Last 30 placed by reviewing the LiDAR-derived metric of stand height versus plot locations and ensuring plots fell in each LiDAR metric 'bin'.
  - Some allowance for adjustment in harvested areas, fire, GIS boundaries

Sample Plot Location

150 samples (30 additional plot sites) distribution vs stand height metric
120 random samples distribution vs stand height metric
Field sampling Approach

- Two plot sizes:
  - Unthinned stands – 0.02ha (~16m dia)
  - Thinned stands – 0.04ha (~23m dia)
  - Approx. 20 trees sampled per plot

- Field data collected for each plot:
  - Plot centroid to sub-metre accuracy
  - Diameter at Breast Height (DBH) of all stems
  - Tree height (Top height) for subset of trees – to fulfil requirements of a Petterson Diameter Height Regression (PDHR) for the plot
  - Stocking rate
  - Stem volume using trigonometric variable from taper function

Data Processing

- DMSI:
  - Process to 3-band RGB and NIR imagery mosaics – Fully ortho-rectified, colour balanced and seamless
  - Derive NDVI using NIR and Red image bands
  - Stratify (smooth) NDVI and threshold to eliminate bare earth areas
  - Derive NDVI statistics at stand/compartment level for consideration in statistical analysis and TSV calcs
<table>
<thead>
<tr>
<th>Plantation</th>
<th>Pyear</th>
<th>Species</th>
<th>LINK_KEY</th>
<th>NDVI_mean</th>
<th>NDVI_max</th>
<th>NDVI_min</th>
<th>NDVI_StdDev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lewana</td>
<td>1963</td>
<td>P</td>
<td>F000013873</td>
<td>0.269</td>
<td>0.462</td>
<td>-0.165</td>
<td>0.083</td>
</tr>
<tr>
<td>Lewana</td>
<td>1979</td>
<td>P</td>
<td>F000013367</td>
<td>0.200</td>
<td>0.441</td>
<td>-0.291</td>
<td>0.109</td>
</tr>
<tr>
<td>Lewana</td>
<td>1996</td>
<td>P</td>
<td>F000013179</td>
<td>0.396</td>
<td>0.565</td>
<td>-0.383</td>
<td>0.068</td>
</tr>
<tr>
<td>Lewana</td>
<td>1997</td>
<td>P</td>
<td>F000013051</td>
<td>0.400</td>
<td>0.616</td>
<td>-0.324</td>
<td>0.092</td>
</tr>
<tr>
<td>Lewana</td>
<td>1996</td>
<td>P</td>
<td>F000013630</td>
<td>0.509</td>
<td>0.672</td>
<td>-0.095</td>
<td>0.104</td>
</tr>
<tr>
<td>Lewana</td>
<td>1996</td>
<td>P</td>
<td>F000013053</td>
<td>0.494</td>
<td>0.652</td>
<td>-0.213</td>
<td>0.074</td>
</tr>
<tr>
<td>Lewana</td>
<td>1996</td>
<td>P</td>
<td>F000013250</td>
<td>0.536</td>
<td>0.641</td>
<td>0.048</td>
<td>0.055</td>
</tr>
<tr>
<td>Lewana</td>
<td>1996</td>
<td>P</td>
<td>F000013053</td>
<td>0.494</td>
<td>0.652</td>
<td>-0.213</td>
<td>0.074</td>
</tr>
<tr>
<td>Lewana</td>
<td>1996</td>
<td>P</td>
<td>F000013313</td>
<td>0.413</td>
<td>0.610</td>
<td>-0.363</td>
<td>0.104</td>
</tr>
<tr>
<td>Lewana</td>
<td>1996</td>
<td>P</td>
<td>F000013763</td>
<td>0.391</td>
<td>0.550</td>
<td>-0.278</td>
<td>0.085</td>
</tr>
<tr>
<td>Lewana</td>
<td>1996</td>
<td>P</td>
<td>F000014080</td>
<td>0.547</td>
<td>0.668</td>
<td>-0.143</td>
<td>0.091</td>
</tr>
<tr>
<td>Lewana</td>
<td>1996</td>
<td>P</td>
<td>F000013889</td>
<td>0.585</td>
<td>0.660</td>
<td>0.052</td>
<td>0.056</td>
</tr>
<tr>
<td>Lewana</td>
<td>1996</td>
<td>P</td>
<td>F000013259</td>
<td>0.541</td>
<td>0.671</td>
<td>-0.358</td>
<td>0.123</td>
</tr>
<tr>
<td>Lewana</td>
<td>1996</td>
<td>P</td>
<td>F000013162</td>
<td>0.510</td>
<td>0.664</td>
<td>-0.244</td>
<td>0.080</td>
</tr>
<tr>
<td>Lewana</td>
<td>1997</td>
<td>P</td>
<td>F000013417</td>
<td>0.401</td>
<td>0.572</td>
<td>-0.279</td>
<td>0.108</td>
</tr>
<tr>
<td>Lewana</td>
<td>1965</td>
<td>P</td>
<td>F000014346</td>
<td>0.154</td>
<td>0.343</td>
<td>-0.256</td>
<td>0.098</td>
</tr>
<tr>
<td>Lewana</td>
<td>1965</td>
<td>P</td>
<td>F000013698</td>
<td>0.264</td>
<td>0.555</td>
<td>-0.336</td>
<td>0.112</td>
</tr>
</tbody>
</table>

Data Processing

- **LIDAR:**
  - Produce DTM (ground only)
  - Produce DSM (ground + trees)
  - Derive CHM (DSM – DTM)
  - Derive tree/stand height and stocking estimates at sample plot level from CHM using USDA Fusion software
  - Assess accuracy of different parameters and analysis variables by visual/manual review of results versus DMSI and regression against sample plot data:
    - Test different search window sizes for canopy maxima
    - Test different minimum tree height thresholds
    - Break analysis into groups based on tree age and thinning status
  - Utilising the ‘best’ parameters and analysis variables for different tree ages and thinning regimes, run search windows on a per compartment basis to derive estimates of average tree height and stocking rate on a compartment basis.
### SAMPLE PLOT LEVEL RESULTS:
Tree Maxima Search Window and Height Thresholds
By AGE/THINNING Categories

<table>
<thead>
<tr>
<th>Category</th>
<th>Description (Age, Thinning)</th>
<th>Average Canopy Maxima Search Window</th>
<th>Min Height Threshold (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>99 to 2003 un-thinned</td>
<td>2.4m (5 x 5)</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>95 to 98 un-thinned</td>
<td>2.6m (5 x 5)</td>
<td>12</td>
</tr>
<tr>
<td>3</td>
<td>89 to 94 thinned</td>
<td>3.5m (7 x 7)</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>89 to 94 unthinned</td>
<td>2.5m (5 x 5)</td>
<td>15</td>
</tr>
<tr>
<td>5</td>
<td>83 to 88 thinned</td>
<td>4m (8 x 8)</td>
<td>15</td>
</tr>
<tr>
<td>6</td>
<td>83 to 88 unthinned</td>
<td>3m (6 x 6)</td>
<td>15</td>
</tr>
</tbody>
</table>
FPC Final Analysis

• AveHt
• TopHt
• Sph
• TSV for unthinned stands
• TSV for thinned stands

STATISTICAL ANALYSIS (FPC)

Considered the following variables:

• Average Tree Height from LIDAR
• Stems per Hectare from LIDAR
• Age
• Thinning status (thinned or unthinned)
• Time (years) since thinning
• Percent Cover (from LIDAR): percent canopy hits vs ground hits
Applied to Wood Flow Model

- FPC’s wood flow model required the capture of all current standing radiata resource
  - Ground based MRI assessments were commenced in March 2010
  - Aerial LiDAR was undertaken in February 2011 as an option that would allow us to meet the project deadlines
  - Yield tables for the workflow model were derived using stratified MRI and LiDAR information.
Summary

- The Blackwood Valley region was chosen for data capture by Aerial LiDAR for a number of reasons
- The 13,000ha of plantations are reasonably close geographically
- The terrain is variable, it has steep, flat and undulating regions. Firm up our DEM’s.
- The plantations cover a wide range of ages, stockings, site qualities and thinning status.
- To be able to successfully capture a resource in a region of such variability would indicate that LiDAR should be viable across our other plantations outside the Blackwood Valley.
- Height prediction (both top height and average height) from aerial LiDAR is excellent
- FPC need to do more work on getting better relationships between TSV and SPH.
- Cost benefit has not been carried out at this stage

Thank you for listening,
questions welcome.