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QUANTIFYING FUEL HAZARD ASSESSMENTS

Fuels3D annual report 2019-2020

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Cover: Data collection testing in closed lowland forests of Victoria. Source: Karin Reinke



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EXECUTIVE SUMMARY

This annual report summarises the year 2019 for the Fuels3D project. This project was funded as half a project; the work considers the lack of repeatability and reliability with current field fuel hazard assessments. It demonstrates the precision of a semi-automated non-visual based assessments as compared to those collected through traditional visual assessment. The opportunity to bring together off-the-shelf, smart phone cameras and consumer grade digital cameras with advances in computer vision and photogrammetric techniques provide a cheap alternative for quantitative assessments compared to more accurate, but more expensive 3D mapping technologies (i.e. Lidar TLS). A tool chain and suite of computer vision and photogrammetric algorithms that use images captured in the field to produce 3D point clouds from which fuel hazard metrics are calculated. The developed technique is adaptive to 3D point clouds captured from other terrestrial technologies and can allow for changes in data collection technologies.

Highlights of 2018-2019 have included:

- End-user trials using Fuels3D iPhone and app delivered and completed across south-eastern Australia and new sampling transect method assessed to increase rate of in-field image capture of surface and near-surface fuels.
- Fuels3D requirements workshop conducted with end-users following (unsuccessful iPhone and transect sampling) trials.



END-USER PROJECT IMPACT STATEMENT

Rachel Bessell and Alex Chen, *Country Fire Authority, Victoria.*

"In late 2018, we received a Fuels3D app installed on an iPhone, coupled with an infield sampling protocol to test. The solution was designed to determine surface and near-surface fuel hazard in an objective and repeatable way, that would be available to all CFA members. Working with RMIT researchers we were taken through the workflow. From the trial we were learnt that the smartphone cameras did not provide the level of quality needed to create a 3D fuel hazard environment. Recognising the potential of the solution to adapt to different terrestrial sensing technologies we look forward to a more robust data collection solution in the future."



INTRODUCTION

Improvement of the understanding of how fuel load and condition correlate with fire severity is critical to the ongoing handling of risk and recovery in fire-prone environments. Current standards and protocols for describing fuel hazard (for example, "Overall Fuel Hazard Assessment Guide", Victorian Department of Sustainability and Environment) and post-burn severity (for example, "Fire Severity Assessment Guide", Victorian Department of Sustainability and Environment) are the culmination of decades of empirical study across a wide and diverse array of Australian environments, and the metrics described in these guides remain the measures of key drivers of fire risk. As these guides were written for information adapted from data-sparse subjective descriptions of the landscape, the ability of information from these assessment techniques to be adapted to modern risk assessment tools such as fire behavior models, or for calibration and validation of datasets, is limited. Quantitative data-rich methods of measuring and assessing fuel load and structure are the missing link between the knowledge of land management personnel in the field, and the model drivers and decision makers at organizational level.

Handheld devices with high quality sensors, in the form of mobile phones, are ubiquitous. Rapid and comprehensive capture of information by these devices, coupled with the use of computer vision techniques, allows for the 3D description of the surrounding environment. This project aims to exploit this technology to provide robust measurement of metrics that can be built into existing fuel hazard assessment frameworks. Providing key metrics as data products rather than a single product enables flexibility across jurisdictions and ecosystem types, and capacity to adapt as end-user requirements change.

The Fuels3D project has created a suite of tools and methods for image capture in the field during fuel hazard assessments. 3D point clouds are generated using computer vision and photogrammetry techniques. From these 3D point clouds, scale is added and decision rules are programmed to calculate quantifiable surface / near-surface metrics that replicate those used in current fuel hazard visual assessment guides. The key steps in the strategy have included:

- Discussion with end-users on fuel strata definitions, and opportunities for new and existing fuel hazard metrics to enable the extraction of metrics from Fuels3D point clouds.
- Field validation of derived fuel metrics will be ongoing as Fuels3D is trialled across a greater number of fuel landscape types (as identified in the draft AFAC Bushfire Fuel Classification System). Fuels3D data will be collected by both the research team and end-users. Terrestrial Laser Scanning, destructive sampling and field measurements will form part of the validation method.
- Methods (in-field positioning and image recognition) will be investigated and developed to allow for scaling to be automatically built into the resulting 3D point cloud from which fuel metrics can be derived.
- End-user field trials being conducted to assessment solution usability and performance, and workflow processes.



BACKGROUND

Visual estimation is the standard practice for land management agencies across Australia for collecting fuel hazard assessments. Visual assessment provides a low-cost and efficient method to rapidly describe and estimate fuels and individual fuel layers. However, it is well known and documented in the literature, that visual assessments are subjective and can vary greatly between assessors [1, 2, 3, 4].

In response to understanding the performance of Fuels3D against visual assessments using the Overall Fuel Hazard Assessment Guide, an end-user field day was held with end-users from SA DEWNR, ACT Parks and Wildlife, VIC DELWP, VIC CFA, Melbourne Water and Parks Victoria. The field day aimed to introduce end-users to the Fuels3D collection protocol and to assess its ease of use and repeatability between data collectors in comparison to traditional visual assessment techniques. Participants were asked to undertake a visual assessment and collect Fuels3D data at three plots as shown in Figure 1.

The results, published in *Sensors* in 2017 [4], indicated that surface and near-surface metrics related to fuel hazard can be measured with greater repeatability between different observers. Even more critical was the propagation of this error when the metrics were combined to calculate hazard ratings. This is demonstrated in Figure 2 where the range of surface cover and height is significantly lower across all plots than seen in the visual assessment approach, spanning across almost four hazard rating classes.

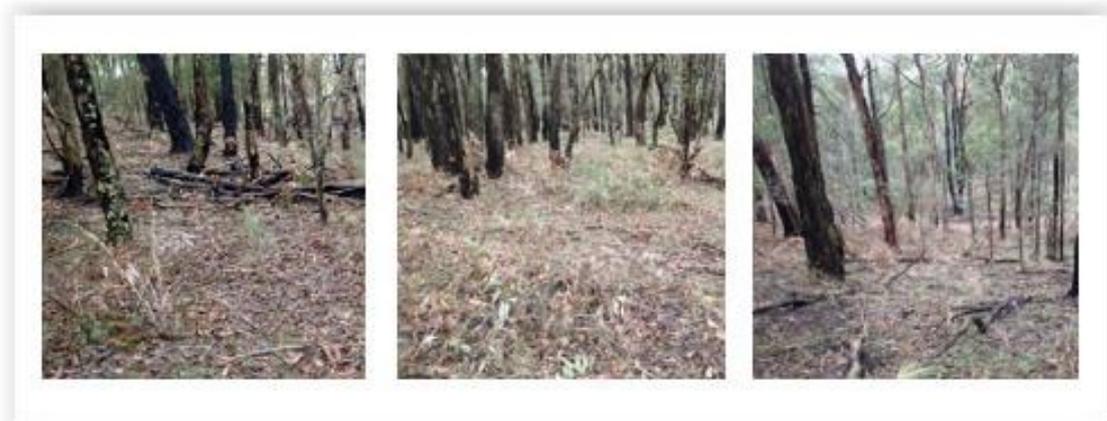


FIGURE 1. EXAMPLES OF THE THREE SITES FROM WHICH PLOT LEVEL FUEL HAZARD ASSESSMENTS WERE COLLECTED BY END-USERS.



RESEARCH APPROACH

The research approach employed for the development of Fuels3D began with a review of remote sensing technologies suited for capturing vegetation structure. Remote sensing captured from airborne and satellite platforms have long been used as a viable option for characterising vegetation in the landscape. However, estimates of fuel hazard and risk made using remote sensing data still require input at the local, or plot, scale for calibration and validation purposes. Terrestrial remote sensing techniques on the other hand, can provide an alternative or complementary source of information to traditional field assessments and support large scale remote sensing used to quantify and describe vegetation properties.

Terrestrial Laser Scanning (TLS) allows for precise information characterising the amount and structural arrangement of fuel [5] to be collected, otherwise unavailable from visual assessments and large-scale remote sensing. However, laser scanning technology remains limited for operational deployment and uptake due to the cost of instrumentation and expertise required to operate scanners in the field. In this project, TLS was used as a comparison for the validation phase of point clouds collected using Fuels3D.

Computer vision and photogrammetric algorithms, which utilise overlapping imagery, are currently being employed in a wide variety of environmental and agricultural applications to provide information describing the 3D structure of the surrounding environment. Unlike other remote sensing techniques, the collection of this information requires relatively low-cost sensors (such as consumer-grade digital cameras) and lower expertise for data collection in comparison to laser scanning technology [6].

Structure from Motion is a technique developed recover 3D geometry from a set of overlapping images and underpins the Fuels3D solution. Common features between images are used to reconstruct the 3D environment. Knowing the locations of several features in multiple images allows estimates of the 3D camera location and 3D point coordinates in relative image-space to be made based on the principles of photogrammetry [7]. The coordinates of camera locations and features are provided in an arbitrary space, which can then be transformed (scaled, rotated and translated) into object (or real-world) coordinates based on a small number of ground control points [7]. In this project, ground control points consisted of unique colour-coded vertical target poles.

Validation of Fuels3D results have been compared against field measures (using intensive point intercept methods), destructive sampling (dry weights correlated to volumetric measures from 3D point clouds) and TLS to determine the accuracy of the solution. Data has been collected across multiple vegetation and fuel types including closed forest, open forest, woodland, low woodland, conifer, hummock grasslands, low shrubland and grasslands (as described in the AFAC Draft Bushfire Classification System).



KEY MILESTONES

End-user trials have produced image datasets being collected by end-users in their nominated priority areas and uploaded onto Cloudstor as per the workflow and data handling solution documented in the Fuels3D quick guides. End-users had access to iPhone and Android apps, quickstart guides and in-field targets. As part of this process automated processing of target identification, fuel hazard layer extraction, and quantification of fuel hazard metrics was designed and implemented in research-grade Python code. Following the trial, image quality control was completed to assess suitability of Smartphones and the new transect method for producing 3D point clouds of fuel hazard.



UTILISATION AND IMPACT

SUMMARY

End-users from SA, Victoria and ACT were delivered Fuels3D kits (smartphone and target pole) and instructions provided in person and through support documentation. The purpose of the trial was to assess current smartphone camera technology, the developed apps for data handling, and a new transect sampling methodology for utilisation uptake.

During the infield utilisation trial phase, the processing workflow was found to be highly sensitive to the specifications of the imaging sensor. In other words, inconsistency between different smartphone camera sensors, or versions of smartphones, impact on image quality for the solution. In particular, the newly released iPhone for which a data collection app had been designed and implemented to provide an end-to-end solution, was particularly problematic.

Representatives from end-user agency trialled different smartphone/tablet options in the field and the rate of success in conversion of the image dataset to a point cloud (using Agisoft Metashape) was deemed unsatisfactory for devices including the iPhone. Key to the Fuels3D process is the physical size of the imaging sensor used (noting this is different to the number of megapixels), this is often an unpublished specification with research experiments needed to determine the minimum sensor size required for the process. For example, Apple have not released the sensor size specifications for the iPhone 6 through to the iPhone X. Although there was a trend in increasing sensor size in smartphone technology in the early stages of this project (see the Panasonic Lumix CM1 released in 2015 as a prime example of this), it appears that manufacturers have opted for multiple smaller sensors to improve image quality (see Huawei P20 or iPhone X). Unfortunately, this option does not improve the aspects of the image required for the fuels3D workflow to be used with these newer phones. Although current smartphones could be tested for suitability this trend suggests that the requirements for the type of sensor that results in the best outcomes for Fuels3D is not a priority in smartphone technology and the next generation of smartphones are likely to remain unsuitable. A more reliable option would be to move to mirrorless DSLR cameras as the image capture device.

Evaluation of the transect sampling approach and infield targets identified that small plot sampling provided a more robust solution for 3D point creation than the new transect-based image collecting approach. This was largely due to the reduced impact of feature obscuration achieved by taking images 360 degrees around and over the area of interest.

UTILISATION AND IMPACT EVIDENCE

Documented in Wallace, L.; Reinke, R.; Jones, S.; Hillman, S.; Leavesley, A.; Telfer, S.; Bessel, R.; Thomas, I. Experiences in the in-field utilisation of Fuels3D. AFAC Conference Proceedings, September 5-8 2018, Perth, Australia.

Other utilisation observations and comments include:



- Engagement with operational staff from Victorian Department of Environment Land Water and Planning, CFA, ACT parks and Wildlife, NSW RFS, South Australia Department of Environment, Water and Natural Resources at Fire Behaviour and Fuels Conference, ICFRR, UAV4RS and agency specific meetings has shown broader recognition that point clouds provide a viable method to be able to empirically quantify fuel hazard.
- Engagement internationally at ICFRR has also highlighted the international push towards accurate, empirical quantification of fuels.
- Interviews have been conducted with ACT Parks and Wildlife and Department of Environment Land Water and Planning in Victoria to trial the Fuels 3D approach.
 - The city of Canberra features significant fire risk (historical precedence from the 2003 fires) with highly populated areas on the wildland-urban interface. In order to reduce the risk to communities, mechanical treatment works and planned burning are completed to alter and reduce the fuel arrangement (in turn reducing potential intensity and rate of spread of fire in these areas). Accurate quantification of the fuel hazard is vital for modelling the effect of potential fuel treatments.
 - With visual assessments shown to be highly subjective and difficult to input these measurements within a fire behaviour modelling system, Fuels3d was seen as a potential option here to a) allow the empirical quantification of fuel and b) a communication tool for fire managers to demonstrate the effect of fuel treatments to the organisation and local communities.
 - Engagement with field crew highlighted the desire to move towards an objective based assessment of fuel. Additionally, the utility of this approach to communicate to all staff and community the effect of fuel treatments.
 - Feedback from users during the testing phase highlighted the ease of use in capturing images on a camera instead of a phone. Additionally, with different restrictions for Agency computers, the ability to upload files directly from a memory card was deemed significantly easier than the phone. Point clouds were then constructed remotely.
 - Further work is being conducted to improve the workflow to allow images to be added to a portal and running the processing workflow remotely.
 - Desires from users from this trial:
 - Workflow is easy to use on all devices (personal or agency).
 - investigate new metrics that could be extracted from the point clouds that previously have been only able to be visually assessed with a yes or no ie is there enough vertical connectivity for fire to carry.



- Possibility to integrate other 3D point clouds into the portal. The ACT have a LiDAR capture every 12 months.
- Agency wide engagement:
 - Several agencies have expressed interest in utilising 3D point clouds e.g. airborne LiDAR that are captured routinely through other groups within the agency. This data is often collected by the agency for a number of purposes and investigation into the capability to derive metrics that are relevant to fuel hazard.
 - Potential to use different sensors to scale data from the plot/transect scale to broader landscape.
- Work with the US Forest Service
 - Prior work has been completed by the US Forest Service using 3D point clouds to capture of canopy fuels information. Work currently funded through the BNHCRC involves collaboration with the US Forest Service to investigate how 3D sub-canopy fuels can be captured and relevant metrics extracted from the point clouds.
 - Collaboration has begun in investigating the potential to use Terrestrial Laser Scanners to identify and extract meaningful parameters that relate to fuels information as a gold standard/high accuracy approach.
- Examples and Case Studies
 - Case studies over the last year can largely be broken up into two main categories – validation and location trials.
 - Validation results have demonstrated that point clouds captured using terrestrial Structure from Motion and Terrestrial Laser Scanners represent fine fuel structure. These tests were carried out in a variety of landscapes.
 - Case Studies over the last 12 months have been focussed on the technologies to capture 3D representations of a variety of fire prone landscapes in South Eastern Australia
 - High Camp – Heathy Dry forest. Common Forest type in South Eastern Australia. All technologies (terrestrial Structure from Motion, Terrestrial Laser Scanning, Airborne SfM and Airborne LiDAR) have been captured to evaluate the different characteristics of each technology and platform.
 - Tasmania – Dry Sclerophyll forest. Common forest type in South Eastern Australia. All technologies (terrestrial Structure from Motion, Terrestrial Laser Scanning, Airborne SfM and Airborne LiDAR) have been captured to evaluate the different characteristics of each technology and platform.
 - Silvan – Wet forest. This forest type is found in close proximity to a number of Melbourne's water sources and represents an area of high priority for fuel management. Due to the



closed nature of the canopies, airborne technologies have not been trialled here. Results from these sites have highlighted that terrestrial structure from motion presents a suitable method of capturing information on the surface and near-surface vegetation due to the close proximity to the vegetation of interest.



NEXT STEPS

Issues arising from the end user trial show that a smartphone + app solution is not feasible without a large investment to solve the App and device-related issues. Proposed further development will use consumer grade mirrorless cameras as an alternative to get the Fuels3D concept to a semi-automated solution.

A workshop has been conducted at Predictive Service Group on 13 June, 2019 to develop the high level requirements specification for next steps of the Fuels3D project. The workshop covered:

- Rapid introduction to Fuels3D (supported by briefing papers and background reading materials)
- Straw proposal covering a proposed system architecture, capabilities and user interfaces, and data inputs/outputs.
- Architecture discussion, including data storage requirements, accessibility, historical data availability and archiving.
- Functionality, including range of vegetation types / fuel layers / metrics, scale, and technology sources (data inputs).
- User interface, including data input / output requirements.



PUBLICATIONS LIST

PEER-REVIEWED JOURNAL ARTICLES

- 1 Wallace, L.; Bellman, C.; Hally, B.; Hernandez, J.; Jones, S.; Hillman, S. **Assessing the Ability of Image Based Point Clouds Captured from a UAV to Measure the Terrain in the Presence of Canopy Cover.** *Forests* 2019, 10, 284. (impact factor: 2.252)
- 2 Wallace, L.; Saldias, D. S.; Reinke, K.; Hillman, S.; Hally, B.; Jones, S. **Using orthoimages generated from oblique terrestrial photography to estimate and monitor vegetation cover.** *Ecological Indicators*, 2019, 101, p. 91-101. (impact factor: 3.983)
- 3 Hillman, S.; Wallace, L.; Reinke, K.; Hally, B.; Jones, S.; Saldias, D. S. **A method for validating the structural completeness of vegetation models captured with 3D remote sensing.** *Methods in Ecology and Evolution* 2019 (in review). (impact factor: 6.36)

CONFERENCE PAPERS

- 1 Wallace, L.; Reinke, R.; Jones, S.; Hillman, S.; Leavesley, A.; Telfer, S.; Bessel, R.; Thomas, I. **Experiences in the in-field utilisation of Fuels3D.** *AFAC Conference, September 5-8, Perth, Australia.*
- 2 Wallace, L.; Hillman, S.; Taneja, R.; Reinke, K.; Hally, B.; Jones, S. **Characterising vegetation and fuel structure in Mallee woodlands using Terrestrial Laser Scanning.** *ForestSat Conference, October 1-5, 2018, College Park, MD, USA.*
- 3 Hillman, S.; Wallace, L.; Reinke, K.; Hally, B.; Jones, S.; Taneja, R. **Assessment of below-canopy forest structure using UAV Structure from Motion (SfM) points clouds.** *ForestSat Conference, October 1-5, 2018, College Park, MD, USA.*
- 4 Wallace, L.; Reinke, R.; Hillman, S.; Hally, B.; Jones, S. **A rapid technique to quantify bark fuel hazard with smartphones.** *VIII International Conference on Forest Fire Research, November 9-16, 2018, Coimbra, Portugal.*
- 5 Hillman, S.; Wallace, L.; Lucieer, A.; Reinke, K.; Turner, D.; Jones, S.; Fallatah, A.; **Inter-comparison of UAS SfM and UAS LiDAR to capture effectiveness of burns in dry sclerophyll forests.** *UAS4RS 2018, December 5-6, Melbourne, Australia.*
- 6 Wallace, L. **Not so chilly in Chile – Trials, tribulations and triumphs of international RPAS field campaigns.** *UAS4RS 2018, December 5-6, Melbourne, Australia.*
- 7 Hillman, S.; Wallace, L.; Reinke, K.; Jones, S.; Hally, B. **Linking point clouds to fuel hazard.** *6th International Fire Behaviour and Fuels Conference, April 29 – May 3, 2019, Sydney, Australia.*
- 8 Wallace, L.; Hillman, S.; Reinke, K.; Hally, B.; Jones, S.; Bellman, C.. **Remote fuel hazard mapping in the Mallee.** *6th International Fire Behaviour and Fuels Conference, April 29 – May 3, 2019, Sydney, Australia.*

Forthcoming – accepted conference presentations

- 9 Wallace, L.; Jones, S.; Bellman, C.; Shortis, M.; Lucieer, A.; Hally, B.; Turner, D.; Hillman, S. **Innovative data capture and algorithms for improving outcomes from UAV image-based point clouds of forests.** *XXV IUFRO Congress, 29 September – 5 October, Curitiba, Brazil.*
- 10 Hillman, S.; Wallace, L.; Lucieer, A.; Reinke, K.; Turner, D.; Jones, S.; Hally, B. **Inter-comparison of UAV SfM and UAV LiDAR to capture understorey structural characteristics.** *XXV IUFRO Congress, 29 September – 5 October, Curitiba, Brazil.*



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REFERENCES

- 1 Watson, P.J.; Penman, S.H.; Bradstock, R.A., 2012, A comparison of bushfire fuel hazard assessors and assessment methods in dry sclerophyll forest near Sydney, Australia. *Int. J. Wildland Fire*, 21, 755–763.
- 2 Sikkink, P.G.; Keane, R.E. 2008, A comparison of five sampling techniques to estimate surface fuel loading in montane forests. *Int. J. Wildland Fire*, 17, 363–379.
- 3 Zhou, Q.; Robson, M.; Pilesjo, P., 1998, On the ground estimation of vegetation cover in Australian rangelands. *Int. J. Remote Sens.*, 19, 1815–1820
- 4 Spits, C., Wallace, L. and Reinke, K., 2017, Investigating surface and near-surface bushfire fuel attributes: a comparison between visual assessments and image-based point clouds. *Sensors*, 17(4), p.910.
- 5 Wallace, L., Gupta, V., Reinke, K. and Jones, S., 2016. An assessment of pre-and post fire near surface fuel hazard in an Australian dry sclerophyll forest using point cloud data captured using a terrestrial laser scanner. *Remote Sensing*, 8(8), p.679.
- 6 Wallace, L., Hally, B., Reinke, J.K., Jones, D.S. and Hillman, S., 2016, April. Leveraging smart phone technology for assessing fuel hazard in fire prone landscapes. In *Proceedings of the 5th International Fire Behaviour and Fuels Conference, Melbourne, Australia* (pp. 11-15).
- 7 Snavely, N., Seitz, S.M. and Szeliski, R., 2006, July. Photo tourism: exploring photo collections in 3D. In *ACM transactions on graphics (TOG)* (Vol. 25, No. 3, pp. 835-846). ACM.