



Last updated: 28 March 2024 Report No : PSP-T015

UAV Survival Assessment: RGB Ortho-plotting and assessing Seedling Detection methods for Accuracy, Precision and Recall

This SOP was created by Jacob Emmens as part of the Tools For Foresters UAV Survival Assessments project funded by the Forest Grower’s Research (FGR) Precision Silviculture Programme.

Objective

This guide will tell you what RGB ortho-plotting is, and how best to use this in Forest operations to conduct unmanned aerial vehicle (UAV) survival assessments. Following this basic introduction will be a general outline on how to perform this operation, recommended aircraft, and flight parameters. Finally, there will be an optional section explaining how to check this data against field plots to assess accuracy, precision and recall for those wishing to ground truth the results themselves. This will include a step-by-step example of how to process and analyse the data retrieved using this method.

Introduction to ortho-plotting using RGB orthomosaics

Ortho-plotting is the method of using an orthomosaic dataset in a geographic information system (GIS) to extract information similar to what is recorded in traditional field plotting and survival assessments.

An orthomosaic is created from a collection of RGB photogrammetric images seamlessly stitched together to create one high level dataset (or single map/image) where the geometric distortion has been corrected and the imagery has been colour balanced to produce a seamless mosaic dataset.

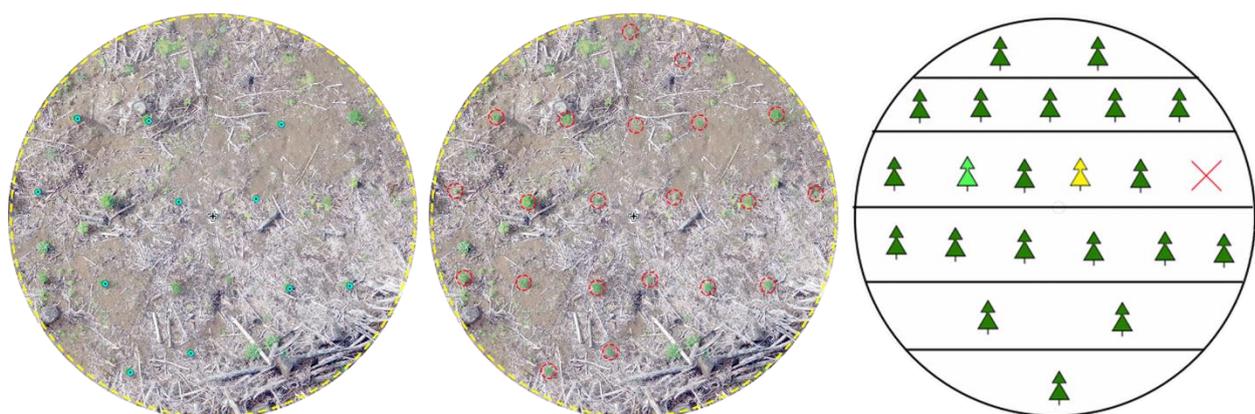


Figure 1. Orthomosaic-plotting using a deep learning seedling detection algorithm (left), Orthomosaic-plotting with manual GIS annotation (centre) and a digitised Field Plot showing stocking, gaps, and tree health status (right).

Survival assessments are an important part of the post-establishment cycle, as these assessments provide foresters with crucial information regarding tree survival rates, missing trees, stocking irregularities, wilding or regenerating rates, and overall stand condition and health. Traditionally, survival assessments have been carried out on the ground, in the field, which can at times be a very arduous task. These assessments can

involve unpleasant conditions, challenging environments, and laborious processes to obtain the required metrics for the desired outcomes.

In this SOP you will be informed on how to conduct orthomosaic-plotting, along with two methods of analysing and using your captured orthomosaic datasets to extract metrics for a UAV survival assessment. This includes manual annotation and automatic seedling detection methods. Additionally, a method for assessing the accuracy of the UAV plots using ground truth plots has been described for those wishing to compare the results with field plots. The following section details a methodology for establishing ground truth if desired. For those not wishing to establish ground truth, a report complementing this SOP was recently published to give an idea of the range of accuracy that can be expected from this methodology.

Establishing ground truth

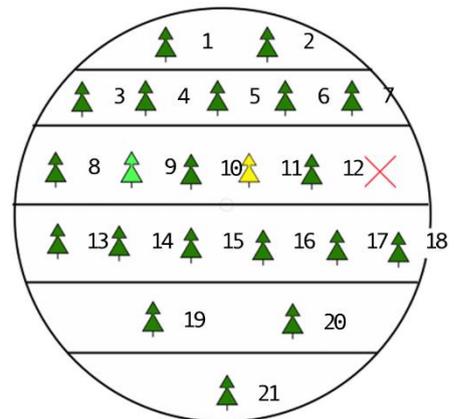
If you wish to evaluate the efficacy of these orthomosaic plotting methods once tested, field plots can be established in conjunction with the UAV data capture. Creation of digitised plot maps of your field ground truth data will then be required in later sections of this SOP.

To determine the truth of each one of your seedling detections, the digitised field data is annotated with a number for each individual tree, producing what is known as the 'ground truth' or 'actual detections' – trees that are there in reality.

These 'actual detections' will be used to evaluate the Accuracy, Precision and Recall metrics of your chosen orthomosaic plotting method.

A digitised ground truth is required for each survey plot, and represents the true tree location, overall stocking, health status, and spacing recorded. The more information detailed here, the more metrics you will be able to evaluate down the line.

Note: if you are acquiring field data to ground truth manual plots, it is important to mark the plot centre with something clearly visible from the air. A brightly painted cross on the ground at the plot centre, or a high contrast target will aid in aligning the data sets and ensure that the same trees are being assessed with each method.



Workflow - acquiring the necessary data to create an orthomosaic

To gather the necessary photogrammetric imagery used in the creation of an orthomosaic, a UAV flight planning and control software, for example Drone Deploy, Map Pilot Pro, UgCS for DJI Ground Station Pro, must be used to plan, control and gather data with your UAV.

To aid with field operations planning, a UAV operations plan along with UAV pre-flight checks can be found on Tools for Foresters:

<https://www.toolsforforesters.co.nz/tools/standard-operating-procedures>

These guides will assist you in following the correct pre-flight criteria for all forms of UAV forest operations, and they will also assist in planning safe operations to keep you in control of your UAV, and keep those around you safe and free from potential harm.

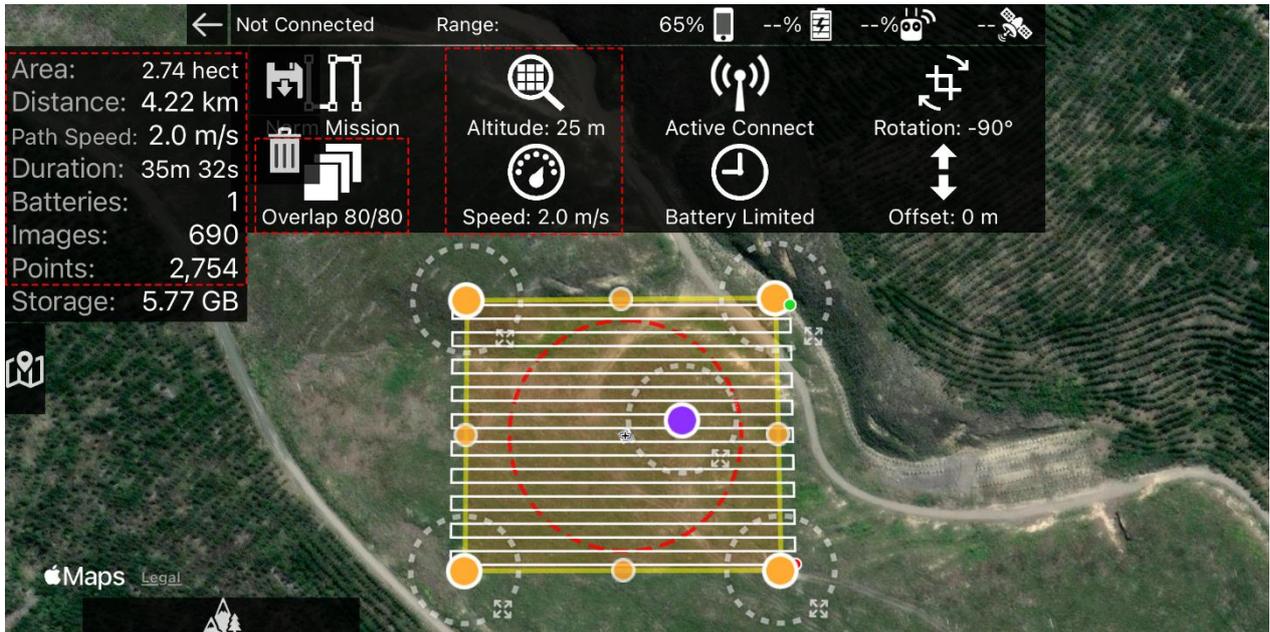


Figure 2. A planned flight over the area of survey using Planning and Control software *MapPilotPro*.

Pro tip: square flight maps/paths, such as that pictured above, are typically the most efficient in terms of the amount of passes and 180 degree turns the UAV makes above your survey area.

When planning a flight above your survey area, it is important to create your total flight area (yellow grid) to be greater than the area of your sample plot (red circle) as pictured above. This will make sure you have enough imagery coverage of the area you wish to survey.

An important factor when choosing flight altitudes is the change in ground sampling distance (GSD). As a UAV gains altitude, GSD grows larger with it. GSD can be considered as the size of one pixel of a captured image. As the UAV gains altitude, the size of the pixel increases, ultimately leading to greater loss of usable detail, definition and clarity in captured imagery.

Suggested Flight Parameters			Aircraft example: DJI Phantom 4 Pro	
Altitude	Speed	Overlap	Result	
25m AGL	1.5m/sec	80:80	Best quality image	Long flight duration
35m AGL	2.0/m/sec	80:80	Good quality image	Average flight duration
50m AGL	3.0m/sec	80:80	Lower quality image	Low flight duration

Once you have completed your flight(s) and are confident you have collected enough data to cover your sample plot, a photogrammetric software can be used to turn this data into a usable, spatially accurate orthomosaic dataset, ready for you to load into a GIS and perform your desired analysis. Examples of photogrammetric software include the following, with more information available from <https://www.toolsforforesters.co.nz/tools>:

Pix4D Mapper - Annual subscription USD \$3500. This software is consistently rated as one of the top photogrammetric packages on the market. Excellent software with a wealth of features on offer.

MapsMadeEasy - This software is used by several forestry companies, giving the second-best results after Pix4D. Very affordable Pay-As-You-Go options for the infrequent user, or subscription options available from USD \$1989 per year. Foresters requiring a reliable no-thrills option should consider this.

Workflow - methods for orthomosaic annotation

Once you have obtained your orthomosaic files back from your chosen photogrammetric software, you can now consider how you would like to analyse your data, using one of the following methods:

- **Automatic seedling detection** using a commercial service that detects seedlings
- **Manual Ortho-plotting** using a GIS software to manually annotate your survey areas

Automatic Seedling Detection:

For the forester who is strapped for time and is interested in outsourcing their orthomosaic analysis, Indufor Asia Pacific Ltd, Auckland offer a commercial service that uses deep learning algorithms to predict detections (trees) from your generated orthomosaic datasets which will be returned to you as point files for further analysis.

This method outsources the highly manual and time-consuming process of annotating individual seedlings within a GIS (see next section). Automatic seedling detection has also been found to offer reliable results when working with imagery with low vegetation, low-average shadows and contrast, and low foreign objective interference imaged on the forest floor, such as shrubs and vegetation.

'The workflow developed uses data collected from an airborne camera system and deep learning algorithms to map and classify tree seedlings.'

<https://indufor.co.nz/2022/09/08/tree-seedling-detection-using-ai/>

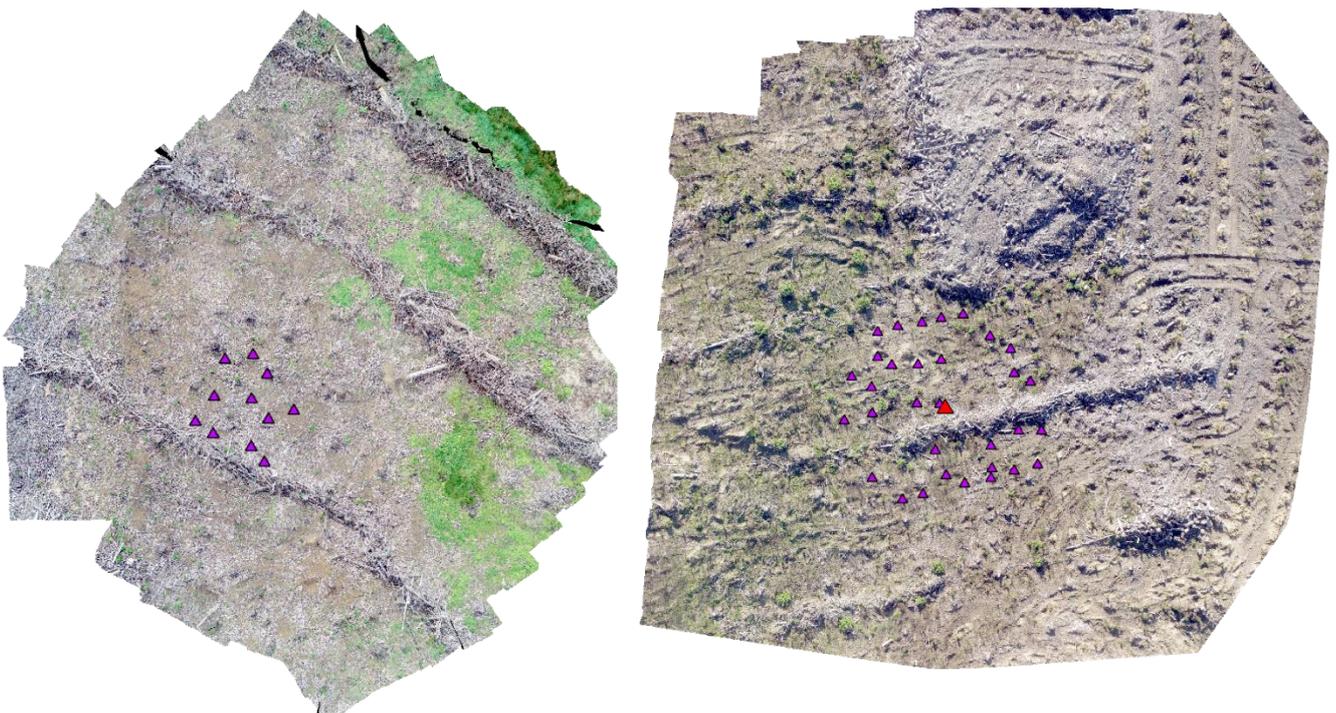


Figure 3. A pair of Orthomosaics which have been processed using Indufor's commercially available deep learning algorithms.

Manual Ortho-plotting

The idea behind manual ortho-plotting is to annotate an orthomosaic with the locations of seedlings that you can visually identify in the imagery. The same principles for field plotting apply here, however, you are performing this process from an aerial perspective. Examples below:



Figure 4. A pair of Orthomosaics which have been Manually Annotated in ArcGIS Pro.

To establish the correct parameters for this method, load your orthomosaic files into a GIS software. Typically, orthomosaics retain the geospatial information captured in the images collected by the UAV. The orthomosaic will, therefore, be spatially located in the correct location when uploaded to the GIS, provided that the projected coordinate system matches that of the orthomosaic. In New Zealand, NZGD 2000 NZ Transverse Mercator is the standard coordinate system. Note that the accuracy of the location depends on the accuracy of the global navigational satellite system (GNSS) on the craft that captured the data. If a craft with a highly accurate GNSS, such as the DJI Matrice 300 using real time kinematic (RTK) corrections was used, then the locational accuracy will be a lot higher than, for example, a DJI Phantom 4 pro. Lower spatial accuracy would become obvious in the GIS, for example, when overlaying a UAV orthomosaic onto a satellite image where there are obvious features like roads.

Once you have loaded in your orthomosaic datasets, you must now establish accurate plot centres and annotate these on your maps. To begin, this can be achieved by zooming into the imagery, and locating the clearly marked plot centre which was established at the time of manual surveying. Next, in the GIS, a Geodatabase must be created, which will be used to store and create feature classes. For mapping plot centres, a 'point feature' can be created and this feature class will be used to represent the accurate plot centres. In the below example (pictured), a 'point feature' in the form of a small red triangle has been used to accurately mark the position of the plot centre.

Next, a second feature class must be created to insert a plot boundary polygon. This can be created using the same method as the point features, however this time a polygon feature class must be selected. This polygon will be used to represent an accurate plot boundary. In the below example (pictured), a large yellow circle 'polygon feature' has been used to accurately mark the plot boundary, using a 0.02 ha or 7.98 m radius buffer.

For ArcGIS Pro users, the following guide will be helpful for navigating to the correct locations:
<https://pro.arcgis.com/en/pro-app/latest/help/data/feature-classes/create-a-feature-class.htm>

For example, for a 0.02 ha sample plot, a 7.98 m radius is required. For a 0.06 ha sample plot, a 13.82 m radius is required. Both examples assume zero slope factor.



Figure 5. Examples of orthomosaics in which the plot centre has been manually annotated (red triangle) in ArcGIS Pro, and a circular buffer (yellow) added demarcating the plot boundary.

Once complete, zoom into your orthomosaic layer to a level where you are confident you can distinguish seedlings from ground vegetation. Typically, anywhere between 1:10 and 1:50 should suffice. The level of vegetation, pest species, cutover waste and shadows will determine your visibility factors.

From here, following the same steps used to create the plot centres or boundaries, create another feature class of your choosing, and insert, a point, or any symbol of your choice to represent the locations of where you believe a seedling sits inside of the plot boundary. Examples found below:



Figure 6. A pair of orthomosaic plots which have been manually annotated with seedling detections (red circles) in ArcGIS Pro.

Once all plots in the survival survey have been annotated with either automatic seedling detections, or manual ortho-plotting techniques, untoggle (turn off) plot centres and plot boundaries in your GIS software. Next, when only your detection points remain, use the *Select* tool and select all points that were annotated within each plot boundary. From here, record the total tally of detection points for further comparison to plot ground truths.

Optional: Data Analysis – Accuracy, Precision and Recall

Now that each detection point has been determined and annotated, these points can be directly compared to the digitised ground truth plots to determine their true or false classifications.

<https://developers.google.com/machine-learning/crash-course/classification/true-false-positive-negative>

These classifications are required to calculate the overall accuracy, precision and recall of your findings.

To understand the true or false nature of the automatic and manual detections, a confusion matrix can be used to assist in the understanding of these detections, and to help in determining each classification of each detection point.



Figure 7. Explanation of a confusion matrix created for seedling detection.

Pro tip: for seedling detection, it is best to disregard *True Negative* in your calculations. These are machine learning metrics, and if we applied this classification in seedling detection, we would receive an unfathomable quantity of true negative data.

Using the previously annotated digitised ground truth data, correctly orientate and directly compare tree-for-tree between your annotations and the ground truth. For instance, *tree 1* on the ground truth; was it detected in your method? Tree 2, tree 3 etc. Once the total plot has been compared, you should end up with a list tally of detections which fall into each class.

For example, for the below Automatic detections: **11 True Positive, 0 False Positive, 10 False Negative, 0 True Negative.** For the below Manual Annotations **20 True Positive, 1 False Positive, 1 False Negative, 0 True Negative.** For example purposes, the below annotations use symbology to represent each classification, however this is merely a visual aid and not a necessary element.

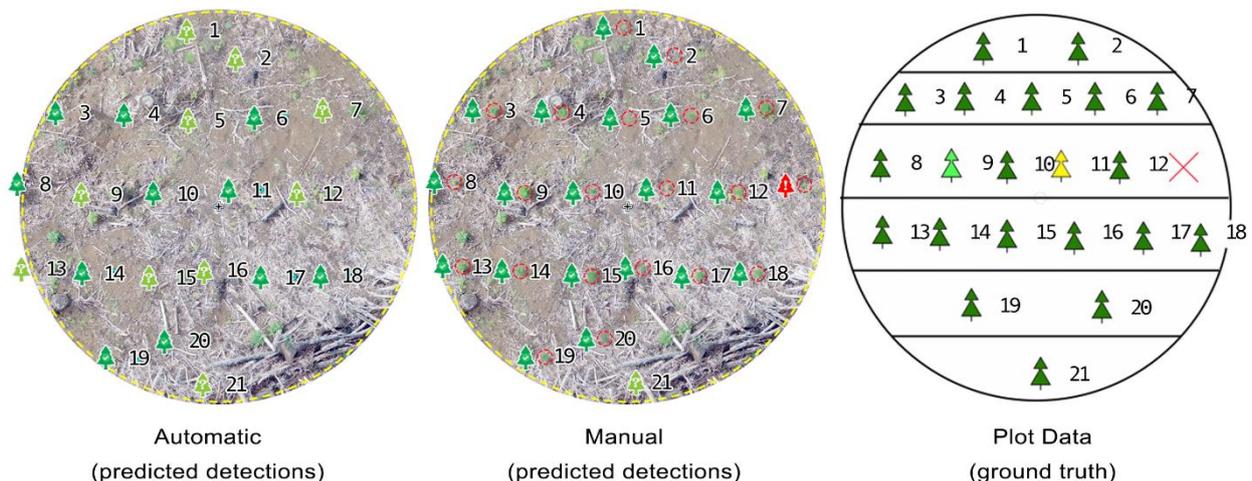


Figure 6. A pair of Orthomosaic plots which have been annotated with detection classifications.

Optional: Data Analysis - Predicting Metrics for Each Method

To determine the efficacy of the two seedling detection methods for ortho-plotting, metrics for Accuracy, Precision and Recall can now be determined using the classification data sets (example: 11 TP, 0 FP, 10 FN, 0 TN) analysed in the previous section.

'Accuracy is the fraction of the predictions our methods got right'

'Precision attempts to determine what proportion of the positive identifications were actually correct'

'Recall attempts to determine what proportion of the actual correct positives were identified correctly'

<https://developers.google.com/machine-learning/crash-course/classification/accuracy>

<https://developers.google.com/machine-learning/crash-course/classification/precision-and-recall>

For example, if a single plots classifications were as follows, we would receive the following metrics:

42 True Positives, 6 False Positives, 4 False Negatives, 0 True Negatives

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN} = \frac{42 + 0}{42 + 0 + 6 + 4} = 0.81 \text{ or } 81\% \text{ (Accuracy)}$$

$$\text{Precision} = \frac{TP}{TP + FP} = \frac{42}{42 + 6} = 0.88 \text{ or } 88\% \text{ (Precision)}$$

$$\text{Recall} = \frac{TP}{TP + FN} = \frac{42}{42 + 4} = 0.91 \text{ or } 91\% \text{ (Recall)}$$

Figure 7. Formulas used to determine accuracy, precision and recall for methods for orthomosaic annotation.

81% Accuracy - the percentage of the predictions our methods got right.

88% Precision – the proportion of positive identifications that were actually correct.

91% Recall – the proportion of actual correct values that were identified correctly.

To conclude, this guide has demonstrated what RGB Ortho-plotting is, and how best to use this in forest operations to conduct UAV survival assessments. This guide has offered a general outline on how to perform this operation, recommended flight parameters, and finally a step-by-step example of how to process and analyse the data retrieved using automatic and manual ortho-plotting methods, and how to determine the efficacy of the two seedling detection methods for accuracy, precision, and recall.