Prediction of productivity indices using remotely sensed data

Michael Watt, Jonathan Dash, Pete Watt, Santosh Bhandari
Introduction

- Site Index, 300 Index commonly used metrics to describe plantation productivity

- Typically estimates of these properties made at the stand level by foresters

- Estimates of these productivity surfaces have also been made using environmental variables
Introduction

• Little research has investigated the utility of remotely sensed data sources for predicting productivity metrics

• Use of remotely sensed data could:
  – improve prediction accuracy
  – allow fine scale spatial prediction

• Combinations of the following three data sources could be useful:
  – Environmental Surfaces
  – Satellite Imagery
  – LiDAR
Data sources
- Environmental surfaces

- Data mostly at 100 m² resolution
- Air temperature
- Solar radiation
- Rainfall
- Relative humidity
- Slope
- Soil fertility
Pete, Santosh, if you have any additional information or pictures please add these.

Michael Watt, 4/03/2015
Data sources
- satellite imagery

• RapidEye most useful satellite
  – 5 m resolution, 0.01-0.02 $/ha

• 5 spectral bands
• Vegetation ratios that describe photosynthetic activity can be derived.
• Textural measures that describe vegetation surfaces can be derived.
• Easily incorporated into GIS
Data sources

- Light detection and ranging (LiDAR)

Active remote sensing technology

LiDAR emits ~ 200,000 pulses per second
Records up to 4 returns per pulse
Each return is converted to 3D point
**Site Index from LiDAR**

- LiDAR can be used to accurately predict height.
- Using stand age and an age-height equation, we can estimate Site Index.
- Site Index predicted from LiDAR was used for modelling.
Objective

- Develop models of 300 Index and Site Index using different combinations of LiDAR, satellite imagery and environmental surfaces

- Models developed with and without stand age using both non-parametric and parametric methods
Methods

- LiDAR acquired early 2014 ~ 11 points m²
- RapidEye acquired January 2014
- Total of 493 plots installed early 2014
- 433 plots used for model fitting, 60 plots set aside for model validation
Methods

- Total of 14 models developed using various combinations of the three datasets.
- Parametric method used was multiple regression
- Non-parametric method used was k-nearest neighbour
  - Random forest or k-MSN used to assign neighbours
  - Values of k were optimised to minimise model error
Results - Site Index

Models used to predict Site Index

Without age

Coefficient of determination ($R^2$)

- Parametric
- Non-parametric k-NN

With age

Root mean square error (m)
Results - 300 Index

- RapidEye (RE) spectral
- RE ratios
- RE texture
- RE spectral + ratios + texture
- Environmental variables
- Environmental variables + RE
- LiDAR predicted Site Index (SI)
- LiDAR Pred. SI + Environ. + RE

Coefficient of determination ($R^2$)

- Without age
- With age

Root mean square error (m$^3$ ha$^{-1}$ yr$^{-1}$)

Models used to predict 300 Index
## Results – Best Models

<table>
<thead>
<tr>
<th>Metric</th>
<th>Age?</th>
<th>Type</th>
<th>Variables</th>
<th>$R^2$</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Index</td>
<td>Y</td>
<td>NP</td>
<td>LiDAR + Environ. + RapidEye</td>
<td>0.91</td>
<td>1.40 m</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>P</td>
<td>Environmental + RapidEye</td>
<td>0.79</td>
<td>2.46 m</td>
</tr>
<tr>
<td>300 Index</td>
<td>Y</td>
<td>P</td>
<td>LiDAR</td>
<td>0.79</td>
<td>2.45 m³ ha⁻¹ yr⁻¹</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>NP</td>
<td>Environmental + RapidEye</td>
<td>0.65</td>
<td>3.21 m³ ha⁻¹ yr⁻¹</td>
</tr>
</tbody>
</table>
Variable importance

**Site Index**

(a) Mean $F$-value

- LiDAR derived SI
- Av. spring air temp
- Band 5 ME-25 Red reflectance
- NIR reflectance
- Age
- Blue reflectance
- EVI
- Band 4 SD-25
- NDVI
- Simple ratio
- Band 4 ASM-25
- Band 5 COR-15
- Band 5 CON-15
- Av. spring solar rad
- Av. solar rad

(b) Mean Importance

- LiDAR derived SI
- Av. spring air temp
- Band 5 ME-25
- Red reflectance
- NIR reflectance
- Age
- Blue reflectance
- EVI
- Band 4 SD-25
- NDVI
- Simple ratio
- Band 4 ASM-25
- Band 5 COR-15
- Band 4 ME-25
- Av. spring solar rad
- Av. solar rad

**300 Index**

(a) Mean $F$-value

- LiDAR derived SI
- Av. spring air temp
- Band 5 ME-25
- Red reflectance
- NIR reflectance
- Age
- Blue reflectance
- EVI
- Band 4 SD-25
- NDVI
- Simple ratio
- Band 4 ASM-25
- Band 5 COR-15
- Band 4 ME-25
- Av. solar rad
- IntLkurtosis
- CN ratio

(b) Mean Importance

- LiDAR derived SI
- Av. spring air temp
- Band 5 ME-25
- Red reflectance
- NIR reflectance
- Age
- Blue reflectance
- EVI
- Band 4 SD-25
- NDVI
- Simple ratio
- Band 4 ASM-25
- Band 5 COR-15
- Band 4 ME-25
- Av. solar rad
- IntLkurtosis
- CN ratio
### Results – Top three variables

<table>
<thead>
<tr>
<th>Metric</th>
<th>Type</th>
<th>Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Index</td>
<td>P</td>
<td>LiDAR derived Site Index; Av. spring air temp; NIR mean texture</td>
</tr>
<tr>
<td></td>
<td>NP</td>
<td>LiDAR derived Site Index; Av. spring air temp; Av. spring solar rad.</td>
</tr>
<tr>
<td>300 Index</td>
<td>P</td>
<td>LiDAR derived Site Index; Av. spring air temp; NIR mean texture</td>
</tr>
<tr>
<td></td>
<td>NP</td>
<td>LiDAR derived Site Index; Av. spring air temp; Av. summer VPD</td>
</tr>
</tbody>
</table>
Research gains

Using Environmental Surfaces (previous method)

Using all variables, including LiDAR

![Graph showing predicted vs measured site index and 300 index.](image)
Research gains

Using Environmental Surfaces (previous method)

- $R^2 = 0.76$
- RMSE = 2.30 m
- RMSE = 3.55 m$^3$ ha$^{-1}$ yr$^{-1}$

Using all variables, including LiDAR

- $R^2 = 0.91$
- RMSE = 1.40 m
- RMSE = 2.45 m$^3$ ha$^{-1}$ yr$^{-1}$
Summary

• Models of Site Index and 300 Index created

• Significant gains in precision possible using information from LiDAR and RapidEye

• For models without age, best data source were environmental surfaces + RapidEye

• For models with age, best data source was LiDAR

• RapidEye and environmental surfaces useful cost effective alternative to LiDAR
Acknowledgements

• GCFF programme jointly funded by MBIE and NZ Forest Growers Levy Trust

• Timberlands

• Professional contribution of all field teams involved
http://research.nzfoa.org.nz/
www.scionresearch.com/gcff

Michael Watt
Research Leader – Forest Operations and Monitoring
michael.watt@scionresearch.com

Date: 24 March 2015