RADIATA MANAGEMENT TECHNICAL NOTE

Number: RTN-013
Date: May 2013

ACCURATE TREE COUNTING FROM IMAGES – FINALLY A REALITY?

Summary

One of the objectives of New Inventory research is to define a robust and accurate operational tree counting method that uses remotely sensed images and tree detection algorithms. Tree counting studies using a semi-automated image processing system called TIMBRS[1] showed some early promise. An experienced TIMBRS operator using ortho-photography can estimate tree counts to within 5% of the ground counts made by field teams. However there is a lack of repeatability across different image types and operators.

We have studied these issues over the past year and a number of innovations have led to the development of the new tree counting method **VPlot** based on calibration plots used in combination with image processing.

The new method is more systematic than TIMBRS alone, and requires less operator input to determine a total count. **Calibration counts** are used to set key parameters of the image processing and establish a ratio[2] applied to the count derived from image processing to obtain a final count along with an estimate of precision.

Three variations of the basic method are being evaluated. They differ in how calibration counts are obtained.

- In the OC method calibration counts are made by an operator on the image within bounded **virtual plots** drawn on the image.
- The GC method uses tree counts from actual ground **tally plots**.
- The VC method uses a further refinement to the GC method by recording the likely visibility of the crown of each tree in the ground plot.

Results to date show the GC and VC methods deliver repeatable counts while the OC method is variable across operators and image types.

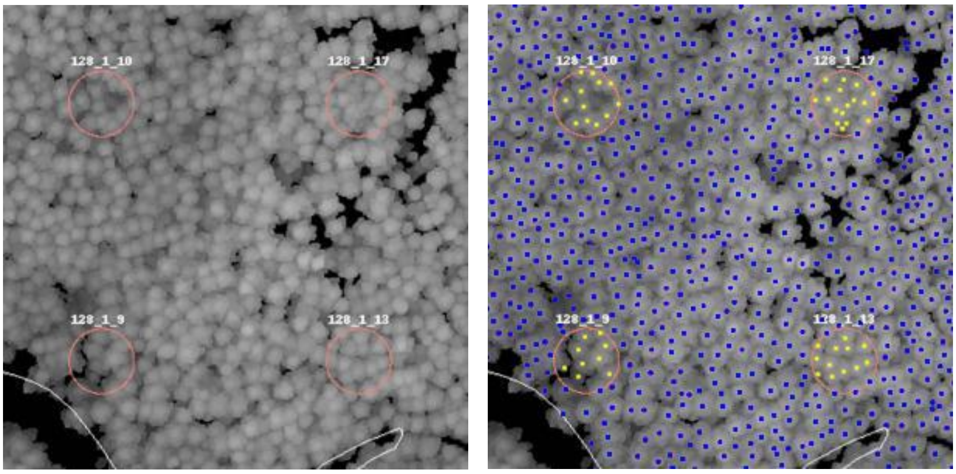

Figure 1 – Case Study Stand: Shows the LiDAR image (left) processed by VPlot with stand boundary in white and calibration plots in red. The output image (right) shows tree locations predicted by TIMBRS in blue and yellow (inside calibration plots).

An extensive case study is currently underway where we are evaluating the new counting methods in terms of the accuracy (target to be within 10% of true) and precision of the total count. Accuracy is being determined using a reference count estimated from high intensity bounded ground plots (a 10% area sample). As an example, Figure 1 shows the trees identified by VPlot on a LiDAR image using the GC method for a stand in the study.

This technical note explains these new tree counting methods and describes some of the key research findings that have led to their development.

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[1] Tree Identification Methodology Based on Remote Sensing (TIMBRS) is a semi-automated image processing system developed by CSIRO Forestry and Forest Products in 2000, which uses a spatial clustering Tree Identification and Delineation Algorithm (TIDA) to identify and count tree crowns.
[2] A statistical technique called ratio estimation is used to calculate the ratio between counts made in calibration plots (on the image or on the ground) and counts made by TIMBRS on the image at the same location.

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Image Analysis and the “VPlot” Tool

Images from satellite, aerial photography, and LiDAR (Light Detection And Ranging) contain spectral and spatial information that can be used to automatically identify tree crowns with image processing software. In TIMBRS the TIDA algorithm seeks the centre of a crown which is expected to be brighter than the edge of the crown.

With any image type, the image should be **geometrically corrected** (“ortho-rectified”), and have a **spatial resolution smaller than the tree crowns** being counted. For mature radiata pine stands a pixel size less than or equal to one metre should be used, with a resolution of 0.5 metres recommended.

A key parameter of most tree identification systems, including TIMBRS, is the amount of smoothing to apply to the input image to avoid the tendency of image processing to identify too many trees (actually large branches and other irregularities within each crown). The “**VPlot” tool** was initially developed to determine the smoothing and minimum tree distance parameters to use in TIMBRS.

To apply the **Gaussian smoothing** method used in TIMBRS, VPlot uses a simple relationship to estimate the smoothing level based on the stocking observed in the calibration plots. TIMBRS can also apply a between-tree **minimum distance** that limits instances where multi-leaders, forks, large branches and other spurious features are identified as individual trees. In VPlot this minimum distance is also estimated from the observed stocking.

Another feature introduced during early development of VPlot was the use of forest company **GIS shapefiles** to define stand boundaries. This removed the need for operators to digitise stand boundaries in TIMBRS, saving considerable time and removing a source of error in the tree counting process.

About Virtual Plots

Could other uses of virtual plots lead to further tree counting improvements?

Calibration plots are tree counts on small areas within the stand and this information can also be used to improve the estimate of total count from image processing by using a statistical technique called **ratio estimation**. This technique, incorporated in the latest version of VPlot, adjusts the count from TIMBRS using the ratio between the calibration counts and the TIMBRS counts within the calibration plots. In the case of the OC method this helps avoid errors like wrongly counting shrubs as trees. With the GC and VC methods this effectively anchors the count with ground truth, avoiding potential error in counts from images due to multiple leaders and suppressed trees. Ratio estimation has the additional benefit of providing a measure of precision, expressed as a PLE, on the final tree count.

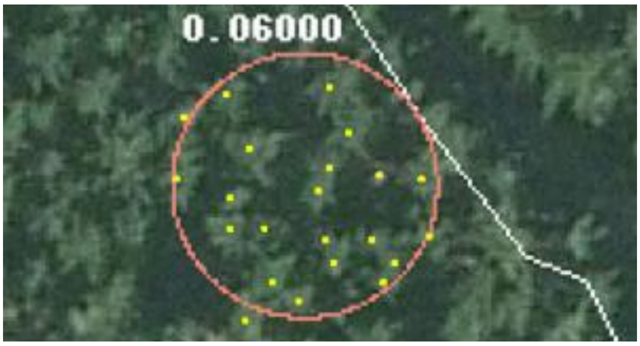

Figure 2 – ‘Trees’ selected by an operator (yellow) in a virtual plot on an ortho-photo.

Circular bounded calibration plots (either on an image or on the ground), are located with a sampling design that ensures all trees have an equal chance of being selected, as in conventional forest inventory practice. Investigations into the required number and size of calibration plots found that conventional practice for bounded inventory plots was generally applicable to calibration plots for tree counting with VPlot. Plots should be sized with respect to stocking to obtain a nominal 20 trees per plot. Generally a certain number of plots per hectare (sample fraction) are used; dependant largely on the expected variation within the stand, with a minimum of 8 plots indicated for calibrating VPlot.

A key issue to address was **edge plots** and the bias that can occur in estimates if they are not handled correctly. **Mirage plots** are the most commonly used method in the NZ forest industry. Another method is the **mapped plot** method where plots can be included if any part of the plot intersects the stand. This includes plots where the plot centre is located outside the boundary of the stand. The mapped plot method is convenient with the OC method where both the operator and TIMBRS count trees in virtual plots on the image as it simplifies calculations. With the GC and VC methods ground plots are required and it is important to know the edge sampling method used in order to correctly handle calculations of the counts in VPlot.

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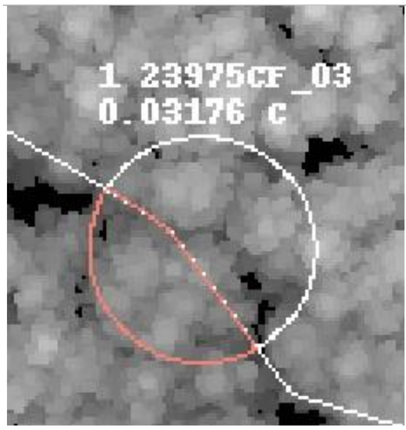

Figure 3 – A 0.08 hectare circular plot mapped by VPlot on a LiDAR image.

The plot centre is outside the stand boundary, with the area in red, 0.03176 hectares, being inside the stand.

The Tree Map

A useful by-product of the tree counting process is a geo-location (at the top of the crown) for each tree identified. This can be represented as a tree map (Figure 4).

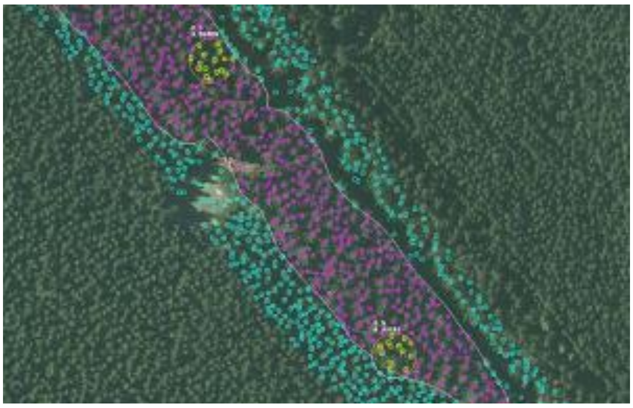

Figure 4 – A tree map showing the trees that are being counted for this stand in magenta or yellow (within calibration plots).

LiDAR images enable the variability of the stocking in a stand and unmapped small gaps within stands can be clearly seen (Figure 5). A tree map allows variation in stocking to be quantified and could be used as the basis of **stratification** of stands for management and inventory. With some further processing small unstocked areas can also be mapped with high resolution and this could be used to improve the accuracy of inventory and stand records.

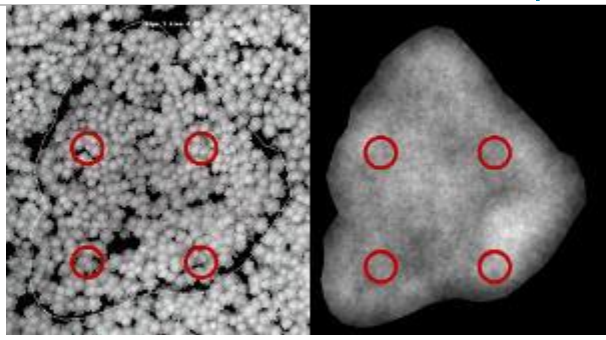

Figure 5 – A canopy image (left) can show unmapped gaps. Tree locations from VPlot can be used to generate a stocking map (right) which could be used for stratification purposes.

Three New Tree Counting Methods

The three new tree counting methods are:

1. Operator count (OC)
2. Ground count (GC)
3. Visible count (VC)

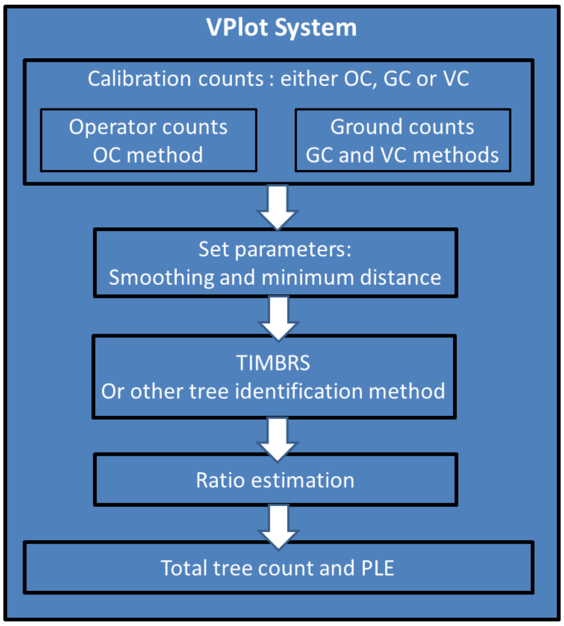

Figure 6 – Diagram of VPlot system and the three counting methods

These methods reduce operator time and improve repeatability over the early TIMBRS-only system, and they are easy to implement operationally (see Figure 6). The GC and VC methods reduce operator input to a minimum, and have more repeatable counts across different operators and image types. The OC system can also generate repeatable counts but this requires experienced operators using quality images.

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The key difference between these counting methods is simply whether **ground plot data** can be measured for calibration. If ground plot data is not available, for example there might be stand access issues, then the OC method can be applied and operator counts on the image are used for calibration (Figure 6).

Comparing Figures 7 and 8, the repeatability of tree counts improved when calibration from ground tally plots was used (Figure 8), compared to calibration from virtual plots on the image (Figure 7, OC method).

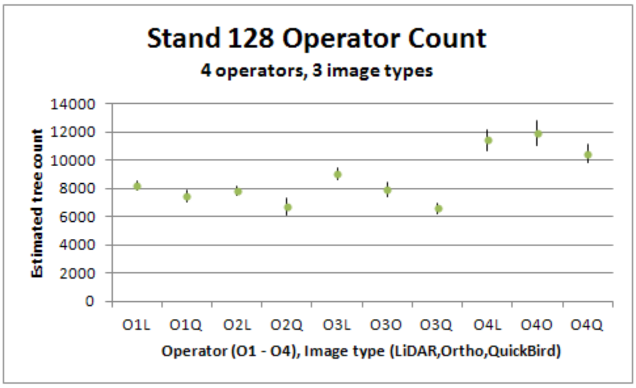

Figure 7 – A wide range in tree count for a stand from four operators and three image types with calibration on the image (OC method).

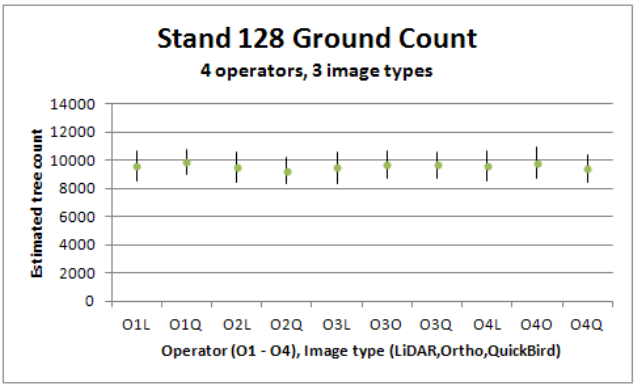

Figure 8 – Repeatability in tree counts for a stand from four operators and three image types with calibration from ground tally plots (GC method).

The minimum ground plot data required are **GPS plot co-ordinates** and **plot tally counts**. This information can be reasonably quick to gather in the field. Tally plot counts using a Leica DISTO laser range finder and a tape for checking marginal trees in 0.04 and 0.06 ha plots ranged from 3 to 6 minutes a plot. Investigations indicate about 8 minutes are required to achieve suitable GPS accuracy. The size, number and location of tally plots are currently recommended to be as per conventional forest inventory practice.

In-field assessment of crown visibility (VC method) was also included in the study. Preliminary results on a small set of stands suggest that crown visibility assessment added little improvement to using only the tally plot count (GC method). The VC method may be useful in stands with a high number of suppressed, multi-leader or top-out trees where crown visibility is significantly affected.

Image Types

Tree counting tests have been carried out using ortho-photography, QuickBird satellite, LiDAR based images and multi-ray[2] images. The advantage of ortho-photography is cost and availability. On the downside, shadows, image distortions and interpretation issues are problematic for tree counting.[3] The OC method can be particularly unreliable. Some preliminary case study results with the GC method are promising on pre-harvest stands using 2011 BOPLASS ortho-photography.[4]

A development in the FFR Canopy project research saw images for tree counting created from LiDAR data. Unlike the ortho-photography and QuickBird images, the LiDAR images had no problems with shadows or distortion, and they had less interpretation issues. They also offer the ability to mask out understory using the height information inherent in LiDAR.

We determined the effect of LiDAR data point density on the tree counting image. By randomly sub-sampling LiDAR pulses, data sets with varying levels of point density were created. A range from 4 to 8 first returns per square metre, with grid sizes of 0.5 to 1 metre were identified as suitable for tree counting. In the case study we are planning to test the advantages of LiDAR images, particularly with the OC tree counting method as this would avoid the need for ground tally plots.

Because it also offers perception of depth, a multi-ray image looks similar to a LiDAR image (Figure 9).

[2] Multi-ray uses multiple overlapping ortho-photos to ortho-rectify each pixel to create 3D digital terrain models.
[3] QuickBird images were identified as having similar issues for tree counting as ortho-photos.
[4] The 2011 BOPLASS images had a 0.4 metre pixel size. Distortion issues were not apparent but lighting was variable across the stands studied causing interpretation issues.

Multi-ray images underestimated total tree counts by 30%. This was attributed to the high level of pre-processing that had been applied to the images by the Microsoft multi-ray technology Ultramap V3.0. With multi-ray technology showing some potential for tree counting, further research to address cost effectiveness and the level of pre-processing is being considered.

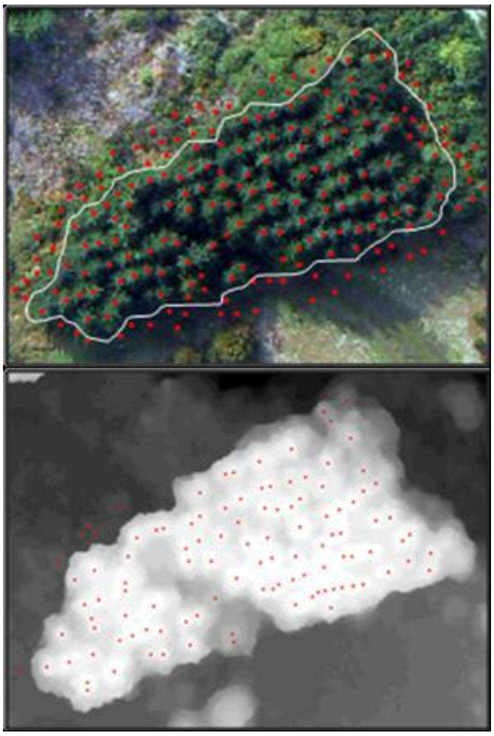

Figure 9 – Tree counts on an ortho-photo (top) and multi-ray image (bottom) of a stand.

Links with Other Research

The primary reason for developing tree counts was to enable the use of individual tree sampling methods, initially targeted for use by small woodlot owners, but also applicable to larger forest stands. This is still an objective of New Inventory research with simulations of sampling methods being carried out in tandem with developing tree counting. Most of the simulation work is on small areas where the location of every tree has been collected. Interestingly the VPlot tree map from a LiDAR image of an operational sized stand has also been used in this simulation research.

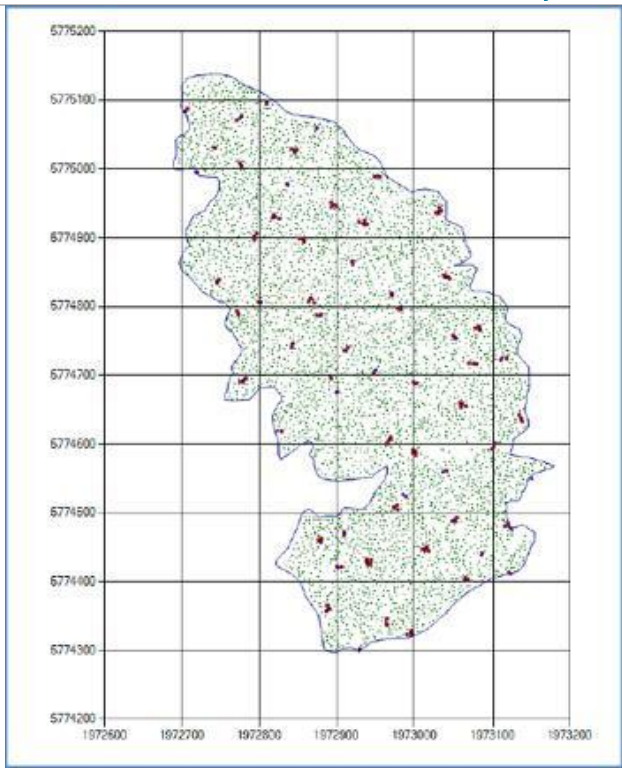

Figure 10 – Quasi-random (Sobol) sampling example on a tree map from a LiDAR image of a very steep, 22.8 hectare stand (sampling research and image by A. Gordon).

There is great potential for **individual tree level analysis** of remotely sensed data such as aerial, satellite and LiDAR. The ability to accurately identify single trees in such data sources will unlock information not previously available. Future research is already planned to develop the methods and applications in this new area.

Technical Transfer

While the VPlot methodology has been developed for use with the TIMBRS software it could be applicable to other tree counting software. An alternate algorithm to TIDA in TIMBRS has been tested to give similar results. The success of this TIMBRS alternative will be evaluated further in the case study. After the case study we are considering developing a beta version of VPlot for use by other researchers and any interested FFR members.