Case Studies Forestry and Urban Tree management projects

Forestry Tasmania
Usage of full waveform Lidar in forestry taxation

Objective of the Project:
Forestry Tasmania is Australia's biggest forestry operator and handles approximately 3.5 Mio ha of plantations and native forests. In 2008 Forestry Tasmania contracted Dimap to fly a test area of 6000 ha with the full waveform Lidar to develop optimized taxation procedure of the forests using Lidar technology to reduce the taxation costs and get full area taxations with faster turnaround times of the data.
The solution should also provide additional data layer for other departments like harvesting planning.

Technical Solution:
Dimap applied the Riegl 560 full waveform scanner together with a digital camera to fly the steep mountain terrain in central Tasmania generating more than 4 pts/sqm and an Orthophoto with a resolution of 10cm while forestry Tasmania collected traditional plot data for the different forest structures. During the processing Dimap provided not only the Images, intensity images, LAS point files, DTM and DSM but also full waveform data and statistically summarized waveform data describing the forest in more details.
The ground plot data were then used to calibrate the Lidar data (using synthetic and real waveform data) and calculate top and mean heights, basal area per hectar and stem volumes with better than 90% accuracies. Furthermore the segmentation of the forests and additional data layer for the GIS system run by Forestry Tasmania were calculated. The stratification of the forests could be analysed as well as fuel load as part of the forest fire prevention.

Achievements:
The technology allowed Forestry Tasmania to reduce the manual field effort for taxations by 80% and ended in a setup to collect taxation data's for the 3.5 Mio ha based on airborne full waveform Lidar within a 3 year project. The technology replaced the classical ground based taxation approach completely and is established as standard operation procedure.
During the project Dimap also found the tallest tree Australia's with over 100m height.

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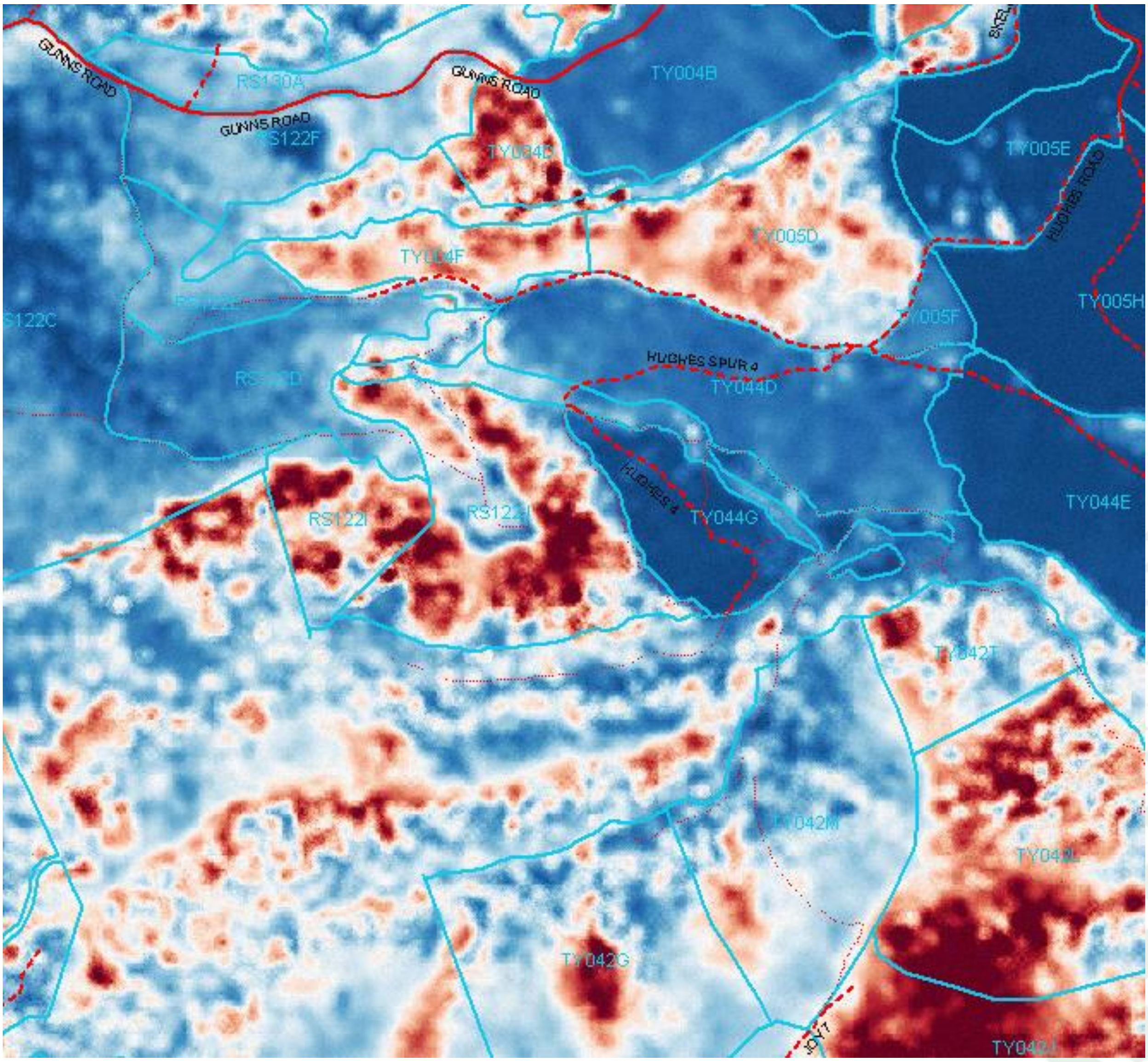

Figure 1: LiDAR-derived metrics used to predict merchantable volume. Volume surfaces (merch vol/hectare) - high spatial precision

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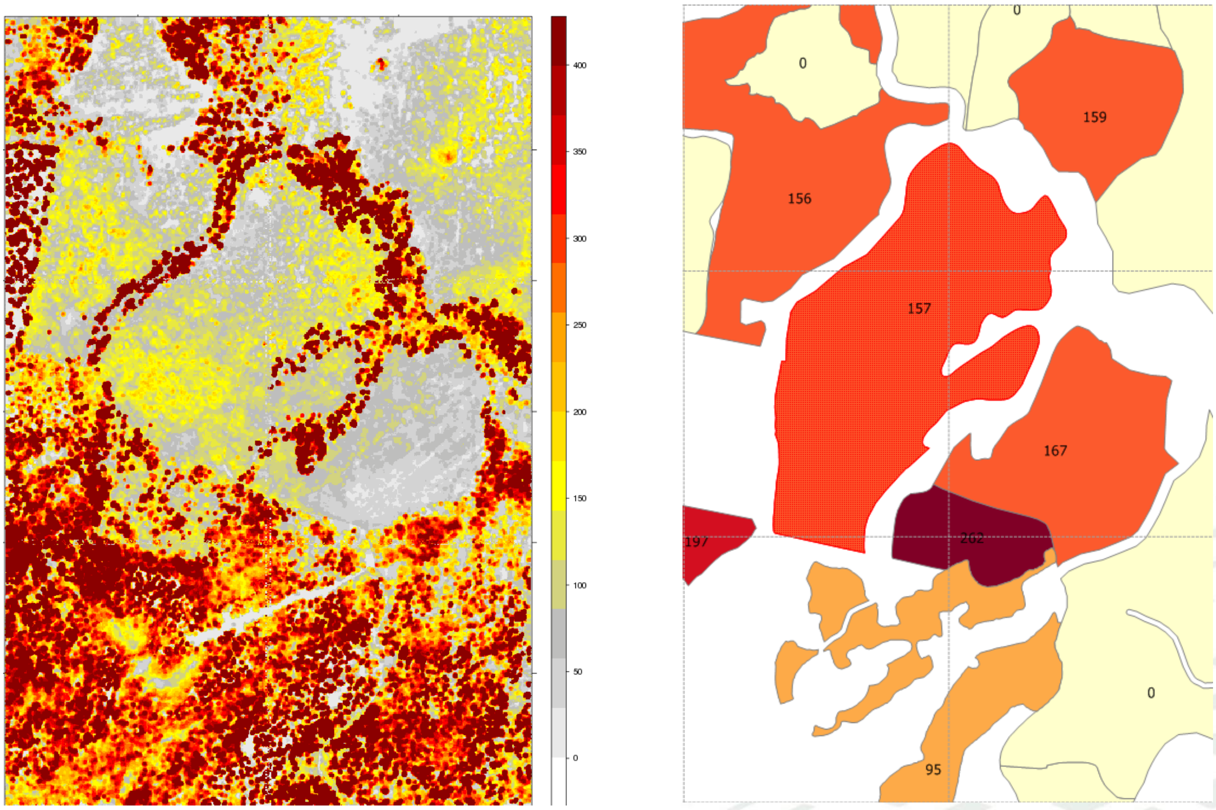

Figure 2: Two views of the same patch - the stratified random sampling approach, and the LiDAR surface-based approach. LiDAR-based timber inventory has resolution at Strategic, Tactical and Operational levels.

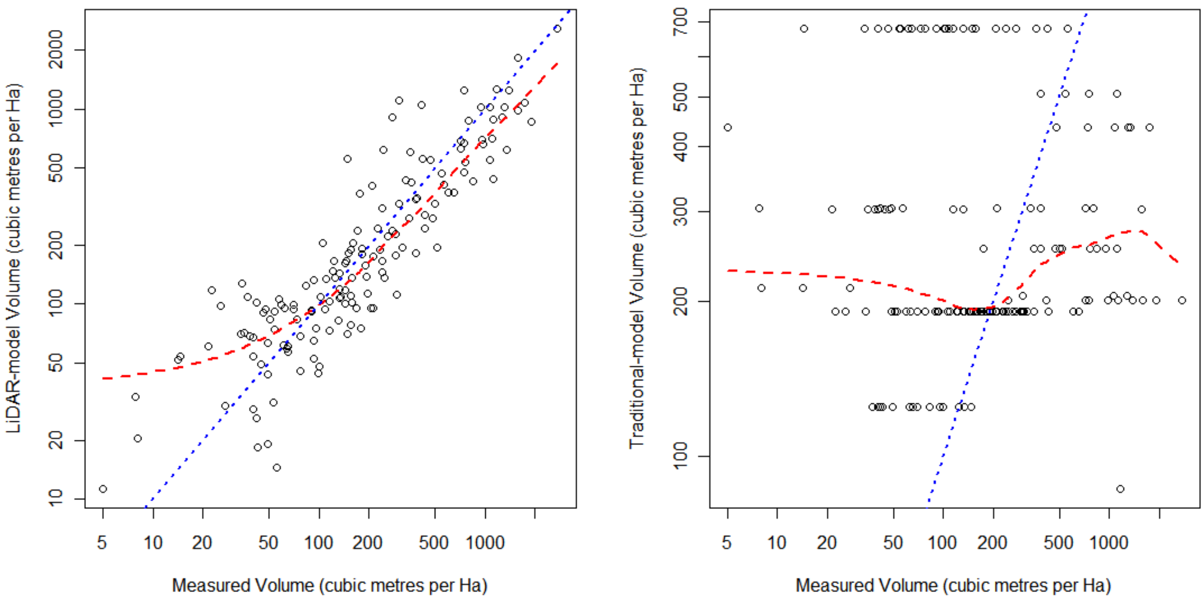

Figure 3: LiDAR volume model predictions vs stratified random sampling derived estimates (plot predicted vs. measured) for native forest development model. Red line is the bias trend.

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General comparison with classical photogrammetry approach:
Analysing publications from Canada, Australia and Scandinavia and comparing Dimap's and other Lidar provider results with classical photogrammetry procedure results and ground plots following RMSE can be achieved. One has to note that the errors in forestry taxation using Lidar data are depending on the tree species (better RMSE for coniferous and plantations) and that individual tree detections works not on all species and only in the upper strata.
One has also to note that the integration of Hyperspectral tree species detection improves the results of the individual tree detection but also allows the collection of taxation parameters in mixed forest including the implementation of species dependent BHD-Height-Canopy diameter relationships.

Parameter	Lidar based on forest stands	Lidar based on individual tree detection min 8pts/sqm	Lidar 4 pts/sqm and Hyperspectral approach	Classical photogrammetry approach
Individual tree detection top strata	N/A	15 – 25%	2 - 15%	0 - 5%
Individual tree detection second and third strata	N/A	40 – 50%	30 - 40%	Not possible
Number of trees per ha (also species dependent)	10 – 15%	5 – 20%	5 – 10%	20 – 30%
Species detection	Possible in plantations based on intensity	Not possible	Non rainforests 5 - 30%	Limited possible
Tree species distribution	Not possible	Limited possible	100%	20 – 30%
Mean tree height - absolute	40 – 60cm	20 - 40cm	20 – 50cm	30 – 70cm
Mean tree height - relative	5 – 10%	5-10%	5 – 10%	10 – 25%
Automatic Canopy diameter top strata	N/A	20 - 50%	10 - 35%%	10 – 40%
Basal area	10 – 15%	5 – 15% only plantations	5 – 25% Also mixed forest	20 – 30%
Mean diameter (depending on species)	10 – 15%	10 – 15%	10 – 15%	10 - 35%
Diameter distribution	Not	10 – 20%	5 – 20%	Not possible
Forestry relevant Volume per ha (tree species)	5 – 15%%	5 – 20%	5 – 20%	15 – 30%
Carbon volume including branches	15 – 30%	10 – 20%	7 – 15%	20 – 40%

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Rainforest Mapping - Malaysia

Objective of the Project:
A block of 20 sqkm of indigenous rainforest in peninsula Malaysia was mapped using full waveform Lidar and VNIR Hyperspectral sensor to identify individual tree species and demonstrate the usability of the technology for forestry taxation and management of complex rainforests.

Technical Solution:
The area was flown using a Eurocopter 135 equipped with full waveform Lidar, digital camera and VNIR Hyperspectral sensor. The points density for the Lidar data was better than 20 pts/sqm while the resolution of the VNIR Hyperspectral data was 0.3m with 160 bands. The raw VNIR data showed the vibration of the helicopter but after applying the orthorectification with Parge these effects were eliminated.
All data were processed, mosaicked and further analysed.

Achievements:
The collected data were processed within 10 days to a complete dataset for further analysis. The results can be summarized as following:

1. Due to the extreme dense forest and the wet underground less than 3% of all Lidar strikes reached the ground. Therefor the ground classification of the data was problematic but is enough for a vegetation height classification.
2. The processing of the DSM allowed the generation of a vegetation height layer, which is with 0.5m resolution suitable for surveying top and second strata trees.
3. Further detailed structural analysis using the Full Waveform and Synthetic Waveforms allowing details for the structural analysis of the lower strata.
4. The high resolution Hyperspectral data in fusion with the point cloud allows the discrimination of individual trees and species in the top two strata based. The collection of ground sample data can be reduced by collecting data over an area with a known tree cadastre and an in-scene library generation. The detection rate for individual trees is better 80% in the mixed rainforest.
5. The resolution of 0.3m allows also the detection of parasites and epiphytes.
6. The dataset supports the calculation of 20 established broad- and narrow band vegetation indices to identify health status and phytopathological parameters of the individual trees.
7. Based on the fusion between Lidar and hyperspectral data are for the main strata and dominant species also basic taxation parameters like biomass, canopy diameter and height the resulting stem estimations possible.

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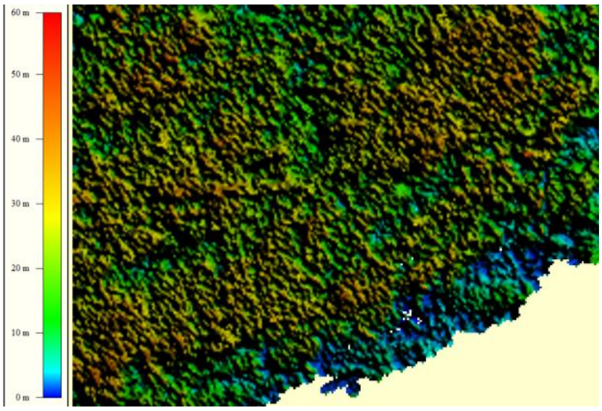

Figure 4: Tree heights based on Lidar data and 0.5m DSM

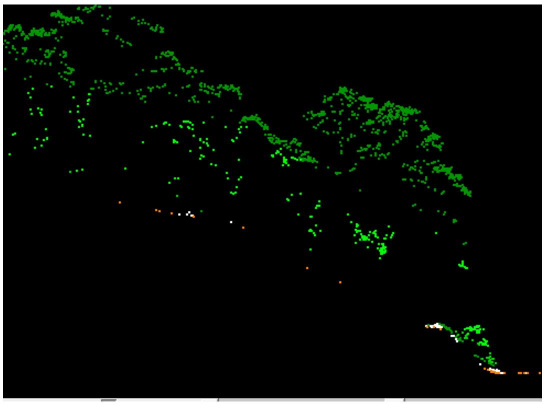

Figure 6: 2m cross section through river bank and rain forest

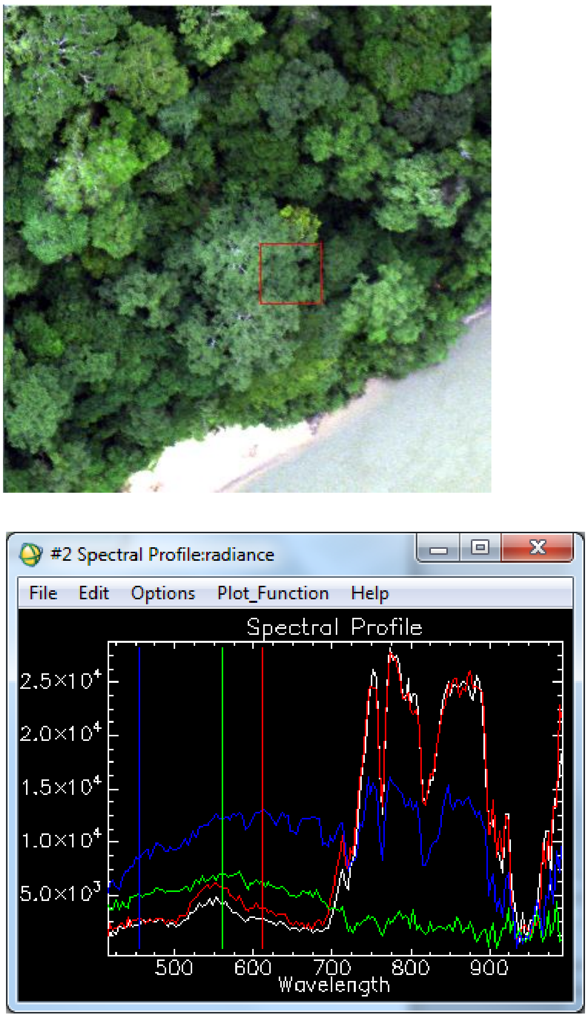

Figure 5: Hyperspectral radiance data set of rainforest (as RGB) and spectra of different objects

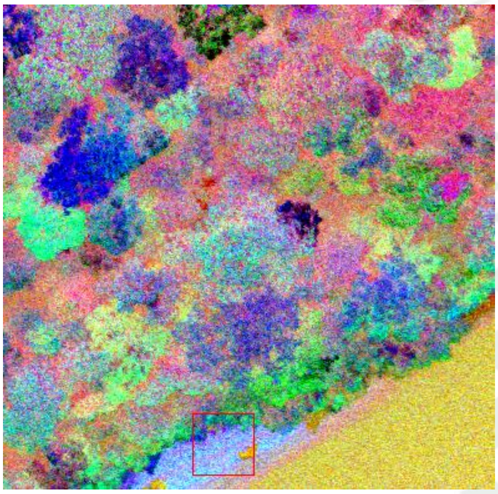

Figure 7: Visualisation of different tree species based on spectral signature

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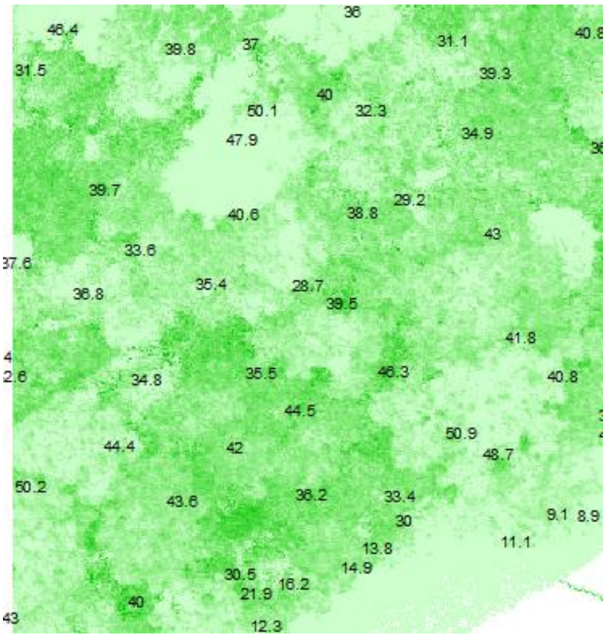

Figure 8: Red edge vegetation index as example of recording physiological parameters including the tree height based on the lidar data and a combine automatic tree detection.

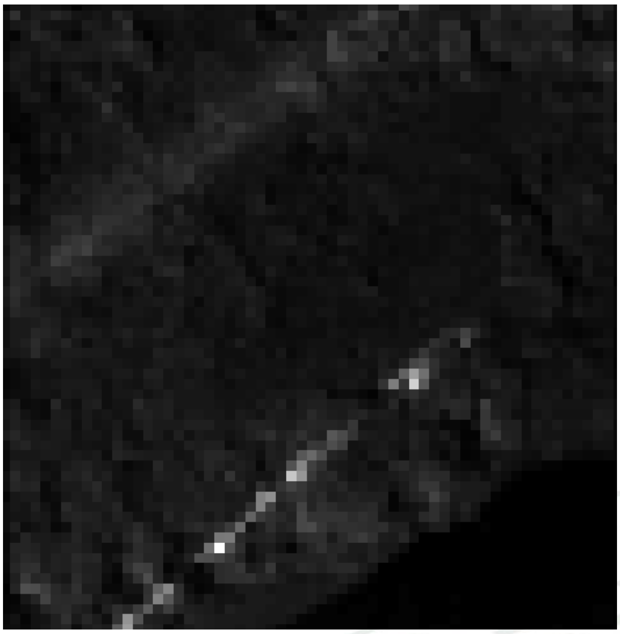

Figure 9: Uncalibrated biomass based a synthetic waveform showing along the river increased forestry structures

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Ramin Tree Detection – Pekan Rainforests - Malaysia

Objective of the Project:
The Ramin tree is a rare species in the native and managed forests in Peninsula Malaysia protected by national and international law. The task was to identify Ramin trees in native and managed forests, map their positions and collect attributes as height and canopy diameters for each identified tree.

Technical Solution:
The test area with a size of 8km by 5km was flown using a fixwing aircraft equipped with full waveform Lidar, digital camera and VNIR Hyperspectral sensor. The points density for the Lidar data was better than 3 pts/sqm while the resolution of the VNIR Hyperspectral data was 0.5m with 160 bands.
The ground in the test area was peat swamps, so wide parts were covered with water, what made the ground detection difficult. For the test area Dimap measured together with local foresters individual trees and identified more than 130 Ramin trees in different flowing status as ground truthing data. The analysis using object based classification combining Lidar data and the Hyperspectral data identified with a probability of 88% the Ramin trees of the top strata and mapped their canopies as vector object.

Achievements:
In the test area more than 2100 Ramin trees were identified and mapped. The methodology got accepted by the local authorities as a possible way of monitoring the distribution of endangered species. Ongoing studies will define the perfect season for the mapping work and the relationship of Height, Canopy diameter and stem diameter to support taxations.

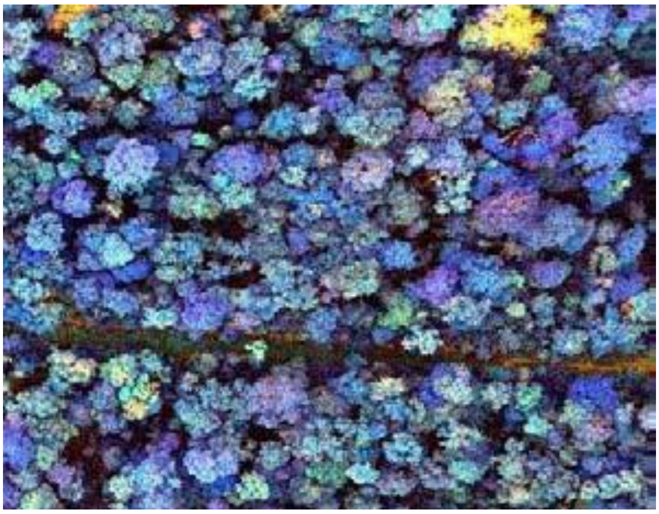

Figure 10: Pekan peat swam rainforest – image shows the density of the forests.

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Urban Forest Tree Mapping – Melbourne

Objective of the Project:
Between 2009 and 2012 different suburbs of Melbourne engaged Dimap to collect multisensory data using thermal, Hyperspectral, Lidar and image sensors to provide data for the government GIS system. Some council required support data for their tree cadastre including tree species/families and height data.

Technical Solution:
During the multisensory flight Dimap collected VNIR Hyperspectral data with a resolution of 0.6m and an absolute accuracy of better 1m and 4 pts/sqm Lidar data. The Hyperspectral data contained 160 bands. In a first step Dimap calculated 19 different vegetation indices describing vegetation activities, health and stress. This data were fused with the Lidar data to identify individual tree object. Using classical and object based classification procedures tree families and the species of the most common trees were identified and vectorized as GIS layer including height, canopy diameter and height of the individual trees. Due to the similarity of some Eucalyptus species a complete separation of all species were not possible. For the classification of the families the results had 88% to 99% confidence, for the most common species the classification accuracy was better than 95%.

Achievements:
Beside other layers for the council GIS Dimap provided layers identifying trees in their spatial extension, their parameter and their families and species. The collection of the data took 2 days of flying and reduced the effort for the arborists doing the ground work significant while location and major measurements for each tree were available.

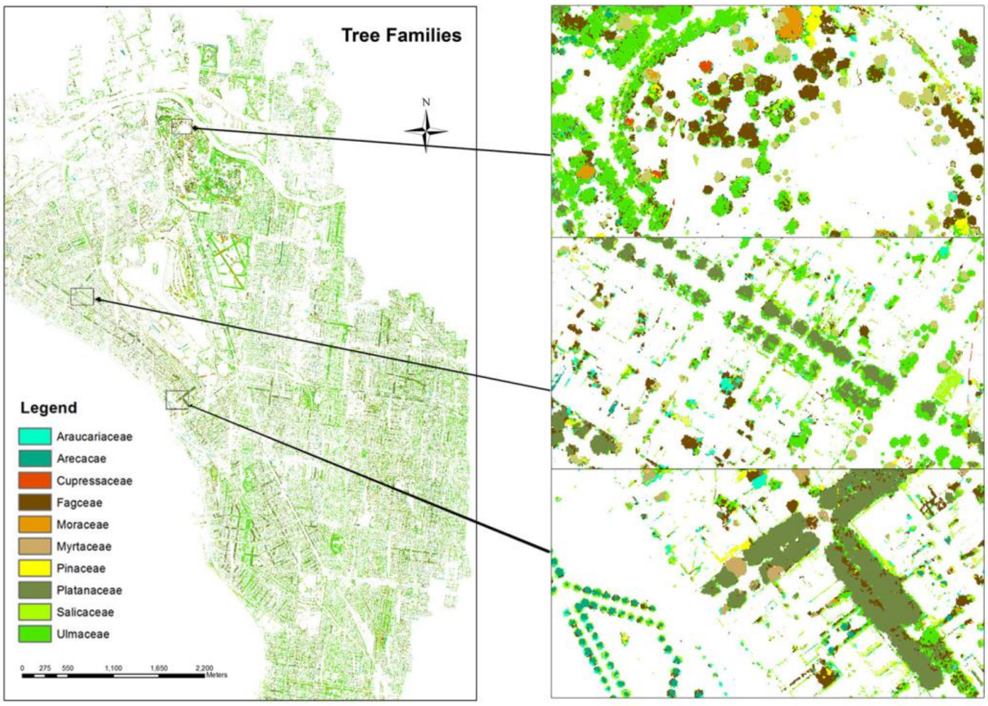

Figure 11: Tree families - GIS layer in one of the Melbourne councils

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