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UAV Wall-to-Wall (100%) Site Capture for Survival Assessment

This SOP was created by Whanarua Edmonds 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 briefly explain what a Wall-to-Wall orthomosaic is, how to capture the imagery required, and how to analyse the data once captured. This guide will provide an outline of the steps to take to capture the data, then will explain the step by step process to analyse the data.

Introduction to UAV Wall to Wall (100%) Site Capture

A wall-to-wall orthomosaic (also known as "100% site capture") is a geospatial product created from overlapping aerial imagery and used to provide the data collector with a complete image of the entire targeted area. A UAV is an efficient tool for capturing this data, flying an area of interest (AOI) on a pre-determined autonomous flight, planned to collect imagery with sufficient overlap between imagery for the task. The collected imagery is then processed within photogrammetric software to produce the wall-to-wall photographic map, also known as an orthomosaic. Correct flight settings are essential to produce good quality and useful imagery. Incorrect settings can result is poor data quality or unusable imagery.

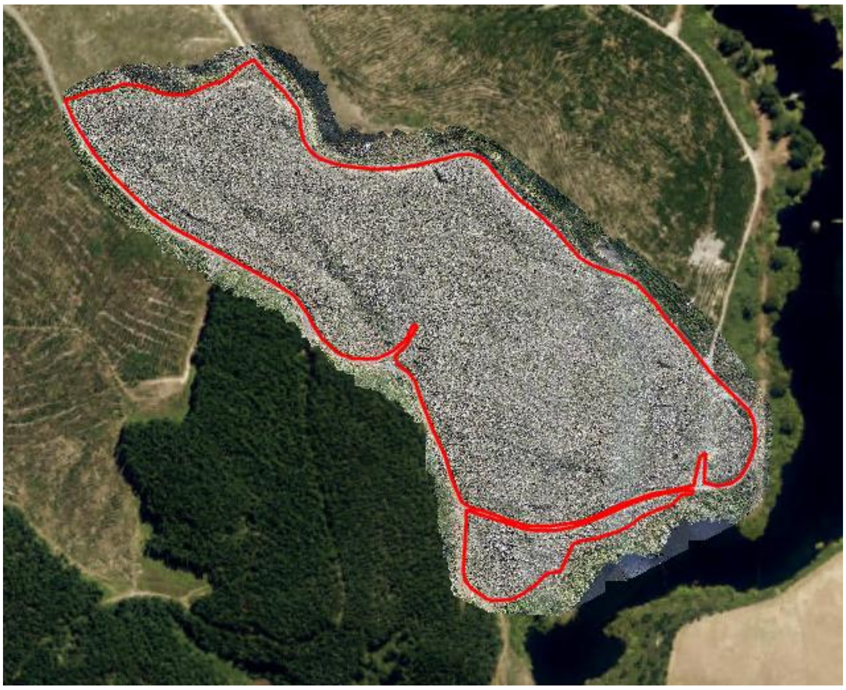

Figure 1. Example of a wall-to-wall site capture (wall to wall) data of a stand in Kinleith forest, captured by Scion.

Flight planning and Pre-mapping

Planning is an essential part to capturing good imagery. With good planning comes better results. When planning the flight, it is important to know

- ***The aircraft intended for use*** – As each aircraft has different capabilities and limitations (such as camera sensor, data storage capacity, battery size). It is important to be aware of these in order to plan accordingly.
- ***The size of area to be surveyed*** – The size of area heavily effects the operation in terms of the flight time, battery usage, and data storage required (SD card size). A slow SD card can result in missing images and GPS data or corrupt files. Research the proper SD card suited for your aircraft.
- ***Site information (Seedling age, weed cover, terrain)*** – This will assist in determining the required resolution, and therefore the flight altitude. As seedling age can determine the width of crown of the seedling, older seedlings tend to be more visible and younger seedlings tend to be less visible. Weed cover and terrain can obstruct the visibility of seedlings through shading area where seedlings are present.
- ***Objective (i.e. planted seedling detection, forest density, re-gen growth, survival rate)*** – The objective of the flight is the greatest determining factor in how the flight is planned and flown. Different objectives each require specific planning.

In knowing all four planning points, the confidence in collecting quality data and the correct data will be much higher.

Flight planning

When planning the flight, aim for days where light is consistent i.e. cloudy or sunny. Avoid days where weather is variable. Keep in mind that in order to capture 100% of site area this may take some time, therefore, a wide window of opportunity of at least (approximately) one hour is needed.
It is best practice to check for restricted flight zones and flight paths when planning the flight. If required, make contact with designated point of contact. Information on flight planning tools can be found on the TTF website https://www.toolsforforesters.co.nz/tools. In addition, the Flight Advisor app is excellent for checking airspace and advertising operations to enhance safety: https://flightadvisornz.io/ .

Pre-flight mapping

Identify area to be flown, determine a suitable take off location (an area that is able to maintain the line of sight of the UAV at all times). This can be done in open source tools, such as Google Earth (https://earth.google.com/web/) or within a geographical information system (GIS). TFF has produced an SOP for guiding the flight planning process, which can be found here:
https://www.toolsforforesters.co.nz/tools/standard-operating-procedures

Select an appropriate flight controller software that is compatible with your aircraft, which can then be used to plan the flight path for the mapping operation, including altitude, overlap and speed. Some software can also produce the orthomosaic product once the flights are completed. More information on some of the available flight controllers can be found on the TTF website
https://www.toolsforforesters.co.nz/tools

As an overview, the basic steps for capturing a wall to wall image and application are as follows:

- Determine the objective and plan other planning points accordingly.

- Plan flights utilising tools for operations planning and programme mapping flights within the flight controller software.

- Perform all pre-flight checks and carry out data capture (UAV imagery etc).

- Process the images in photogrammetric software to create an orthomosaic. Useful instructions for carrying out the orthomosaicing process using Pix4D can be found here: https://support.pix4d.com/hc/en-us/articles/115005242946-How-to-use-GCPs-for-processing-on-PIX4Dcloud.

- Analyse the data.

It is useful to know the overall process during the planning stages as this will create understanding when capturing the data.

Capturing Data

To demonstrate the procedure for the capturing of a wall-to-wall image, the following procedure highlights the step-by-step process to follow for capturing the imagery out in the field. There is a wide variety of software for photogrammetry, and they all have their own guidelines and, in some cases, additional applications to aid in carrying out field surveys. In this guide, we attempt to use easily accessible, open-source software and point to alternative packages that can perform the same tasks, where they can be identified.

Step 1.
Establish a take-off location from which will act as a secure location for the duration of the operations. This take-off location must be in an area where a continuous line of site can be maintained with the aircraft at all times. If the terrain disallows continuous line of sight, the operator must move to an area where they can maintain the line of sight. Alternatively, the operator can fly smaller mapped areas to capture the most data possible within the line of sight before moving.

Step 2.
Perform pre-flight UAV checks. A checklist for UAV pre-flight checks can be found on the TTF website (https://www.toolsforforesters.co.nz/tools/standard-operating-procedures). Adjust flight settings to suit objective. The following flight parameters are suggested for use with the DJI Matrice 300 and Dji P1 45MP camera:

Objective	Altitude (AGL; m)	Speed (m/s)	Approx GSD (cm)	Overlap (fw:side)
Wall-to-wall mapping (seedling detection)	85	5	1	80:80
Wall-to-wall mapping (Site map)	120	5	1.5	80:80

Step 3.
Allow aircraft to capture data. For safety purposes, at all times maintain awareness of the flight operation, position of the aircraft, and other influencing etc.

https://support.pix4d.com/hc/en-us/articles/360000831423-Image-import-and-processing-steps-PIX4Dfields

There is also a getting started manual which tells you about the software and contains some good guidelines for gathering aerial imagery regardless of what image processing software you use; https://support.pix4d.com/hc/en-us/articles/204272989-Offline-Getting-Started-and-Manual-pdf

A common option for orthomosaicing and georeferencing the aerial imagery, once it has been collected, is the Pix4DMapper photogrammetry software. There are numerous additional photogrammetric software available, and an appraisal of some of these software can be found on the Tools For Foresters website https://www.toolsforforesters.co.nz/tools. The specifics of this process in PIX4D can be viewed on the PIX4D website. Skylab Cloud also provides an orthomosaic generating service.

Tools for foresters

Turning data into Effective Information

Once the data has been collected, and an orthomosaic has been created. You will now be able to analyse your orthomosaic within a GIS. This will allow you to derive effective and useful information from the data.

Basic outputs include

- High resolution mapping
- Manual annotation of seedlings for stocking (orthoplotting)
- Automatic seedling detection for stocking (using the likes of Indufor or Skylab – see below)

Information on manual annotation and seedling detection can be found on the Tools for Foresters website.

Automatic Seedling Detection

Independent entities such as Skylab Cloud and Indufor Asia Pacific, Ltd use deep learning algorithms to automatically detect seedlings in a given AOI. From this, they are able to provide you with point data, which can then be translated into useful information on stocking and used to generate other outputs.

Other outputs that can be generated from a combination of an orthomosaic and point data include:

- Overall stand density
- Stand density grid (Heatmap)

Stand Density

The aim of calculating the stand density is to determine the average stocking per ha within the AOI. As there is an expected form of error within the point data of false positives and false negatives (see SOP for "orthoplotting" on the TFF website), the aim of calculating is not to accurately determine the stocking but rather to gain an insight into where there is an estimate of high stocking, where there is an estimate of low stocking, and where/if there is a trend. This will aid in focusing your attention to areas it is needed the most. (The option of outsourcing this is available through Skylab Cloud)

To aid in calculating data from various shapefiles in your preferred GIS software, refer to the online software resources to help guide you through the process.

Keywords: Field calculations, Fishnet/Grid, Clip

Arcgis Pro:
https://www.esri.com/en-us/arcgis/products/arcgis-pro/resources#settingup
https://pro.arcgis.com/en/pro-app/3.1/help/data/tables/fundamentals-of-field-calculations.htm

QGIS:
https://docs.qgis.org/3.4/en/docs/user_manual/index.html

Forest Density Calculation

With detection points, you can now convert this data into numeric figures that can be used to populate formulas and calculate the required results you are looking for through your preferred GIS software. In this case, basic calculation of the forest density in stems per hectare (sph) can be calculated by using the formula below:

formula GIS *formula*

$$sph = \frac{n}{area}$$

$$sph = \frac{joint\ count}{shape\ area}$$

sph = stems per hectare
n = total point count
area = AOI (Area of Interest)

Figure 2. Overall stand density calculated from automatic detections within a stand area shapefile, calculated in Arcgis Pro.

From this you will be able to gain an insight into the overall stocking of the AOI (Area of Interest) based on the data you have. This option is fairly basic and is suggested that it be used in smaller areas as it is more effective and accurate in smaller areas. Larger areas have more points and much more area therefore the results produced from this calculation may not reflect the condition of the forest correctly.

Forest Density Grid (Heatmap)

Producing a heatmap can be an effective way to classify high urgency and low urgency areas. This method is more effective in larger areas. A heatmap is made by first establishing a grid. In creating a grid you now divide the total AOI into smaller square plots. This allows specification over generalisation.

Typically a 0.02ha plot is used in forest inventory, however for this method a 0.04ha plot size is recommended to produce more accurate results. A 0.04ha plot size suggests a 20x20 meter grid size.

Here is a useful tutorial to follow for ArcGIS Pro:

https://www.youtube.com/watch?v=Y987uu1kiVQ

Pro tip: make sure you select Polygon as geometry type, otherwise you won't be able to count tree detections within the fishnet:

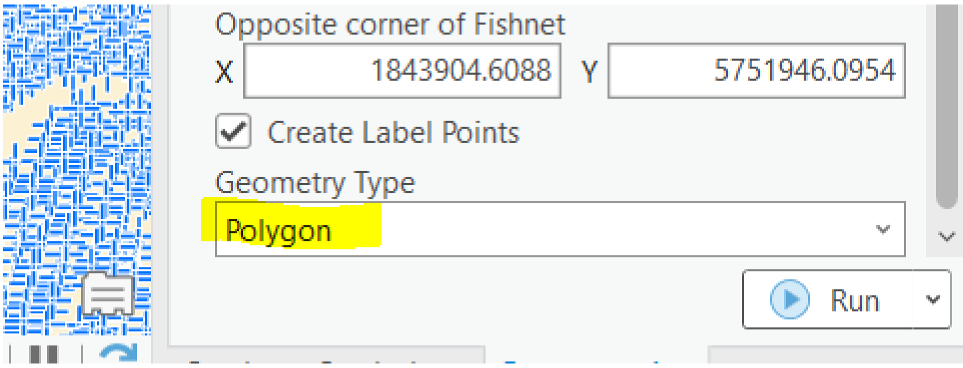

Figure 3. selecting the appropriate geometry time is crucial to enable tree counts within the fishnet.

To clip the grid to the AOI, simple rick click on your newly created fishnet layer, use the Clip analysis tool in ArGIS Pro.

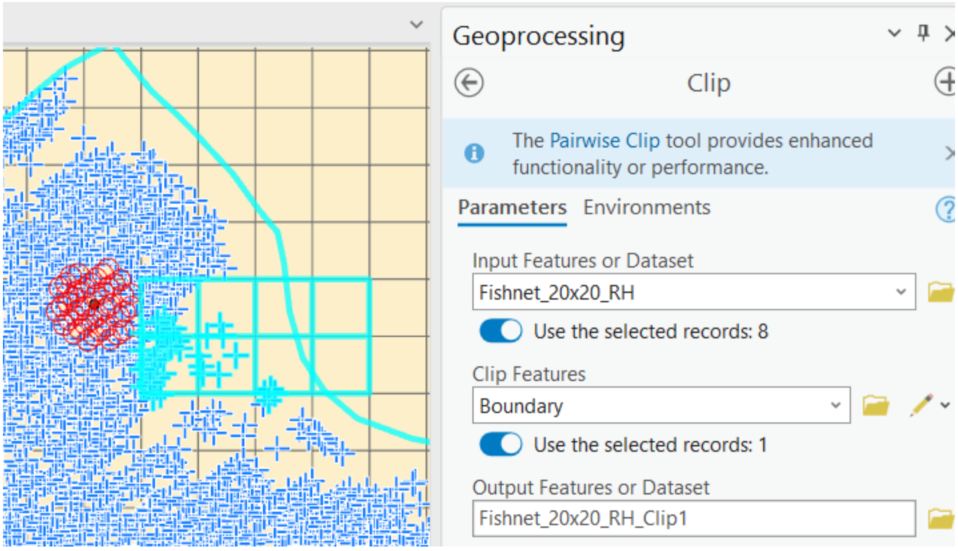

Figure 4. the clipping procedure to remove excess grids from outside the AOI.

To count the number of detected seedlings within each grid square, add a spatial joing by ricght clicking on your clipped fishnet layer > joins and relates > Spatial join. Instructions can be found in this online tutorial:

https://www.youtube.com/watch?v=-h3FIgg0bBQ

The density of a complete square plot can be calculated using the same formula used in figure 2, and re-applied to all other square plots.

$$sph = \frac{joint\ count}{shape\ area\ (plot\ size)}$$

Example:
e.g. 31 points in plot
sph = 31/0.04
= 775sph

Initially in your fishnet, the Shape_area attribute will be in m², so to convert add a new field to the attributes table (call this "Area_in_ha" or something similar), locate the column in the attributes table, R-click on the column header and clock "calculate geometry". Finally, select your fishnet, select you're your new "Area_in_ha" field, select "area" in the property dropdown next to it, select "Hectares" for the area unit, in coordinate system box select your fishnet again, and then click OK:

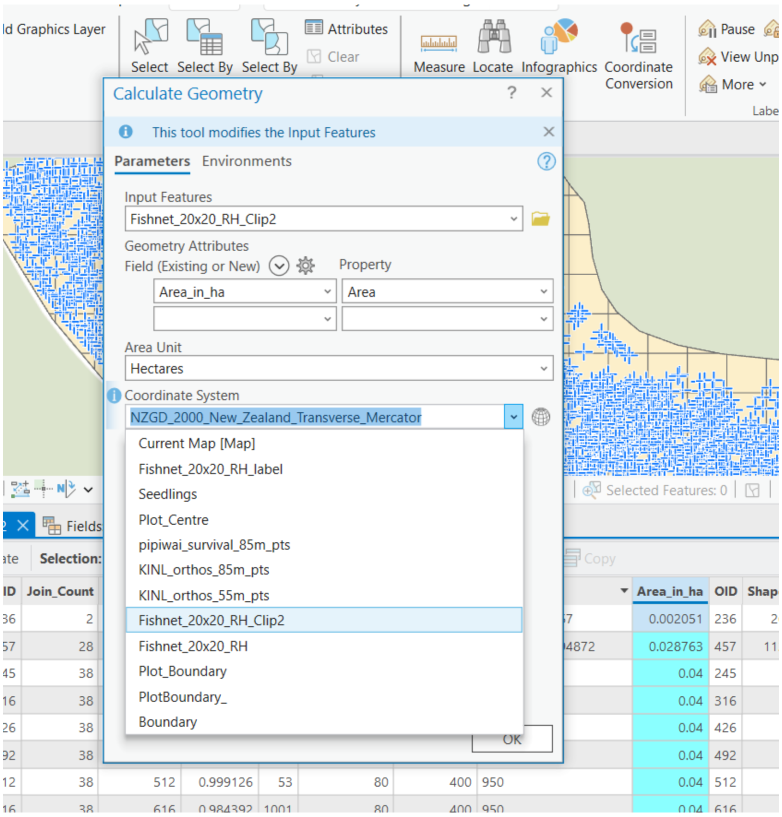

Figure 5. Converting the area of each grid to ha is an important step to determining sph.

Next calculate the stems per hectare per grid cell by clicking "calculate", creating a new field called "Sph", then adding an equation for Join_Count / Area in ha – making sure your select VBScript as the expression type:

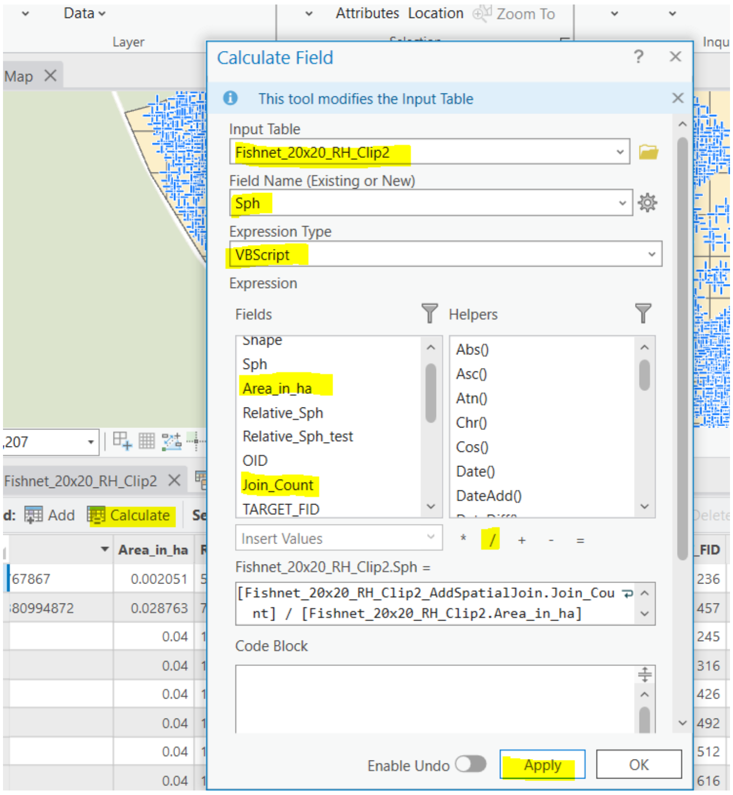

Figure 6. The final calculation to generate sph from the fishnet.

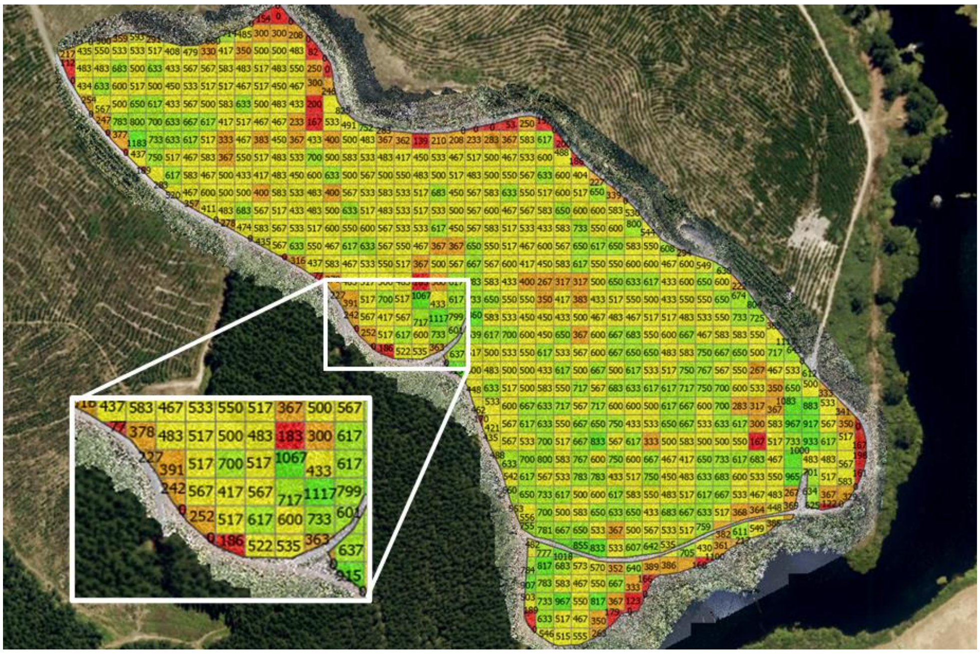

Figure 7. Complete stocking grid with sph values calculated.

Understanding the Data

Once you have calculated your results, the next step is to understand the data so that any appropriate actions can be implementing in the field. Deeper analysis of the results is done by analysing the orthomosaic more post results to determine if the results produced are in fact a true reflection.

Tip: Results that will require a higher urgency for deeper analysis

- High Stocking
- Low Stocking

High stocking
Possible justifications for a high stocking plot could be due to a higher stocking of planted trees, or high detection of weeds (false positives).

Low Stocking
Possible justifications for a low stocking plot could be due to a lower stocking of planted trees, low mortality rate, heavy weed presence preventing point detection, and other terrain or environmental factors (i.e skidder tracks, ponds, native vegetation)

Figure 8. High stocking area (left) and low stocking area (right).

Tools for foresters

The information produced from this analysis can now be taken out into the field to be validated, and an action plan can be implemented to resolve the issues, if any are found. The utilisation of the information produced in these methods of analysis will heavily depend on the interpreter and the objective in which the wall to wall image is captured for.

Resources:
Arcgis Pro:
https://pro.arcgis.com/en/pro-app/3.1/help/data/tables/fundamentals-of-field-calculations.htm
https://pro.arcgis.com/en/pro-app/latest/tool-reference/analysis/clip.htm
https://pro.arcgis.com/en/pro-app/latest/tool-reference/data-management/calculate-field.htm
https://pro.arcgis.com/en/pro-app/latest/tool-reference/data-management/create-fishnet.htm

QGIS:
https://docs.qgis.org/3.4/en/docs/user_manual/index.html
https://docs.qgis.org/2.18/en/docs/user_manual/processing_algs/qgis/vector_creation_tools.html