



# Tools for foresters

*Annual Update 2020-2021*



forest  
tech2022

Remote Sensing • Inventory Management • Mechanised Silviculture

Remote Sensing Cluster Group

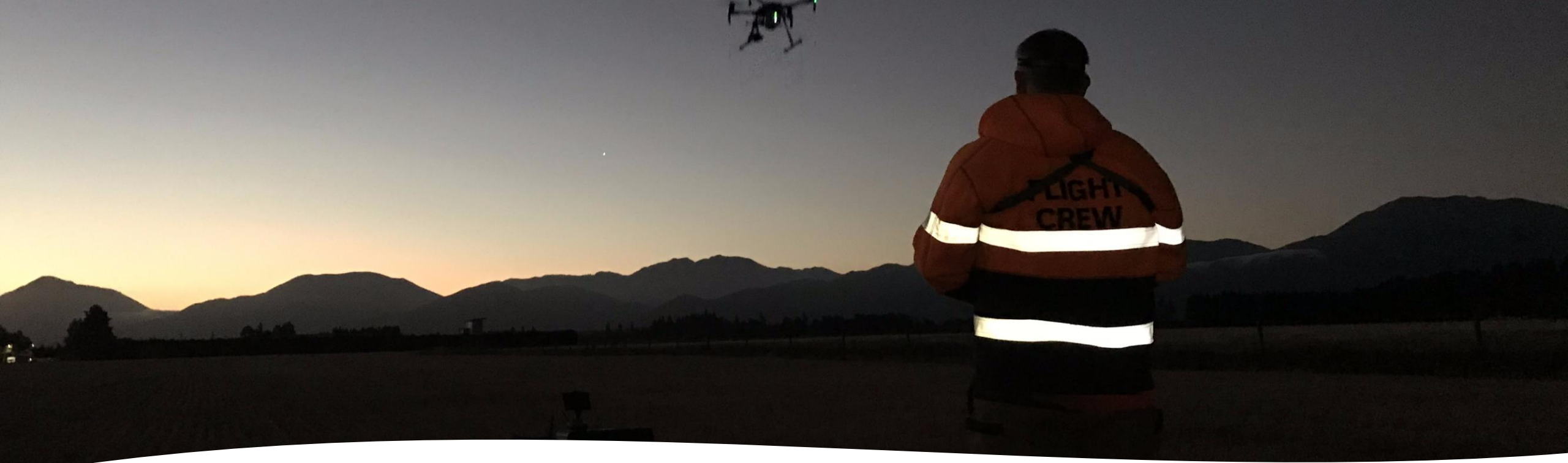
# The TFF Vision

*“Eyes in the air, reducing the boots in the blackberry”*

*“We play a leadership role helping industry and science come together to progress forestry through easier implementation of technology.*

*We aim to remove technical hurdles and roadblocks to get useful technology into the hands of forest users. In doing so, we aim to help attract the next generation of forest workers, upskill workers, reduce downtime, costs and trouble shooting and improve forest profitability. These technologies can provide a sense of kaitiaki through the monitoring of our forests from above and below”*

**Tools for  
foresters**



# Aims

- Create a network
- Disperse knowledge
- Be an advocate for tech users
- Instigate trials
- Familiarise technology
- Democratisise technology
- Drive stretchy research
- Standardise & professionalise UAV operation

# Tools for foresters

## Structure

Industry cluster group

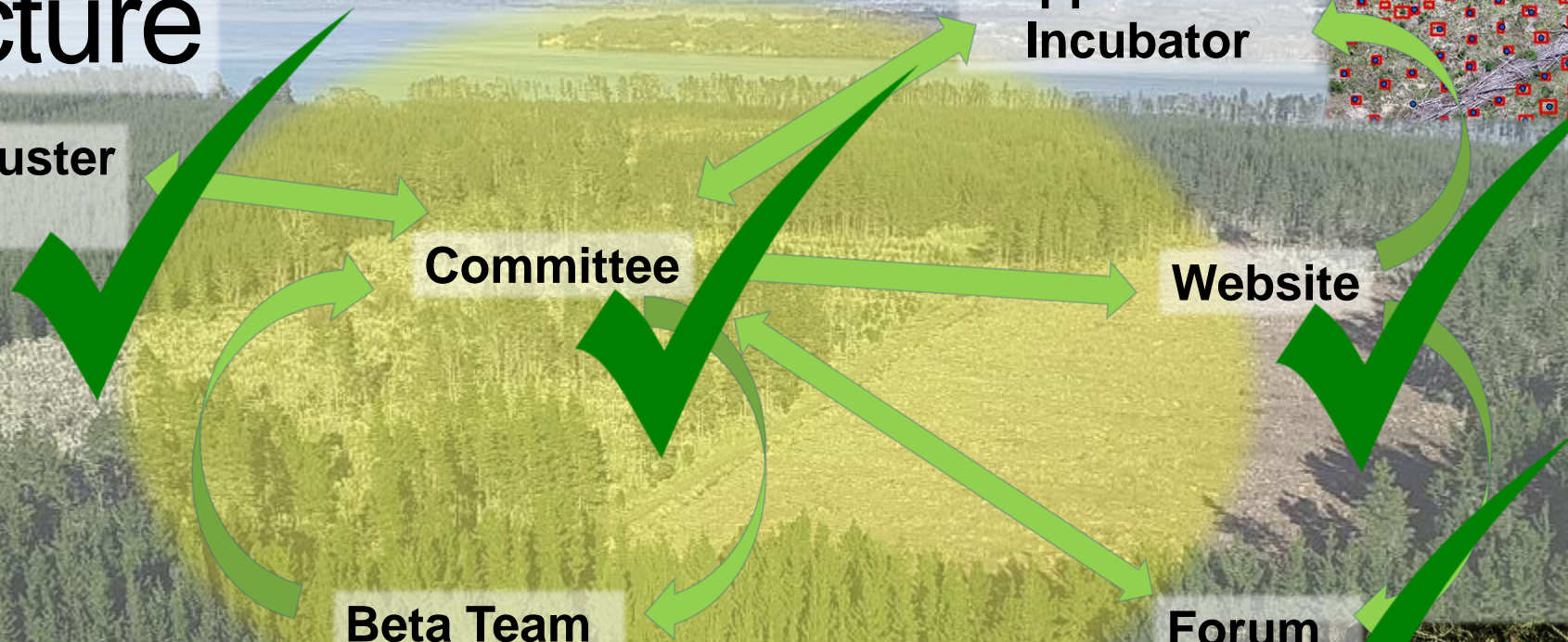
Committee

Application Incubator

Website

Beta Team

Forum



## Update

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- **Where are we at?**
- **Forum**
- **Publications**
- **Applications (SOPs)**
  - **Structure**
  - **Update**
  - **Masters Study**
- **Funding**
- **Website update**
- **Mailing list update**
- **Next steps**



# Tools for foresters

## Forum

- Earlier this year we launched a new forum
- Using the Discord platform
- Little introduction to what's on there
- Encouraging users to use this forum to ask advice RE issues/queries to get started





Discord


Tools For Foresters

tools-for-foresters Follow Welcome to TFF on Discord!

August 31, 2022

Morgan.Scragg\_PanPac 08/31/2022

Hi everyone. Have any of you had experience with using a German company called SKYLAB for post-thinning stocking assessments? We have had trouble with blur in our orthomosaics after processing using Drone2Map. SKYLAB seem to be able to process the images without the blur (note this blur is not present in the raw images). I am keen to see the tree count from this stand but they have yet to send through the results.



September 5, 2022

Morgan.Scragg\_PanPac Click to see attachment

Kevin.Ihaka\_FPS 09/05/2022

We haven't used Skylab but have had issues with blur, most of the blur we found was wind movement in the tree tops between images. Wind speed is a real issue with this type of flight. It is pretty hard to get no wind in a forest but look for the best days. I also found that minimising the number of images help, while you may lose some quality it can help with the blur.

September 6, 2022

Morgan.Scragg\_PanPac Hi everyone. Have any of you had experience with using a German company called SKYLAB for post-thinning stocking assessments? We have had trouble with blur in our orthomosaic...

Honey.Estarija\_Scion 09/06/2022

We've had issues like this before and it is mainly due to stitching the photos and also the environment as Kevin said wind/lighting also contributes a lot. Maybe try different settings/parameters when processing it using Drone2Map or try different software. We mainly process using pix4D and have encountered this kind of issues a lot and we fixed it by using different parameters and relating it onto the actual location environment. Here are some articles from pix4D that might help: <https://support.pix4d.com/hc/en-us/articles/202558869-Photo-stitching-vs-orthomosaic-generation>, <https://support.pix4d.com/hc/en-us/articles/202560459-How-to-correct-Building-Artifacts-in-the-DSM-and-Orthomosaic>, <https://support.pix4d.com/hc/en-us/articles/202561099-Distortions-and-Artifacts-in-the-Orthomosaic>

Support

**Photo stitching vs orthomosaic generation**

Photo stitching  
Orthomosaic

Photo stitching  
The photo stitching method glues images together and requires a low number of matches/keypoints (less than 100). It works well only if the terrain is ...

Support

**How to correct Building Artifacts in the DSM and Orthomosaic**

Note:

Message #tools-for-foresters

COMMITTEE MEMBER — 3

- Morgan.Scragg\_PanPac
- peter.massam\_scion
- Robin.Hartley\_Scion

ONLINE — 3

- David.Cajes\_Scion
- Honey.Estarija\_Scion
- Willy.Grogan\_Aratu

OFFLINE — 24

- Albi | SKYLAB
- Atman,Dhruva\_Scion
- Brendan
- Carolyn Blair
- ClaireStews
- Craig Morley
- dave\_herries
- Gordon
- gregoquinn
- JamesBLT
- Kevin.Ihaka\_FPS
- Liam W
- lilynz

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Discord

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# open-source-spatial-data

## Welcome to #open-source-spatial-data!

This is the start of the #open-source-spatial-data channel.

[Edit Channel](#)

July 13, 2022

**David.Cajes\_Scion** 07/13/2022

**QGIS**  
Anybody working with spatial data needs a robust platform to work with the data. An Open Source GIS option which is incredibly useful, continuously developed and improved, and freely available is QGIS:  
<https://qgis.org/en/site/forusers/download.html> (edited)

**CloudCompare**  
CloudCompare is a must-have tool for anybody working with point cloud data. This allows users to manipulate and visualise pointclouds clouds in 3D in a way that isn't possible using standard GIS packages. There are a number of online tutorials for how to work with data on this GUI-based point cloud software. It is free:  
<http://www.danielgm.net/cc/release> (edited)

**lidR**  
lidR is one of the foremost lidar analysis packages for forestry. This R-based software package allows for a range of operations, such as normalising, denoising and generating canopy height models from point clouds, as well as deriving tree-level or stand level metrics. There is also very good online documentation for its use:  
<https://cran.r-project.org/web/packages/lidR/index.html>  
<https://r-lidar.github.io/lidRbook> (edited)

**lidR: Airborne LiDAR Data Manipulation and Visualization for Forest...**

Airborne LiDAR (Light Detection and Ranging) interface for data

Message #open-source-spatial-data

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- Craig Morley
- dave\_herries
- Gordon
- gregquinn

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## A comparison of photogrammetric software for deriving structure-from-motion 3D point clouds and estimating tree heights

Volga Lipwoni, Michael S. Watt, Robin J.L. Hartley, Ellen Mae C. Leonardo and Justin Morgenroth

### Abstract

The use of structure-from-motion (SfM) photogrammetry from unmanned aerial vehicles (UAVs) is becoming an increasingly popular means of characterising key forestry biophysical variables such as tree height. Despite the wide array of software that is available to process 3D point clouds from SfM, little research has investigated how the precision of predictions vary between software. This study compared the accuracy of tree height estimates for a young *Pinus radiata* trial (height range 1.4 – 6.1 m) obtained from 10 different software packages, which were used to derive canopy height models (CHMs) from UAV-acquired SfM point clouds. To ensure a fair comparison, the default parameters for each software were used without any data tuning.

Predictions of tree height ranged widely in terms of both precision ( $R^2$  range: 0.61 – 0.86) and bias (mean bias error (MBE) range: 0.28 – 3.37 m). Height predictions with the highest precision and lowest bias were made using 3DF Zephyr ( $R^2 = 0.86$ ; MBE = 0.58 m), Pix4DMapper ( $R^2 = 0.78$ ; MBE = 0.28 m) and Maps Made Easy ( $R^2 = 0.85$ ; MBE = 0.85 m). The availability of numerous software options provides choice to the user and this study helps to identify the best software for estimating tree heights from SfM-derived point clouds.

### Introduction

Accurate forest inventory is critical for monitoring crop health and damage, optimisation of silvicultural operations and the prediction of forest volume and value. Traditionally, such information has been acquired through labour-intensive and time-consuming field inventory practices that measure or estimate key biophysical variables such as height, diameter, volume and density at various spatial scales. The use of remotely sensed forest data captured over different spatial and temporal scales has revolutionised inventory practices and has been used to supplement and sometimes replace traditional field inventory (Dash et al., 2015).

Light detection and ranging (LiDAR), a laser-based ranging system that measures the return time taken by

a pulse of laser energy to travel between a sensor and target (Dubayah & Drake, 2000), has been widely used in forestry (De Gouw et al., 2020). LiDAR can be used to scan environments through either airborne (ALS) or terrestrial laser scanning (TLS) platforms. In forestry, the capability of LiDAR to penetrate the forest canopy has provided 3D data for the extraction of the most common biophysical variables at both the tree level and on an area basis. However, ALS is costly, and TLS is labour-intensive and time-demanding (Bréde et al., 2017).

In recent years, airborne laser scanners have been miniaturised and can now be deployed from unmanned aerial vehicles (UAVs). UAVs have increased in popularity as an alternative to airborne and satellite platforms for collecting forestry data at local scales as they are inexpensive and easy to operate over relatively small areas (Mendes et al., 2015). For example, in New Zealand 83% of forestry companies have used UAVs to collect aerial imagery of their forests, while 17% have used UAVs to collect LiDAR data for their forests (De Gouw et al., 2020). There is a growing body of research into UAV laser scanning (ULS) for forestry applications, and this method often provides highly accurate estimates of many key forestry metrics (Hartley et al., 2020). ULS sensors are, however, still relatively expensive and therefore alternative methods for creating 3D models of forests have been developed and applied, including most notably structure-from-motion (SfM) photogrammetry (Wallace et al., 2016; Puliti et al., 2020).

Depending on the level of detail during image capture, 3D point clouds can be derived from UAV imagery using techniques that combine computer vision and photogrammetry, commonly referred to as SfM (Wallace et al., 2016). SfM photogrammetry is a method whereby multiple images are acquired from various camera viewpoints and then combined to form 3D models (Mathews & Jensen, 2013). SfM makes use of algorithms, such as scale invariant feature transform (SIFT) (Lowe, 1999), to find multiple key points in images, match images and create tie points (Mendes et al., 2015). The other key processes in the SfM

### Article

## Assessing the Potential of Backpack-Mounted Mobile Laser Scanning Systems for Tree Phenotyping

Robin J. L. Hartley<sup>1,\*</sup>, Sadeepa Jayathunga<sup>1</sup>, Peter D. Massam<sup>1</sup>, Dilshan De Silva<sup>1</sup>, Honey Jane Estarija<sup>1</sup>, Sam J. Davidson<sup>2</sup>, Adedamola Wuraola<sup>3,4</sup> and Grant D. Pearse<sup>1</sup>

<sup>1</sup> Scion, 49 Sala Street, Private Bag 3020, Rotorua 3046, New Zealand; sadeepa.jayathunga@scionresearch.com (S.J.); peter.massam@scionresearch.com (P.D.M.); dilshan.desilva@scionresearch.com (D.D.S.); honey.estarija@scionresearch.com (H.J.E.); grant.pearse@scionresearch.com (G.D.P.)

<sup>2</sup> Scion, 10 Kyle Street, Riccarton, Christchurch 8011, New Zealand; sam.davidson@scionresearch.com (S.J.D.); adedamola.wuraola@img.co.nz (A.W.)  
<sup>3</sup> Imag Ltd, 16 Makdun Street, Grey Lynn, Auckland 1021, New Zealand  
\* Correspondence: robin.hartley@scionresearch.com

**Abstract:** Phenotyping has been a reality for aiding the selection of optimal crops for specific environments for decades in various horticultural industries. However, until recently, phenotyping was less accessible to tree breeders due to the size of the crop, the length of the rotation and the difficulty in acquiring detailed measurements. With the advent of affordable and non-destructive technologies, such as mobile laser scanners (MLS), phenotyping of mature forests is now becoming practical. Despite the potential of MLS technology, few studies included detailed assessments of its accuracy in mature plantations. In this study, we assessed a novel, high-density MLS operated below canopy for its ability to derive phenotypic measurements from mature *Pinus radiata*. MLS data were co-registered with above-canopy UAV laser scanner (ULS) data and imported to a pipeline that segments individual trees from the point cloud before extracting tree-level metrics. The metrics studied include tree height, diameter at breast height (DBH), stem volume and whorl characteristics. MLS-derived tree metrics were compared to field measurements and metrics derived from ULS alone. Our pipeline was able to segment individual trees with a success rate of 90.3%. We also observed strong agreement between field measurements and MLS-derived DBH ( $R^2 = 0.99$ , RMSE = 5.4%) and stem volume ( $R^2 = 0.99$ , RMSE = 10.16%). Additionally, we proposed a new variable height method for deriving DBH to avoid swelling, with an overall accuracy of 52% for identifying the correct method for where to take the diameter measurement. A key finding of this study was that MLS data acquired from below the canopy was able to derive canopy heights with a level of accuracy comparable to a high-end ULS scanner ( $R^2 = 0.98$ , RMSE = 3.02%), negating the need for capturing above-canopy data to obtain accurate canopy height models. Overall, the findings of this study demonstrate that even in mature forests, MLS technology holds strong potential for advancing forest phenotyping and tree measurement.

**Keywords:** lidar; MLS; SLAM; UAV; ULS; tree form; mensuration

### 1. Introduction

Digital phenotyping is an emerging science that uses non-invasive techniques, such as laser scanning, to assess the interaction between genetics, environmental factors and silviculture (GxE<sub>S</sub>) to guide the selection of the most productive trees for a given environment [1]. In forestry, phenotyping is emerging as a means of selecting the right tree, for the right place, for the right purpose, and to increase the efficiency of tree breeding programmes [2]. Current phenotyping methodologies require the combination of GxE<sub>S</sub> data with the physical description of tree form [3]. Traditional methods for the physical

### Citation:

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### Review

## BVLOS Unmanned Aircraft Operations in Forest Environments

Robin John ap Lewis Hartley<sup>1,\*</sup>, Isaac Levi Henderson<sup>2</sup> and Chris Lewis Jackson<sup>3</sup>

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<sup>2</sup> School of Aviation, Massey University, Palmerston North 4414, New Zealand; i.henderson@massey.ac.nz

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**Abstract:** This article presents a review about Beyond Visual Line Of Sight (BVLOS) operations using unmanned aircraft in forest environments. Forest environments present unique challenges for unmanned aircraft operations due to the presence of trees as obstacles, hilly terrain, and remote areas. BVLOS operations help overcome some of these unique challenges; however, these are not widespread due to a number of technical, operational, and regulatory considerations. To help progress the application of BVLOS unmanned aircraft operations in forest environments, this article reviews the latest literature, practices, and regulations, as well as incorporates the practical experience of the authors. The unique characteristics of the operating environment are addressed alongside a clear argument as to how BVLOS operations can help overcome key challenges. The international regulatory environment is appraised with regard to BVLOS operations, highlighting differences between countries, despite commonalities in the considerations that they take into account. After addressing these points, technological, operational, and other considerations are presented and may be taken into account when taking a risk-based approach to BVLOS operations, with gaps for future research to address clearly highlighted. In total, this article provides a practical understanding of how BVLOS unmanned aircraft operations can be done in forest environments, as well as provides a basis for future research in the topic area.

**Keywords:** unmanned aircraft; drones; forestry; forest environment; BVLOS; aviation regulation

### check for updates

**Citation:** Hartley, R.J.L.; Henderson, I.L.; Jackson, C.L. BVLOS Unmanned Aircraft Operations in Forest Environments. *Drones* **2022**, *6*, 167. <https://doi.org/10.3390/drones607167>

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### 1. Introduction

This review paper has been authored with the intention of providing a reference for both academics and practitioners wishing to undertake beyond visual line of sight (BVLOS) operations in forest environments. To this end, the article reviews extant literature, incorporates practical experience and real-world examples of operations, and identifies some areas for future research. The paper begins by explaining some of the unique difficulties of conducting operations in forest environments alongside some of the common reasons why these operations may be undertaken. Next, the paper explains what BVLOS operations are and why these sorts of operations are particularly attractive in forest environments. Following this, the international regulatory environment, with regard to BVLOS operations, is discussed, identifying some of the common requirements across countries for undertaking such operations. Due to the variability between operations, the section after this provides a number of technological, operational, and other considerations that may be taken into account when taking a risk-based approach to conducting BVLOS operations in forest environments. The paper finishes by identifying some potentially fruitful avenues for future research.

### 2. Operations in Forest Environments

Forest environments are inherently difficult operating areas for unmanned aircraft. One of the major issues is the size of forests, with plantation areas ranging from a small 1 ha woodlot to a large plantation, such as Kaingaroa Forest, the largest pine plantation in

### Article

## A Mixed Methods Approach for Fuel Characterisation in Gorse (*Ulex europaeus* L.) Scrub from High-Density UAV Laser Scanning Point Clouds and Semantic Segmentation of UAV Imagery

Robin J. L. Hartley<sup>1,\*</sup>, Sam J. Davidson<sup>2</sup>, Michael S. Watt<sup>2</sup>, Peter D. Massam<sup>1</sup>, Samuel Aguilar-Arguello<sup>2,3</sup>, Katharine O. Meinik<sup>3,4</sup>, H. Grant Pearce<sup>1,5</sup> and Veronica R. Clifford<sup>2</sup>

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<sup>2</sup> Scion, 10 Kyle Street, Riccarton, Christchurch 8011, New Zealand

<sup>3</sup> Department of Civil and Natural Resources Engineering, University of Canterbury, Christchurch 8140, New Zealand

<sup>4</sup> Fire and Emergency NZ, Fire Engineering Faculty, 79 Creyke Road, Ilam, Christchurch 8041, New Zealand

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### check for updates

**Citation:** Hartley, R.J.L.; Davidson, S.J.; Watt, M.S.; Massam, P.D.; Aguilar-Arguello, S.; Meinik, K.O.; Pearce, H.G.; Clifford, V.R. A Mixed Methods Approach for Fuel Characterisation in Gorse (*Ulex europaeus* L.) Scrub from High-Density UAV Laser Scanning Point Clouds and Semantic Segmentation of UAV Imagery. *Remote Sens.* **2022**, *14*, 4775. <https://doi.org/10.3390/rs14144775>

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### 1. Introduction

With the onset of human-induced climate change, wildfires are growing in frequency and intensity. Wildfires in recent years have reached unprecedented levels in a number of countries, including the United States [1], Australia [2,3], Portugal [4] and Canada [5]. Over the past five years, Aotearoa New Zealand (NZ) has experienced some of the largest and most destructive wildfires in its history [6–8]. The destructive nature of these fires appears to be linked to an increase in the frequency of fires at the rural–urban interface, posing a greater threat to human life and property [6,9]. Shrubby environments comprise a

# Publications

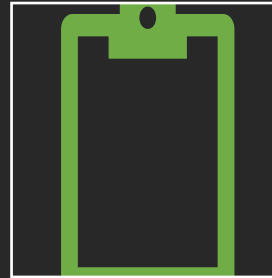
- SfM Software publication
- BVLOS publication (funded by TFF project)
- Hovermap Publication
- Fuel Mapping

# Tools for foresters

# UAV Applications

# Tools for foresters

- We are developing SOPS in 3 areas:

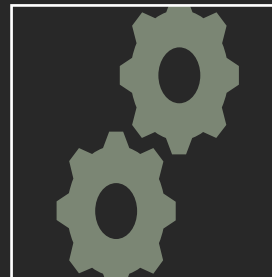


## TFF Essentials

- Basic operational procedures for beginning operations with UAVs in forestry

## TFF Operations

- Specific applications of UAVs to different forestry operations



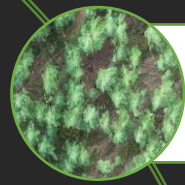
## TFF Processes

- Instructions for how to carry out operational data processing on UAV data

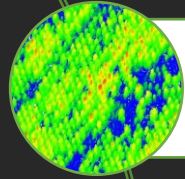


# UAV Applications

- TFF Operations



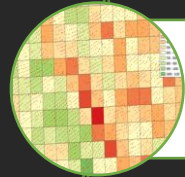
Post-thinning assessment



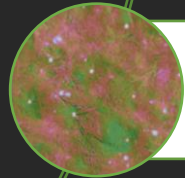
Tree growth



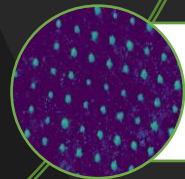
Post-plant



Survival surveys



Crop health assessments



Disease Monitoring

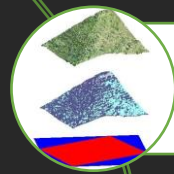


**Tools for  
foresters**

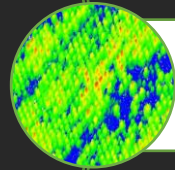
# UAV Applications

# Tools for foresters

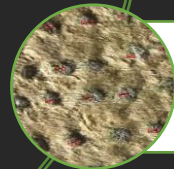
- TFF Processes



Deriving a DTM



Deriving a CHM



Deep Learning for stocking

# Applications Launch

- We have recently compiled a number of SOPs which are freely available to download from [Toolsforforesters.co.nz](https://toolsforforesters.co.nz)
- SOPs with \* have been endorsed by UAVNZ – the professional body for UAV operators in NZ



TFF Essentials

- \*How to plan UAV operations in forestry
- \*Pre-flight checks
- TFF hazard register
- How to establish ground control



TFF Operations

- Post-thinning Assessment



TFF Processes

- Deep Learning for stocking assessment
- Peak Detection for stocking assessment

# Tools for foresters

Coming Soon!

# Masters study: optimal flight parameters for post-thinning assessment using UAVs

Atman Dhruva

Studying MAppSc GIS at University of Otago

Optimal flight parameters for conducting SfM surveys of stands post-thinning

Using UAV lidar as ground truth (DJI Matrice 300 with DJI L1 sensor)

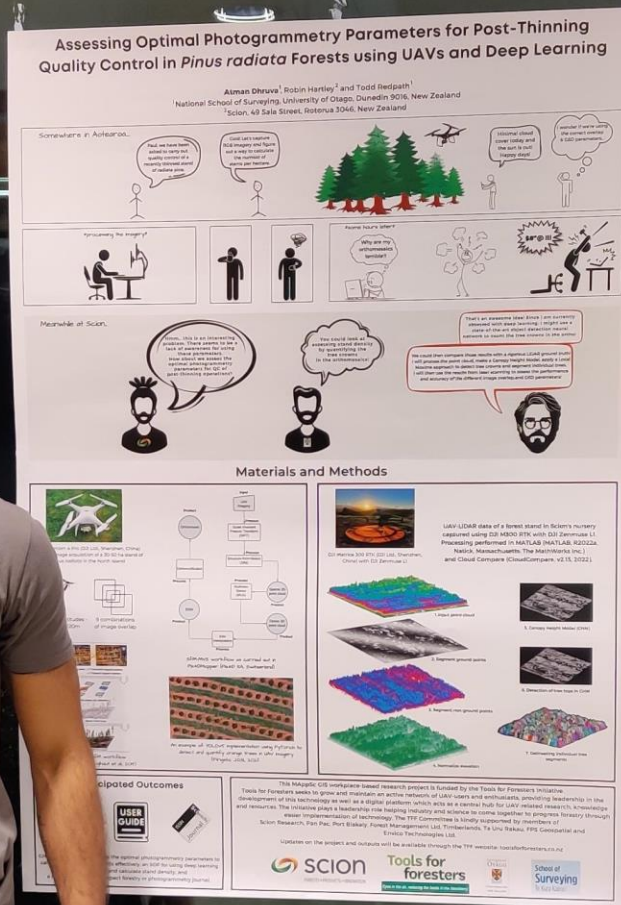
Collected data with a DJI P4 Pro

18 flights in a 30ha stand in challenging terrain

Production thinned “flat”/thin-to-waste steep

Working on SOP for using ESRI DL tools for stocking counts

Delivering a workshop on this at ForestTech



# Funding

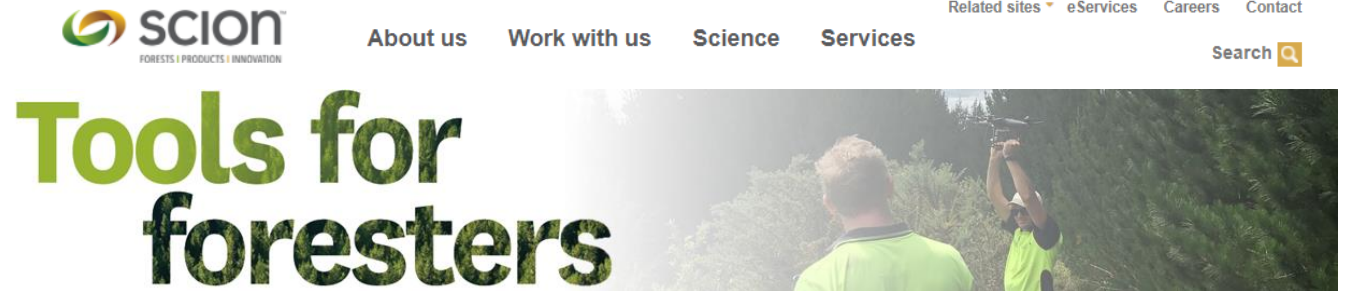
- So far, only funding from Scion to move things forward
  - 2021-2022:
    - Helped us get the website up and running
    - Got our branding sorted
    - Publication of a paper on BVLOS in forestry
  - 2022-2023:
    - Get newsletter up and running
    - Get forum up and running
    - Fund MSc student to develop a SOP for carrying out post-thinning assessments with UAVs
    - Workshop at Forest Tech
- Now out of funding...
  - Applied to FGR to fund the Deep Learning shared data sets
  - Presented TFF initiative to FGR to try to fund more applications
- Without more funding we are unable to do much more...





Toolsforforesters.co.nz

- In the past 6 months:
  - 3000 visits
  - 20% visits to the main page
  - 5% to tools page
  - 4% to publications
  - 4% to sign up page
- Big jump after newsletter
- Will be looking at ways to increase traffic and make the website more interactive



In this section
<a href="#">About Us</a>
<a href="#">The Team</a>
<a href="#">Research</a>
<a href="#">Tools</a>
<a href="#">Application Incubator</a>
<a href="#">Publications</a>
<a href="#">Forum</a>
<a href="#">News &amp; Events</a>

## Welcome to Tools for Foresters

[Home](#) . [Science](#) . [Tools for Foresters](#) . [About Us](#)

“  
*Eyes in the air, reducing the boots in the blackberry*  
”

We play a leadership role helping industry and science come together to progress forestry through easier implementation of technology.

We aim to remove technical hurdles and roadblocks to get useful technology into the hands of forest users. In doing so, we aim to help attract the next generation of forest workers, upskill workers, reduce downtime, costs and trouble shooting and improve forest profitability. These technologies can provide a sense of kaitiaki through the monitoring of our forests from above and below.

You can find resources by...

- Signing up for the [Tools For Foresters mailing list](#)
- Enquire about our [Beta Testing Programme](#)
- Participate in the forum for advice and troubleshooting about technologies such as UAVs in forestry, applications and algorithms
- Read SOPs, best practice and recommendations for use of UAVs and other technologies in forestry.

## Background

**Tools for  
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# Mailing list

- 64 members
- NZ and international
- Forest growers, contractors, consultants, government, research, academia
- Not as many as we would like!
- Please sign up and encourage your staff to sign up at [Toolsforforesters.co.nz](https://toolsforforesters.co.nz)
- Upon subscription, you get your welcome email with a link to our forum!



Subscribe to TFF!



**Tools for  
foresters**

# Next steps

- **Get more involved**
  - **Sign up for beta testing!**
  - **Start using the SOPs!**
  - **Get a login for the forum and start asking questions and sharing images!**
- **Funding**
  - **We will be applying for funding again this year**
  - **Open to suggestions for funding options**
  - **We cannot maintain/gain momentum without it.**
- **Committee will be meeting quarterly this year to keep things pushing along**



# Tools for foresters



## Acknowledgements

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- Innovatek for their support and help with the workshop
- Everyone in industry who has supported us so far

[www.scionresearch.com](http://www.scionresearch.com)  
[www.toolsforforesters.co.nz](http://www.toolsforforesters.co.nz)



Prosperity from trees *Mai i te ngahere oranga*

Scion is the trading name of the New Zealand Forest Research Institute Limited