ENVIRONMENT & SOCIAL TECHNICAL NOTE

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Remote Sensing Biodiversity in Plantation Stands with LiDAR

Summary

Remote sensing technology can potentially help us quantify the biodiversity value of plantation stands at a large spatial scale. This decreases reliance on intensive, repeated, ground based sampling. LiDAR (Light Detection And Ranging) has the ability to quantify stand structural complexity, which is proposed as an important indicator of high biodiversity in plantations. This technical note presents the results of a 12 month long study that compared 127 LiDAR based metrics of stand structure with plant, bird and beetle diversity in 30 planted forest stands from the North Island and upper South Island. Our findings show that key LiDAR metrics can explain differences in observed species richness of plants, birds and beetles. Our preliminary models show that select LiDAR metrics explained 47.4, 32.6, and 41.3 % of the variation in plant, bird and beetles species richness, respectively. This compares favourably with other studies that have attempted to model biodiversity using LiDAR. We must now validate our results on an independent data set before extending the technology to produce an operational tool for use by foresters to map biodiversity values across plantations. This validation step will be completed by September 2013.

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Aim

To identify LiDAR based metrics of forest structural complexity that explain plant, bird and beetle biodiversity in a plantation forest context.

Introduction

This project aims to investigate if the observed understory biodiversity (native plants, birds and beetles) can be explained by LiDAR based metrics of stand structural complexity.

Quantification of stand structural complexity on large spatial scales is difficult as small scale differences in structural complexity, e.g., within small gullies etc, is unlikely to be adequately captured by the existing network of ground-based PSP plot measurements. However, since the 1990's developments in LiDAR technology have transformed the way in which forest managers can measure attributes of forest stands [3]. LiDAR can quickly and efficiently provide continuous quantitative measures of stand structural complexity over large spatial scales as the light pulses emitted by the laser unit are returned to the receiver by reflecting on different layers in the forest canopy. Various metrics can then be derived from the percentage of hits at different heights in the canopy as well as the ground. This allows researchers to accurately distinguish between stands (and areas within stands) that have a dense understory, e.g., tree ferns, as opposed to stands with little understorey and mid-canopy development.

Methods

The methods for this study have been discussed in detail in the previous technical note [6].

Results

A wide variety of native plants, birds and beetles were sampled across the 30 sites (Table 1).

***Table 1**: The number of species observed in ground based surveys from the 30 sites.*

Taxonomic Group	Native	Exotic	Total
Plants	195	75	279
Birds	15	11	26
Beetles	?	?	469

*Note: the total number of species may not equate to the sum of the native and exotic components as the country of origin of some species is unknown. For beetles we have not attempted to determine their origin as they are sorted to morphospecies and for most we cannot provide their full taxonomic names.

The results of these ground based surveys are significant in themselves as they represent 8.3 and 18.3 % of the total described native plant [1]

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and native terrestrial bird fauna [4] respectively. These totals are an under estimate of the true biodiversity value of plantations at a national scale as our surveys were limited both in their geographical and temporal scope. For example, some plants are only visible at certain times of the year (e.g., orchids), and we know from previous work that such species should be present in these forests but were not observed at our study sites at the time of sampling.

A total of 127 LiDAR metrics were derived from the LiDAR data collected by the Ministry for Environment as part of the LUCAS carbon project. Note: A complete list of metrics and their description is available on request from the author. The full list was reduced to 85 individual metrics that represented seven types of potential indicators: Vertical structure (13), Horizontal structure (12), Gap metrics (11), Cluster metrics (12), Cluster metrics 2-5 m height band (13), Cluster metrics canopy tops (14), and intensity metrics (10). The remaining 42 metrics were not considered further as each was highly correlated with at least one of the remaining 85 metrics retained in the analysis.

Each of these seven groups of metrics was then compared against our ground based observations of biodiversity data, in particular against the observed species richness of plants, birds, and beetles. We used a multiple regression approach to identify 31 LiDAR metrics that were important in explaining the variation observed in the biodiversity data (Table 2).

Table 2: *Number of LiDAR metrics within each group that were significant predictors of observed biodiversity data.*

Type of metric	Plants	Birds	Beetles
Vertical	1	1	1
Horizontal	1	1	2
Gap	1	1	4
Cluster	2	0	1
Cluster (2-5m)	2	1	0
Cluster (canopy)	6	2	1
Intensity	1	1	1
Total	**14**	**7**	**10**

Significant metrics from each of the seven groups were then combined and used in a secondary analysis to identify the simplest models that explained the greatest amount of the variation in our observed biodiversity data. These models were:

Plants:
A three factor model explained 47.4% of the variation in plant species richness at the 30 sites. These three factors were:

- Biggest gap size: The LiDAR plot was converted into a grid square with cells of 1 m^2. To be considered part of a gap, a cell could not have any LiDAR returns that were more than 10 m above the ground. Biggest gap size was the strongest predictor of plant species richness and explained 31.9 % of the variation (Figure 1).
- The biggest understory cluster size explained an additional 8.6 % of the variation. An understorey cluster is conceptually the opposite of the gap as defined above, i.e., it is the size of the cluster of cells that have a return within them. Understorey returns are defined as any returns between 0.2 and 5m from the ground.
- The ratio of edge to the square root of the total area of understorey clusters explained an additional 6.9 % of the variation in plant species richness. This metric provides information on the shape of the cluster, i.e., is it big and circular or very irregular in shape.

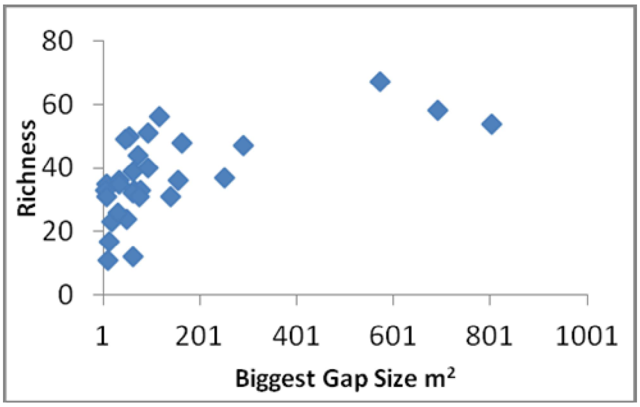

Figure 1. *Total plant species richness as a function of the largest gap size in the canopy.*

Birds:

A two factor model that explained 32.6 % of the variation in total bird species richness at the 30 sites. These two factors were:

- The mean intensity of all LiDAR returns between 80% of maximum height and the maximum height explained 24.7 % of the variation in bird species richness.
- The percentage of the plot that was within 2 m of a canopy gap. As explained in the plant model, a gap refers to a 1 m^2 cell with no returns above 10 m in height. This factor explained an additional 7.91 % of the variation in bird species richness.

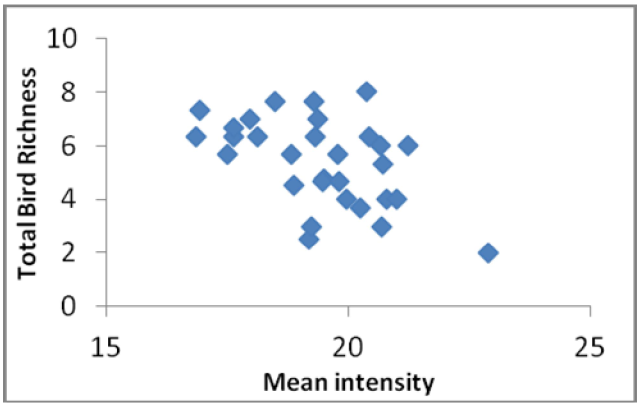

Figure 2. *Total bird species richness declines with increasing mean intensity of all LiDAR returns greater than 80% of maximum tree height.*

Beetles:

A two factor model that explained 41.3 % of the variation in total beetle species richness at the 30 sites. These two factors were:

- The ratio of the edge pixels to total area of the gap explained 33.6% of the variation (Figure 3). Gap is defined as a 1 x 1 m cell with no LiDAR returns above a height of 10 m.
- The biggest gap size explained an additional 7.7 % of the variation in beetle species richness.

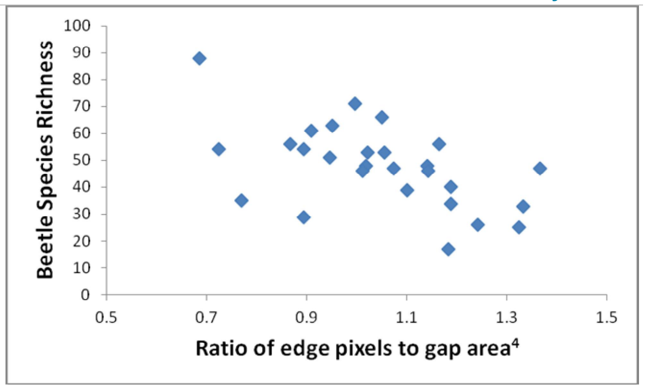

Figure 3. *Change in beetle species richness as a function of ratio of the edge pixels to total area of the gap*

Discussion

The technical note presents a "Post-Hoc", or 'data dredging' style analysis to test the feasibility of using LiDAR to monitor biodiversity. We derived 127 metrics from LiDAR data and we have determined if any are capable of distinguishing zones of high plant, bird or beetle species richness in plantation forest stands. Our results show that metrics describing the structure of the forest are strongly related to the species richness at the site. These results are very promising and suggest that LiDAR data can be successfully used as a means of classifying the biodiversity values of stands across large spatial areas.

To give an indication of how promising our results are we can compare the proportion of variance explained with other studies. For example, Müller and Brandl (2009) were able to explain 26.4% of the variation in beetles species richness in flight intercept traps and 3% of the variation in pitfall traps. In comparison our combined pitfall flight intercept traps explained 41.3% of the variation. Flaspohler et al. was able to explain an impressive 74% of the variation in bird species richness using LiDAR to quantify vegetation height in Hawaiian forest fragments. Their study explains a significantly larger proportion of the variation that we could explain for bird species richness (32.6 %). However, their study is a special case as the height of vegetation (which LiDAR is very good at measuring) in native forest fragments on lava flows is highly correlated with other very important ecosystem attributes, e.g., age and time since last disturbance, that regulate species richness. We are confident that our LiDAR models of bird species richness are robust given the system we are modelling, i.e., at wide spatial scales (national level) and in a constrained or managed system as opposed to a natural forest that has much greater variability in forest structure.

It is important that we conduct a confirmatory study that explicitly tests hypotheses generated from this study. This secondary work is vital to separate potentially spurious correlations (i.e., sampling artefacts) from useful metrics that are consistent, reliable indicators of biodiversity. This additional work will be completed by September 2013.

We are still in the early stages of developing the use of LiDAR for long-term monitoring of biodiversity values in plantations. If successful it will provide forest managers with:

- A robust mechanism for long-term monitoring of the status and trends of biodiversity within plantations.
- Allow rapid assessment of the potential impact of different management activities on a wide spatial scale, e.g., we can analyse the effects of new pruning or thinning regimes on canopy structure and infer potential future impact on biodiversity.
- Reduce (but not eliminate) the reliance on costly ground based surveys for monitoring biodiversity.

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