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WIND SPEED REDUCTION FACTORS (WRFS): UTILITIES FOR WRF ASSESSMENT AND COMMUNICATION

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QUEENSLAND FIRE AND EMERGENCY SERVICES

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This research was part of the Bushfire and Natural Hazards CRC's Black Summer research program, funded by the Australian Government and the CRC to investigate key issues from the 2019-20 bushfire season.

EXECUTIVE SUMMARY

This project commenced in March 2021 as a Bushfire and Natural Hazards CRC Black Summer funded initiative between Queensland Fire and Emergency Services and the School of Earth and Environmental Sciences at the University of Queensland. The purpose of the project was to undertake an evaluation of WRFs used in Australia (including during Black Summer) to quantify the reduction of open space wind speed by Australian fuel types.

Wind is a key driver of fire behaviour and can be highly variable and difficult to predict, particularly within the lowest 1-2km of the atmosphere where it interacts in complex ways with topography and vegetation. Operational fire spread modelling quantifies the impact of vegetation or fuel type on wind speed using Wind speed Reduction Factors (WRFs) or Wind Adjustment Factors (WAFs). Specifically, these factors quantify the impact of vegetation on reducing the speed of the open space prevailing wind. WRF is typically the ratio of 10m open wind speed to 2m wind speed, whereas WAF is the ratio of 'midflame' wind speed to 20 ft open wind speed.

To date, single or static WRFs have been assigned to 62 Queensland Broad Vegetation Groups (BVGs) for use within the operational fire simulation application PHOENIX Rapidfire. These WRFs have been derived via approximation. Specifically, the 10m open wind speed has been approximated by the closest Bureau of Meteorology (BOM) Automatic Weather Station (AWS) to the field site, and the 2m near-surface wind speed has been approximated via the use of a handheld anemometer raised to eye-level at a suitable location within the field site.

The key research aims were to:

- review and summarise the existing international state of knowledge on the definition and quantification of WRFs
- review and summarise current potential methods to quantify WRFs, as well as to assess fuels and their structure
- determine the strengths, weaknesses and suitability of these methods for application in Queensland, as well as their potential for application across Australia
- establish a WRF test site upon which a high priority fuel type is located to test one of the WRF quantification methods, as well as instrumentation
- develop a WRF assessment resource for FBAN use on fire grounds.

The review found that the use of approximated static WRFs has caused minor to significant error accumulation in the fire spread model outputs produced by fire simulation applications, including PHOENIX Rapidfire.

To reduce error in fire spread modelling, the review concluded that the development of dynamic WRF modelling capabilities should be a priority. These dynamic WRFs should respond to key wind, fuel, fire and topography parameters that change over time and space.

However, a dynamic WRF model should not require such high levels of computation so as to delay real-time fire spread modelling outputs. At its simplest, a dynamic WRF model is a discrete, empirically derived WRF profile, illustrating the change in WRF at specific heights measured within a fuel type in the field. A more advanced dynamic WRF model might be a mathematical model for which wind, fuel, fire and topography parameters act as inputs and a mathematically idealised continuous WRF profile is the output. This model should be validated by empirical data. Overall, each fuel type should have its own WRF profile. The end goal should be to replace all static WRFs with dynamic WRF profiles in fire spread models.

A WRF test site was established in the priority fuel type 'moist to dry eucalypt woodland on coastal lowlands and ranges' at the Queensland University of Technology (QUT) Samford Ecological Research Facility (SERF), located on the outskirts of Samford Valley in Southeast Queensland. Installed at the site is a 15m instrumented tower using 3D sonic anemometers to record mean 3D wind speed, vertical wind direction and sonic air temperature. A discrete WRF profile was derived by taking the ratio of the average 10m open wind speed measured by the nearest BOM AWS in Brisbane and the average wind speed measured at heights of 2.5m, 4.5m, 10.5m and 15.5m. This WRF profile is preliminary as it is based on 23 hours of data collected outside the southeast Queensland fire season (August – December).

Preliminary investigations of relationships between variables related to WRF were also conducted. The overall wind profile was compared to the Plant Area Density (PAD) profile of the vegetation obtained via terrestrial LiDAR (Light Detection and Ranging). A weak to moderate relationship was identified ($R^2 = 0.22$) between mean wind speed and PAD, which may be due to the calm conditions experienced over the short length of the data collection period. Additionally, the day-time and night-time subcanopy temperature profiles were compared. The day-time profile was found to be slightly more constant with height, which may indicate that the subcanopy environment is more mixed and turbulent throughout the day. This result was supported by increased measurements of vertical mixing throughout the day. Nevertheless, data collection over a longer period under more varied conditions is recommended to investigate these relationships further.

The WRF test site at the QUT SERF has provided a preliminary insight into the relationships between vegetation and meteorology in the Australian context, which is essential for the development of empirically based dynamic WRF profiles for all fuel types. The methodology used is transferable and will be applied to other sites containing other priority fuel types. Anemometer measurements and LiDAR scans may then be used as key datasets for underpinning and validating the development of advanced dynamic WRF modelling capabilities in the next generation of fire spread models. Until this capability is developed, the new quick-reference WRF profile assessment resource developed by this project will enable FBANs near the fire ground to quickly identify the WRF values most relevant to the ensuing fire spread. These values may then be communicated to fire spread modellers.

END-USER PROJECT IMPACT STATEMENT

Raymond Bott, *Manager Predictive Services Unit, QFES Community Resilience & Risk Mitigation Branch, QLD*

The current state of knowledge and application of wind impacts on bushfire behaviour is limited and somewhat random as it is based on an extrapolation of a small set of site-specific field-based research. This research is based on low-cost anemometers that are restricted to collecting horizontal wind movements only. The use of more accurate three-dimensional anemometers will improve the quality of data and better illustrate the significant impacts that wind-vegetation interactions have on fire behaviour.

Currently, wind and weather contributions utilised by fire behaviour analysts are obtained from 10m automatic weather stations, often located at a considerable distance from the seat of the fire(s), and/or from 2m portable weather stations that are situated in random, often non-ideal locations. Wind turbulence effects are not considered, and the application of data into standard equations for fire parameters can be confused.

The development of a robust, nationally consistent methodology for site selection, data collection and data analysis for wind reduction contributions would greatly enhance the ability of agencies to adopt a standard process and develop a nationally consistent picture. It is hoped that each fire agency will undertake the field data capture and data analysis, or commission other partners to undertake this work.

INTRODUCTION

The *Wind speed Reduction Factors (WRFs): utilities for WRF assessment and communication* project commenced in March 2021 as a Bushfire and Natural Hazards CRC Black Summer funded initiative between Queensland Fire and Emergency Services and the School of Earth and Environmental Sciences at the University of Queensland. The purpose of the project was to undertake an evaluation of WRFs used in Australia to quantify the reduction of open space wind speed by Australian fuel types. WRF is typically the ratio of 10m open wind speed to 2m wind speed and is functionally equivalent to the Wind Adjustment Factor (WAF) used in North America, which is the ratio of 'midflame' wind speed to 20ft open wind speed (Andrews 2012).

Close to the Earth's surface, wind speed theoretically displays a logarithmic relationship, increasing with height (Sutton 1953). This relationship assumes that the underlying surface is flat and devoid of roughness elements such as trees and shrubs. In the presence of these roughness elements, the logarithmic profile may be displaced vertically by their mean height, and the wind speed below this height is assumed to be zero (Figure 1).

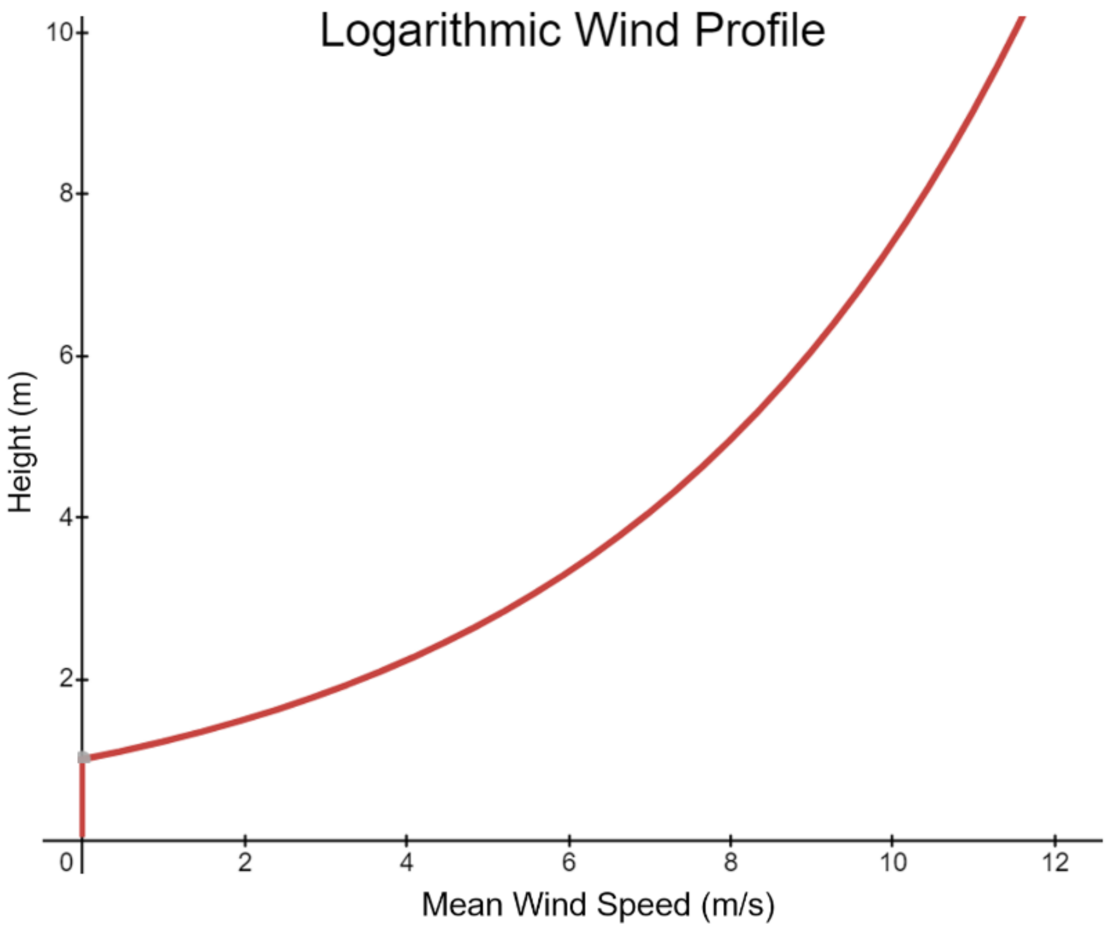

FIGURE 1: THE LOGARITHMIC WIND PROFILE, TRANSFORMED TO SHOW HEIGHT ON THE Y-AXIS. THE MEAN ROUGHNESS ELEMENT HEIGHT IS 1M.

However, in reality, wind may still penetrate into the roughness elements, depending on their density and structural attributes (Andrews 2012). As a result, a vertical subcanopy wind profile exists and will reflect the vertical vegetation structure, often quantified as Plant Area Density (PAD). Knowledge of this wind profile relative to the open space wind speed, i.e., the WRF, is essential to the prediction of fire spread.

To date, fire spread models used in Australia rely on a single or static WRF for the dominant fuel type on the fire ground. As an example, static WRFs have been assigned to 62 Queensland Broad Vegetation Groups (BVGs) for use within the operational fire simulation application PHOENIX Rapidfire. Such WRFs have been derived through simple field observations using a range of non-uniform approximated methods and instrumentation. They have also been derived in the absence of direct measurement of the PAD of the fuel. As a result, there is an absence of robust empirically derived WRFs for Australian fuel types.

WRF REVIEW

A wind reduction factor quantifies the impact of a specific fuel type on reducing the speed of the open space prevailing wind (Andrews 2012). Wind speed Reduction Factors (WRFs) are used in Australia and may be calculated using Equation 1,

$$\boldsymbol{WRF} = \frac{U_{10}}{U_2} \qquad (1)$$

where U_{10} is the open wind speed forecast at 10m (m s^{-1}), and U_2 is the near-surface 2m wind speed (m s^{-1}). Wind Adjustment Factors (WAFs) are used in North America and may be calculated using Equation 2,

$$\boldsymbol{WAF} = \frac{U_{midflame}}{U_{20}} \qquad (2)$$

where $U_{midflame}$ is the wind speed measured at 'midflame height' (ft s^{-1}) and U_{20} is the open wind speed forecast at 20ft (ft s^{-1}). WAFs are sometimes referred to as Relative Wind Speeds (RWSs) in Australia and may be calculated using Equation 3,

$$\boldsymbol{RWS} = \frac{U_2}{U_{10}} \qquad (3)$$

where U_2 is the near-surface 2m wind speed (m s^{-1}) and U_{10} is the open wind speed forecast at 10m (m s^{-1}). WRF, WAF and RWS are functionally equivalent (Moon et al. 2016).

To date, single or static WRFs have been assigned to 62 Queensland Broad Vegetation Groups (BVGs) for use within the Australian operational fire simulation application PHOENIX Rapidfire. These static WRFs have been derived via approximation. Specifically, the open (10m) wind speed has been approximated by the closest Bureau of Meteorology (BOM) Automatic Weather Station (AWS) to the field site, and the near-surface (2m) wind speed has been approximated via the use of a handheld anemometer raised to eye-level at a suitable location within the field site.

These static WRFs are also assumed to be representative of, and therefore valid for, the full vertical subcanopy environment. Hence, the subcanopy wind speed is assumed to be constant with height. The subcanopy wind field and the overall fuel structure are also assumed to be uniform, and the influence of fire, atmospheric stability, and uneven topography are assumed to be irrelevant.

Empirical research suggests that these assumptions are false. For example, Cruz et al. (2006) indicates that subcanopy wind speeds are dynamic, changing distinctly with height. Moon et al. (2013, 2016) found that each fuel type has a distinctly different wind profile, which is related to the change in fuel structure with height. Lee (2000) and Sullivan (2017) found that the presence of fuel and fire creates a turbulent subcanopy wind field as the flow responds to the drag force generated by individual fuel elements such as leaves and branches, as well as the convection generated by heat flux from the fire to the surrounding air. Moon (2016) suggests that turbulence is more common in unstable or well-mixed subcanopy environments and less common in those that are stable or stratified. Such environments may be identified by their temperature profiles; a decreasing lapse profile tends to indicate mixing, whereas a constant or increasing profile tends to indicate stable stratification. Quill et al. (2016) also found that leeward slopes create a sheltering effect that decreases wind speed, whereas terrain gaps and channels create a channelling effect that increases wind speed. Overall, there is consensus in the literature that the use of approximated static WRFs has caused minor to significant error accumulation in the fire spread model outputs produced by fire simulation applications.

Despite their inaccuracies, static WRFs have remained in use because operational fire spread models have remained computationally simple. This is largely because fire spread models based on high-level fluid dynamics still run too slowly to produce the desired real-time outputs. Nonetheless, static WRFs may still be improved within current operational models.

A dynamic WRF model changes in response to a range of wind, fuel, fire and topography parameters. At its simplest, a dynamic WRF model is an empirical WRF profile, illustrating the change in WRF at specific heights measured by instrumentation installed at a field site containing a given fuel type (Equation 4).

$$\boldsymbol{WRF}\ (\boldsymbol{z}) = \frac{U_0}{U_z} \qquad (4)$$

where U_o is the wind speed in an open space above or near the fuel (m s^{-1}) and U_z is the wind speed at measured height z within the fuel (m s^{-1}). Such a profile is, therefore, discrete. A more advanced dynamic WRF might be a mathematical model for which wind, fuel, fire and topography parameters act as inputs and a mathematically idealised continuous WRF profile is the output, which is then validated by empirical data. Derivation of this advanced model is beyond the scope of this project, although Harmon and Finnigan (2007) and Massman et al. (2017) demonstrate promising models for WAF.

The advantage of using a WRF profile is that the most relevant and most accurate WRF is selected based on the height of the flames, which is known to change over time and space and may be estimated via on-ground assessment or a flame height equation. Overall, the use of a WRF profile should reduce the error accumulated in fire spread model outputs.

A discrete WRF profile may be derived by measuring both the wind profile within a selected fuel type and the open wind speed in an open space above or near the fuel type. Securing a series of 3D sonic anemometers to a mast or tower installed at an appropriate location within the fuel is sufficient. All measurements may be averaged over a chosen time period and the final WRF profile may be obtained by taking the average WRF for each measured height.

FUEL ASSESSMENT REVIEW

Fuels may be assessed qualitatively and quantitatively. Qualitative assessment involves the selection and use of a fuel classification system, which categorises fuels into fuel types according to a set of criteria. For example, the Queensland classification system, described in Neldner et al. (2019) and currently used by fire behaviour analysts (FBANs) within Queensland Fire and Emergency Services (QFES), categorises fuels into Broad Vegetation Groups (BVGs) according to structural (cover, height and growth form), floristic (genus), biogeographic and landscape (landform and soil type) criteria.

Quantitative assessment involves the measurement and numerical expression of the spatial arrangement and structure of a fuel type. Common expressions or metrics include vegetation height, the average height of the canopy layer; diameter at breast height (DBH), the diameter of a tree trunk at 1.3m above the ground; and gap fraction, the fraction of hemispheric sky unobstructed by the vegetation, viewed from a single point (Wei et al. 2020). A Plant Area Density (PAD) profile is the most common expression of vertical fuel structure and/or density. PAD represents the one-sided collective vegetation element (leaf, stem, branch, etc.) area per unit volume of vegetation subcanopy space (Wei et al. 2020).

Input data for qualitative and quantitative assessment is obtained via field surveys and remote sensing methodologies. A field survey takes direct field measurements of the fuel via handheld instruments such as tape measures or takes indirect field measurements via optical handheld or ground-based instruments such as fisheye cameras and high-resolution smartphones (Escalante 2012). The latter is commonly referred to as hemispherical photography (HP). HP software and smartphone apps are designed to calculate the Plant Area Index (PAI) of a fuel type by calculating the gap fraction via the assignment of a pixel brightness threshold (Moon 2016). PAI is the integral of PAD over the vegetation height and represents the amount of one-sided collective vegetation element area per unit ground area (Wei et al. 2020). Currently, HP is primarily used in large-scale fuel assessment studies for the validation of remotely sensed measurements.

Remote sensing takes indirect measurements of the fuel, typically from a greater distance via airborne or satellite-based instruments (Escalante 2012). Common methods include LiDAR (Light Detection and Ranging) and photogrammetry. LiDAR is currently regarded as the standard method for three-dimensional fuel assessment, rapidly producing the highest level of detail and accuracy at all scales, uninhibited by the lighting requirements of optical methods. It involves directing laser pulses towards the fuel and measuring the differences in pulse return times to calculate relative distances and construct a three-dimensional point-cloud model of the fuel. However, high instrumentation costs, as well as the high level of technical expertise and computation power typically required for LiDAR processing has led to the popularisation of photogrammetry as an acceptable lower quality, more cost-effective alternative. Photogrammetry involves the transformation of a collection of photos, taken at different angles relative to the fuel, into a similar three-dimensional point-cloud model of the fuel. These photos may be taken on any optical device, from a specialised mounted camera to a high-resolution smartphone. A variety of commercial and free open-source point-cloud software and smartphone apps also exist.

Both LiDAR and photogrammetry are viable options for fuel assessment in a dynamic WRF profile context.

QUANTIFYING WRFS: QUEENSLAND WRF TEST SITE

The Queensland University of Technology (QUT) Samford Ecological Research Facility (SERF) located on the outskirts of Samford Valley, Southeast Queensland (Figure 2) was selected as the field site for the derivation of a dynamic WRF profile for the priority fuel type 'moist to dry eucalypt woodland on coastal lowlands and ranges' (MDEW) (Figure 3).

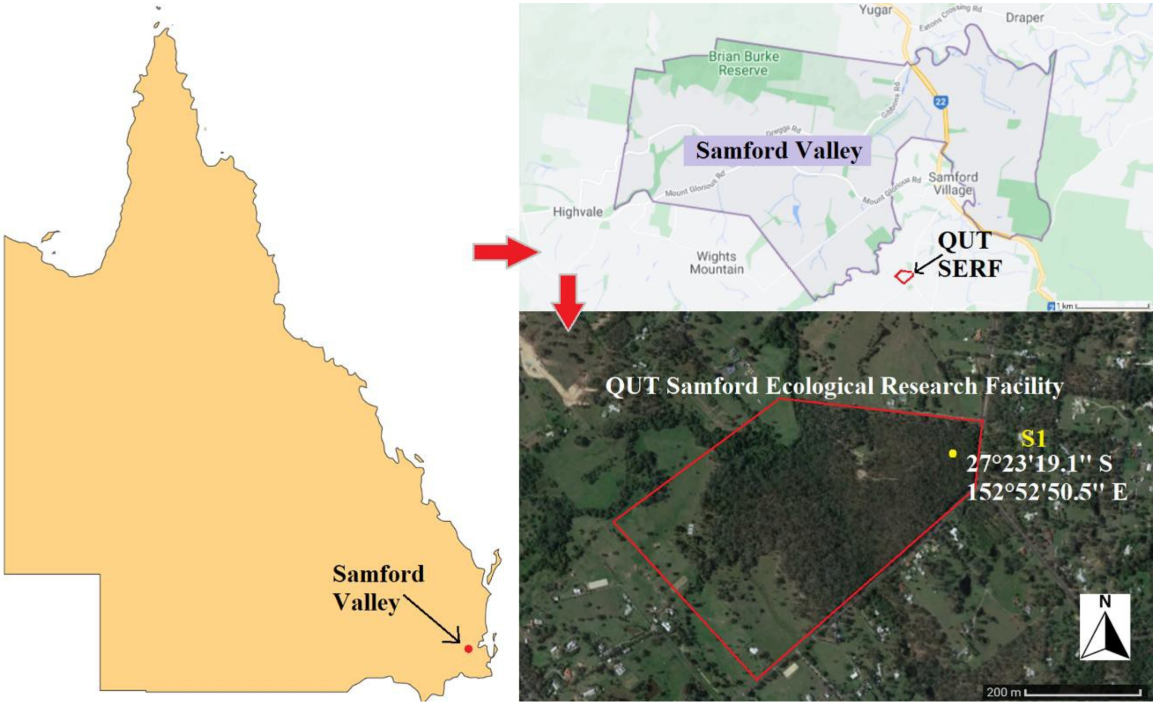

FIGURE 2: THE FIELD SITE (QUT SERF) OUTLINED IN RED AND THE MAST INSTALLATION SITE S1 MARKED BY THE YELLOW DOT (ADAPTED FROM GOOGLE MAPS 2021). COORDINATES WERE TAKEN USING A GARMIN ETREX 10 GPS.

FIGURE 3: A GROUND IMAGE OF THE FIELD SITE FUEL TYPE 'MOIST-DRY EUCALYPT WOODLAND ON COASTAL LOWLANDS AND RANGES'.

MDEW is a priority fuel type because it meets the following criteria: high flammability, rapid fuel accumulation rate, open fuel structure and close proximity to high value areas such as population centres, protected ecosystems and areas of key infrastructure and heritage. QUT SERF was selected as the field site because it was accessible and did not present any significant risks regarding instrument installation or maintenance. A secondary fuel type 'mesophyll to notophyll vine forest sparse' was identified in the western section of the field site and avoided.

A 15 m pneumatic tower was installed in the eastern section of the field site at S1, illustrated by the yellow dot in Figure 2. Four 3D sonic anemometers (R.M. Young 3D Ultrasonic 81000) were installed on the tower at heights of approximately 2 m, 4 m, 10 m and 15 m relative to the ground (Figure 4). Correcting for the 0.5 m distance from the base of the anemometer to the centre of the transducer section, the final measurement heights were 2.5 m, 4.5 m, 10.5, m and 15.5 m.

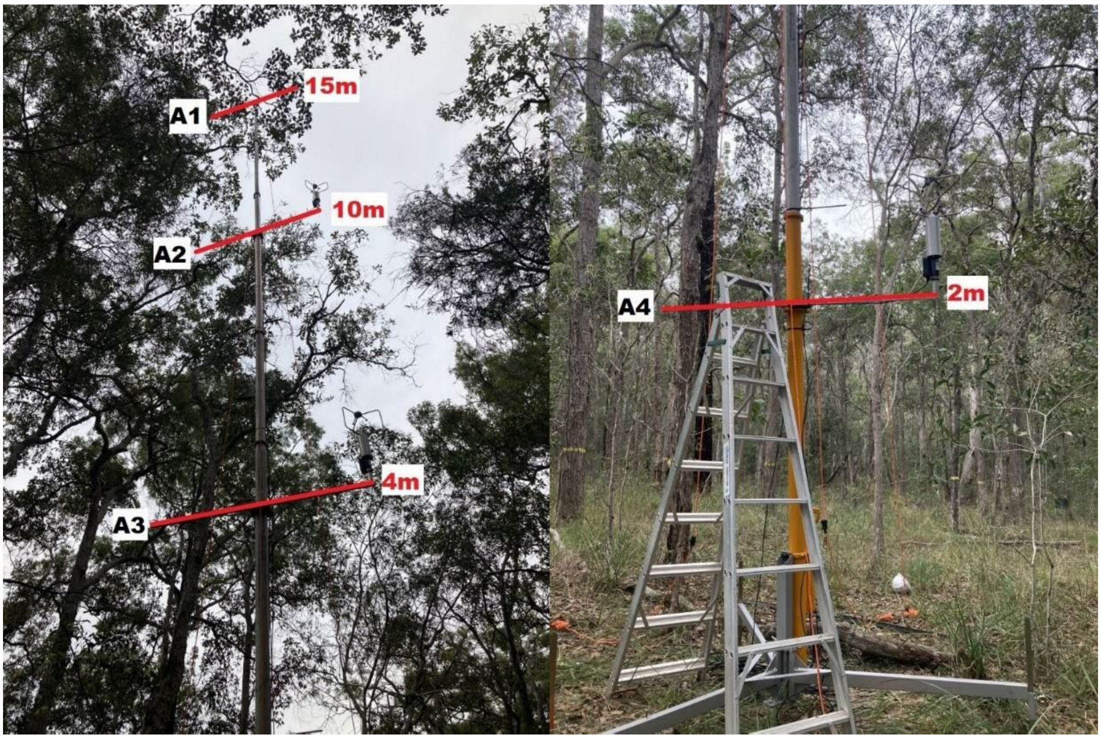

FIGURE 4: (LEFT) THE INSTALLATION HEIGHTS OF THE TOP THREE ANEMOMETERS (A1, A2, A3) AND (RIGHT) THE INSTALLATION HEIGHTS OF THE BOTTOM ANEMOMETER (A4). ADD 0.5M TO EACH FOR THE FINAL MEASUREMENT HEIGHTS.

The sonic anemometers measured mean 3D wind speed (m s^{-1}), vertical wind direction (°), and sonic air temperature (°C), from which subcanopy wind and temperature profiles were obtained. A radiometer (Kipp & Zonen CNR4 Net Radiometer) was also installed on a tripod to measure solar and terrestrial radiation transfers, from which surface and sky temperatures may be calculated. There is also potential to add additional instruments such as relative humidity sensors to the tower, if necessary.

Due to the inability of the tower to penetrate the canopy, open wind speed measurements were intended to be obtained from a flux tower located in an open field approximately 800 m from S1. However, due to time constraints, measurements were instead obtained from the nearest BOM AWS, which was the Brisbane City AWS (040913), located approximately 20 km from S1. Data collection from this distance is not ideal and may contribute to inaccuracies in WRF values.

Prior to tower installation, a three-dimensional point-cloud model of the fuel structure was generated for a square area (110 m x 110 m) surrounding S1 using a terrestrial LiDAR scanner (Riegl-VZ-400i). This area is illustrated in Figure 5. A subsection (10 m x 10 m) directly surrounding S1 is illustrated in Figure 6. A PAD profile was calculated from this subsection. There is also potential to calculate other metrics, including diameter at breast height and mean vegetation height, as well as to generate a Digital Elevation Model (DEM) of the field site, if necessary.

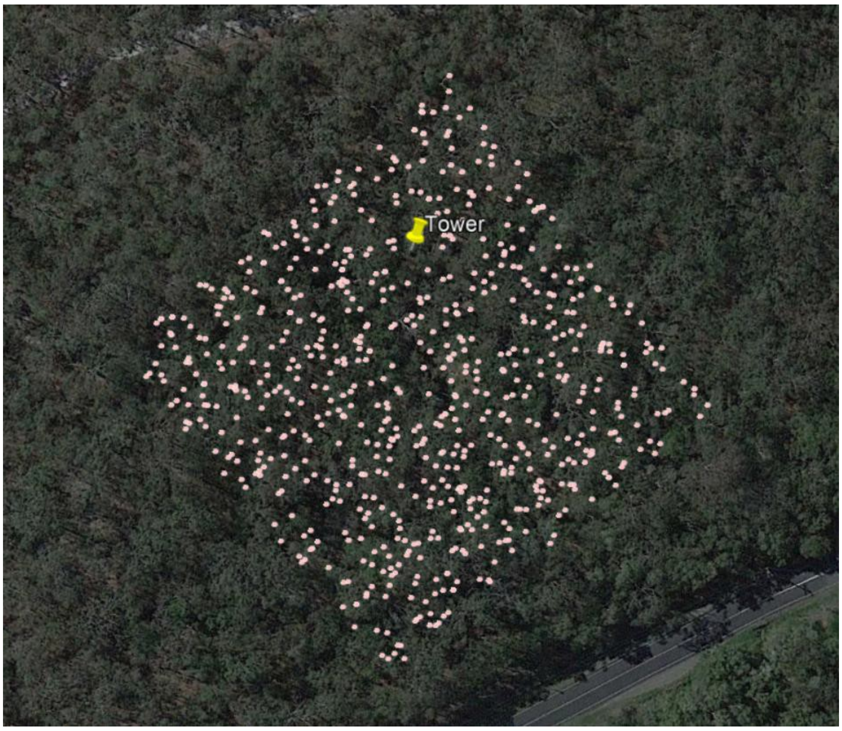

FIGURE 5: THE SQUARE AREA (110 M X 110 M) SURROUNDING THE TOWER POSITION, MARKED BY A YELLOW PIN. THE CREAM-COLOURED DOTS REPRESENT TREE POSITIONS.

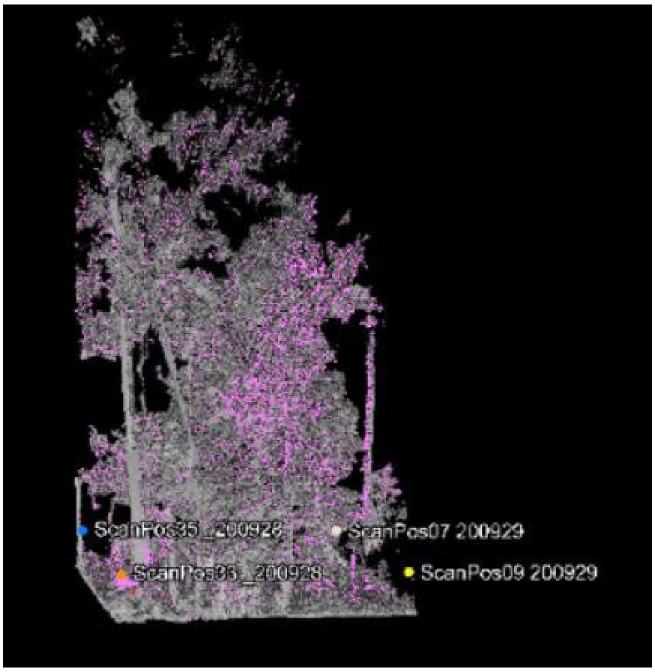

FIGURE 6: THE POINT-CLOUD SUBSECTION (10M X 10M) SURROUNDING THE TOWER LOCATION.

The results illustrated in Figures 7-11 were obtained using a 23-hour subsection of the data collected, averaged over 30-minute intervals. Figure 7 illustrates the discrete WRF profile. Dotted lines are drawn for visual clarity.

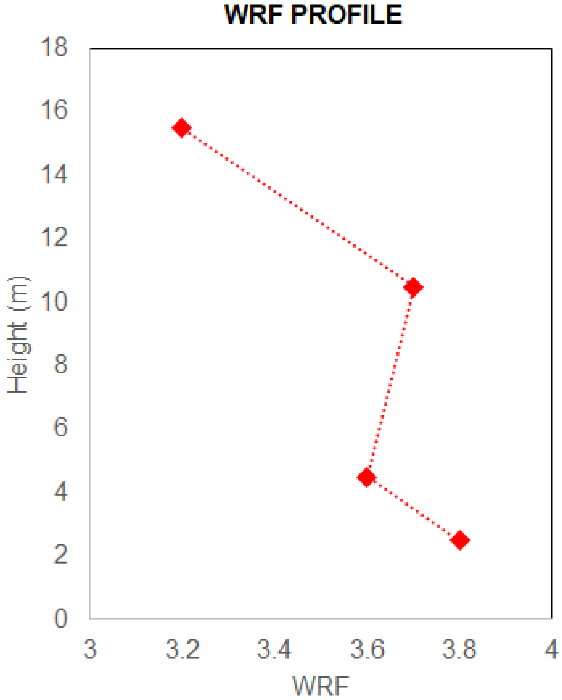

FIGURE 7: THE WRF PROFILE. THE PROFILE IS DISCRETE; DOTTED LINES ARE DRAWN BETWEEN VALUES FOR VISUAL CLARITY.

The WRF profile varies with height, although not as distinctly as in previous studies, namely Moon et al. (2013, 2016). This may be due to the calmer conditions and/or the short length of the data collection period. Data collection over a longer period under more varied conditions is recommended.

Figure 8 illustrates the subcanopy wind profile against the PAD profile to the maximum mean vegetation height (23 m). Outliers have been removed.

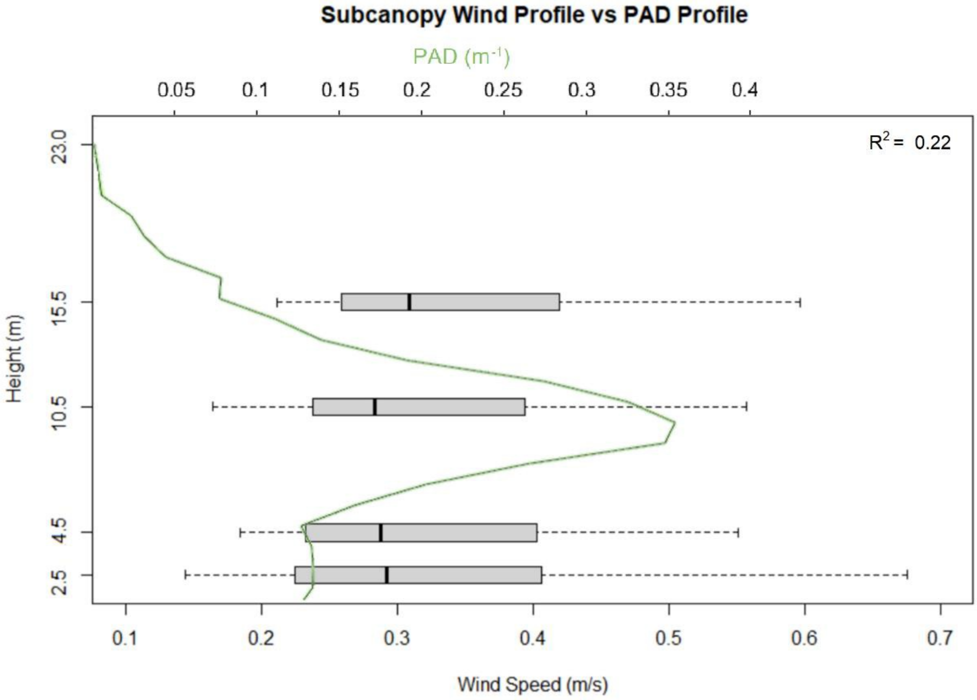

FIGURE 8: THE SUBCANOPY WIND PROFILE, GIVEN AS BOXPLOTS, VS THE PAD PROFILE, GIVEN AS A GREEN LINE.

Overall, 22% of the variance in mean wind speed is explained by PAD ($R^2 = 0.22$), which is a weak to moderate relationship. Distinct changes in the PAD profile do not clearly correspond with distinct changes in the wind profile, despite the inverse relationship between PAD and wind speed previously indicated by Moon et al. (2013, 2016). However, a comparison of the PAD profile with the WRF profile in Figure 9 may suggest a direct relationship between PAD and WRF; increased vegetation density may correspond to increased wind reduction. This result was also indicated by Moon et al. (2013, 2016). Nevertheless, data collection over a longer period under more varied conditions is recommended to investigate this relationship further.

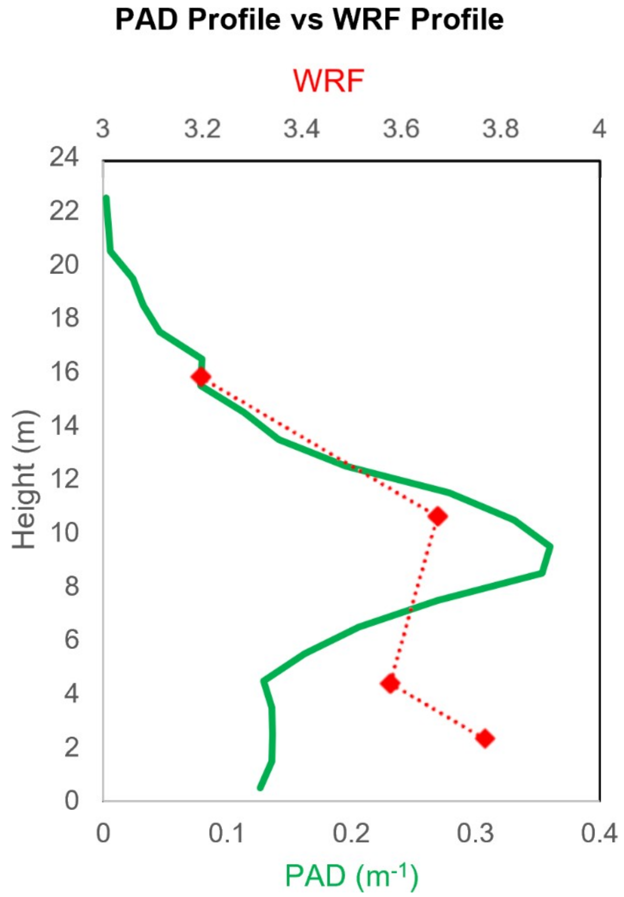

FIGURE 9: THE WRF PROFILE, GIVEN AS RED DIAMONDS CONNECTED BY DOTTED LINES, VS THE PAD PROFILE, GIVEN AS A GREEN LINE. THE WRF PROFILE IS DISCRETE; DOTTED LINES ARE DRAWN BETWEEN VALUES FOR VISUAL CLARITY.

Figures 10 and 11 illustrate the day-time and night-time subcanopy temperature profiles respectively. Values between sunrise and sunset are considered day-time temperatures, whereas values between sunset and sunrise are considered night-time temperatures.

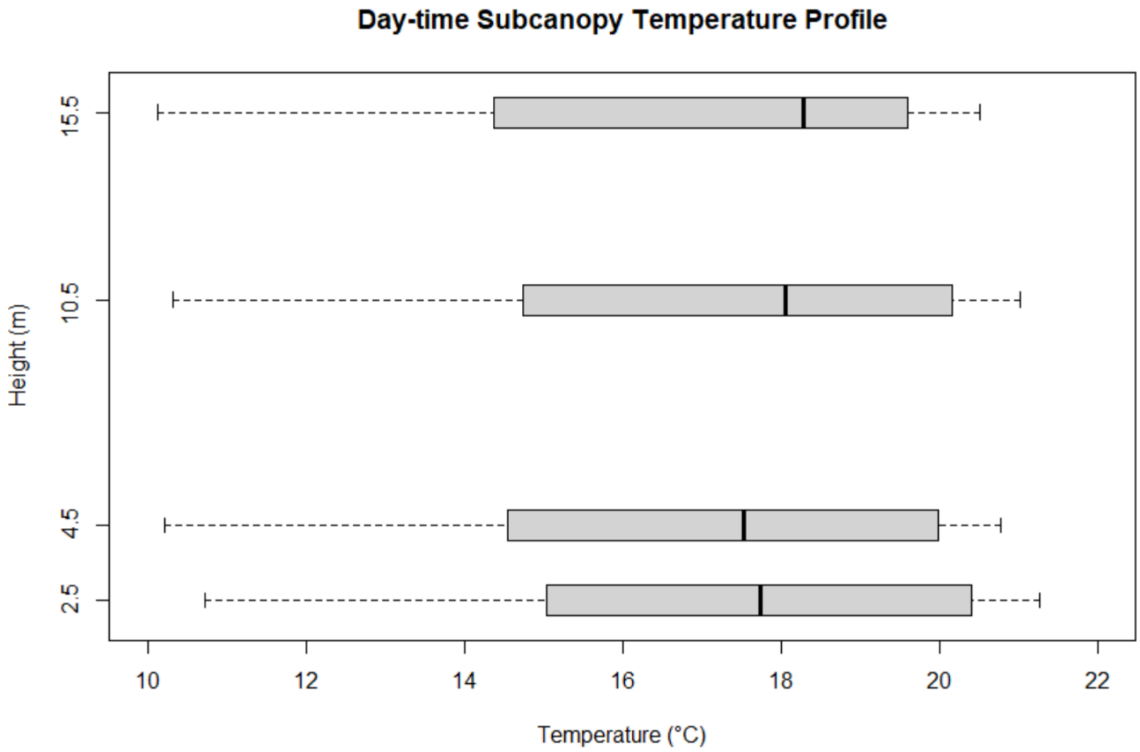

FIGURE 10: THE DAY-TIME SUBCANOPY TEMPERATURE PROFILE.

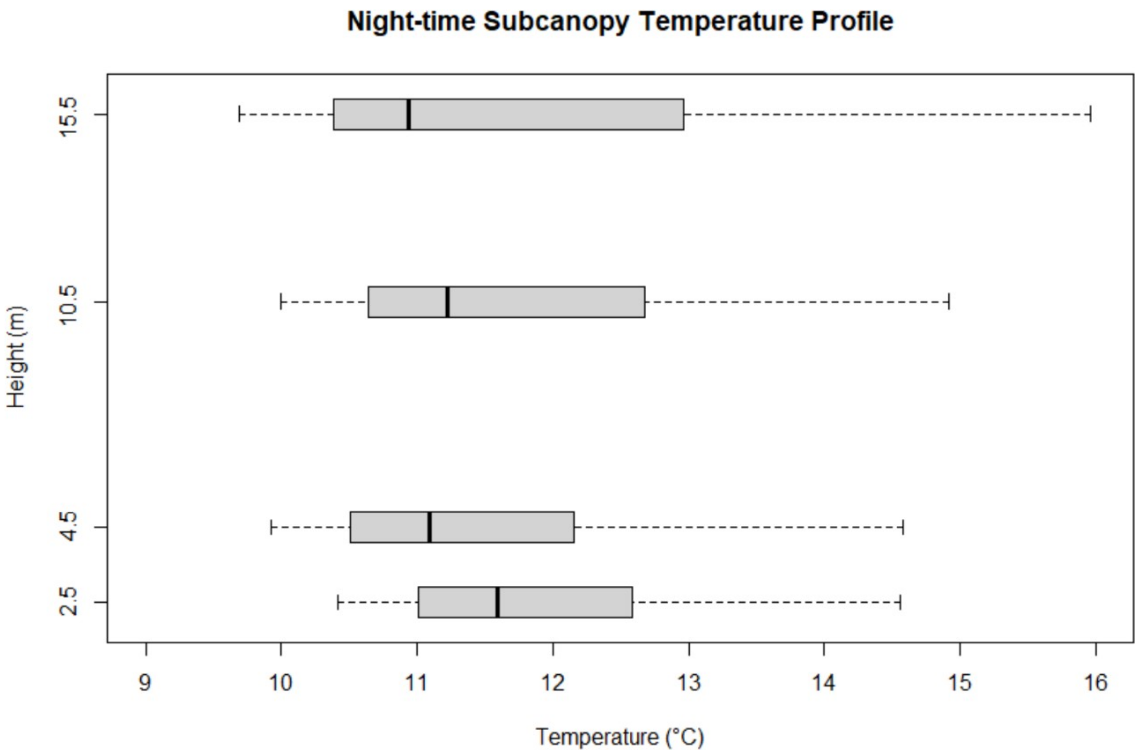

FIGURE 11: THE NIGHT-TIME SUBCANOPY TEMPERATURE PROFILE.

Day-time subcanopy temperatures are comparatively less varied with height than night- time subcanopy temperatures, which may indicate that the subcanopy environment is more mixed and turbulent throughout the day and more stratified at night. This relationship has been previously identified by Moon (2016) and is further supported by Figure 12, which illustrates a day- and night-time comparison of the mean angle of vertical mixing for each measured height.

The angle is measured from the horizontal plane. Overall, it indicates a consistent increase in vertical mixing throughout the day.

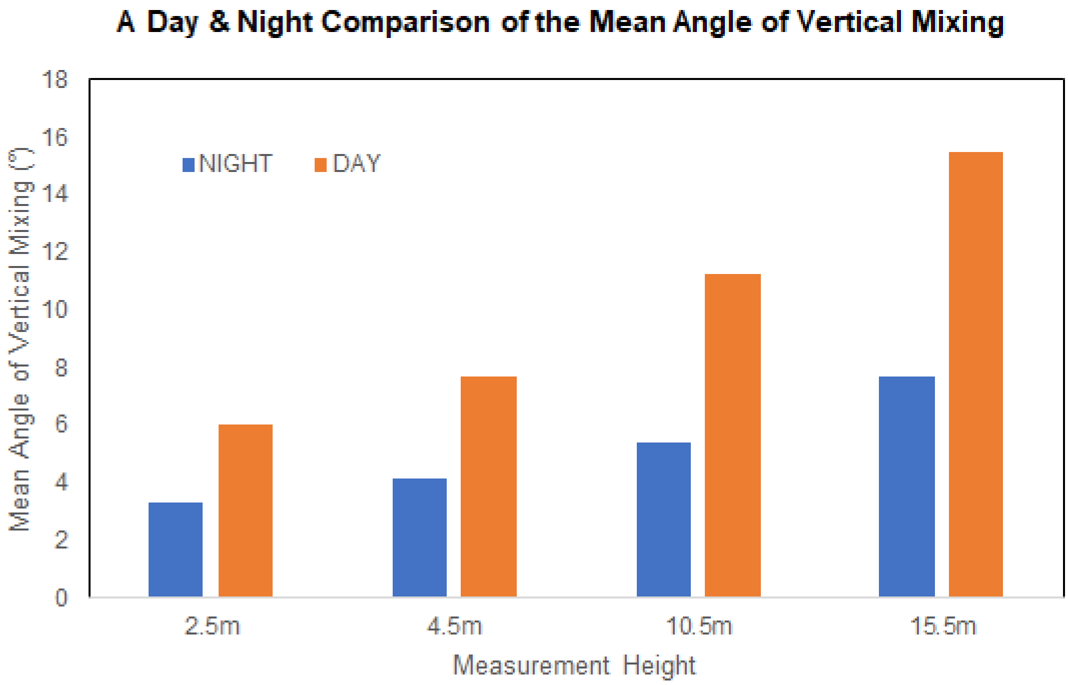

FIGURE 12: A DAY- AND NIGHT-TIME COMPARISON OF THE MEAN ANGLE OF VERTICAL MIXING FOR EACH MEASURED HEIGHT.

Nevertheless, data collection over a longer period under more varied conditions is recommended to investigate these relationships further.

UTILISATION AND IMPACT

SUMMARY

Understanding the influence of vegetation on wind speed is essential to enable accurate modelling of fire spread. To date, WRFs, which quantify the impact of vegetation on reducing the speed of the open space wind, have been approximated from simple field measurements recorded by handheld and fixed weather stations. Such WRFs are static, that is, a single WRF has been assigned to each fuel type with the assumption that wind speed is constant with height through the subcanopy environment.

However, the complexity of vegetation structure, atmospheric thermodynamics and topography means that the subcanopy wind speed profile is dynamic, changing distinctly with height, as well as between fuel types. As a result, the use of static WRFs has led to error accumulation in modelled fire spread. Error may be reduced through the use of a dynamic WRF model. The simplest model is a discrete, empirically based WRF profile, illustrating the change in WRF at specific heights measured by instrumentation installed in the field.

Here we have developed, applied, and continue to test methods to obtain discrete, empirically based WRF profiles for priority fuel types, as well as to obtain quantifications of vegetation structure, atmospheric thermodynamics and topography. Such methods are deemed suitable for application across Queensland and Australia and hence, may be standardised and applied at all future field sites.

The development of more advanced WRF models that output mathematically idealised, continuous WRF profiles is necessary but beyond the scope of this project at its current stage. The raw datasets collected at the Queensland WRF test site in Samford Valley may be used as key validation datasets for these models. Until such models are developed, a new quick-reference WRF profile assessment resource has been developed by this project to assist FBANs in their on-ground assessment and reporting of WRFs. This resource will continue to be developed in collaboration with QFES personnel with the aim of eventually making it available nationwide.

OUTPUT 1

Review of current Wind Reduction Factor knowledge

Output description

Literature Review – covering all current peer-reviewed information on the definition and derivation of WRFs and other equivalents (WAF and RWS).

Utilisation impact

The literature review provides essential background for the development of a dynamic WRF profile derivation method.

OUTPUT 2

Extended review of current fuel assessment technologies

Output description

Literature Review – covering all current peer-reviewed information on methods for the qualitative and quantitative assessment of fuels.

Utilisation impact

The literature review provides essential background for the development of a PAD profile derivation method, among other vegetation metric derivations. The use of Queensland Broad Vegetation Groups (BVGs) as a fuel classification system allows standardisation across Queensland government agencies and provides and a good level of resolution (25 m) for fire behaviour analysis, although other acceptable national classification systems are discussed. The use of LiDAR and photogrammetry as fuel quantification methods complements the current destructive sampling methods used by QFES for the quantification of fuel loads.

OUTPUT 3

Guidelines & example methodology to quantify dynamic Wind Reduction Factors

Output description

Technical Report – covering general WRF derivation guidelines with a detailed example method from the Southeast Queensland WRF test site.

Utilisation potential impact

The guidelines are intended for use by all future WRF field studies conducted in Australia to establish a standardised level of national consistency. The method used at the Queensland test site to quantify WRFs is transferable and will be applied to other sites containing other priority fuel types.

OUTPUT 4

Field guide to WRF assessment

Output description

Quick-reference WRF profile assessment resource – provides WRF and PAD profiles for two fuel types, as well as identification and discussion of variables that act as WRF drivers (fuel structure, open wind speed, temperature, topography and bushfire heat flux).

Utilisation potential impact

The WRF assessment resource enables FBANs near the fire ground to quickly identify the WRF values most relevant to the ensuing fire spread, which will lead to more accurate WRF reporting and fire spread prediction. The identification of WRF drivers provides FBANs with an overall awareness of how different environmental conditions will influence wind speed reduction, informing FBAN decision-making. The resource is designed to be modified as additional fuel types and drivers are investigated.

CONCLUSION & NEXT STEPS

The *Wind Speed Reduction Factors (WRFs): utilities for WRF assessment and communication* project was a collaboration between Queensland Fire and Emergency Services and the School of Earth and Environmental Sciences at the University of Queensland. The project has delivered comprehensive reviews of the current state of knowledge on the definition and quantification of WRFs, as well as the qualitative and quantitative assessment of fuels. The project has established a WRF test site near Brisbane using a methodology that can be applied to all Australian fuel types to obtain discrete WRF profiles, as well as other subcanopy meteorology and structural attribute data. The project has also delivered a new quick-reference WRF assessment resource for use by FBANs on the fire ground to support real-time reporting of WRFs to fire spread modellers.

Due to the very limited project timeframe (March – June 2021), direct measurements of WRFs were not able to be obtained at the test site under typical fire weather conditions. Hence, the WRF profile derived at the test site is preliminary. Furthermore, the accuracy of the WRF profile reflects the use of open wind speeds measured at the nearest Bureau of Meteorology station - a 20 km distance from the test site. Additional WRF test sites were also not able to be established within other priority fuel types. As a result, the project team plans to continue operating the test site through the southeast Queensland fire season (August – December 2021) and to establish an open wind speed tower closer to the test site. The team also plans to continue investigating opportunities to establish additional WRF test sites within other priority fuel types in Queensland, as well as the potential to develop more advanced WRF models. A priority will be to seek support for such research by offering new PhD projects.

PUBLICATIONS LIST

TECHNICAL REPORTS

1 Rosenthal, K. and McGowan, H. 2021: REVIEW OF CURRENT WIND REDUCTION FACTOR KNOWLEDGE. Unpublished report, The University of Queensland, Brisbane, Australia, 30p.
2 Rosenthal, K. and McGowan, H. 2021: EXTENDED REVIEW OF CURRENT FUEL ASSESSMENT METHODOLOGIES. Unpublished report, The University of Queensland, Brisbane, Australia, 25p.
3 Rosenthal, K. and McGowan, H. 2021: GUIDELINES & EXAMPLE METHODOLOGY TO QUANTIFY DYNAMIC WIND REDUCTION FACTORS. Unpublished report, The University of Queensland, Brisbane, Australia, 16p.

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END-USERS

End-user organisation	End-user representative	Extent of engagement
Queensland Fire and Emergency Services.	Dr Raymond Bott, Manager Predictive Services Unit QFES Community Resilience & Risk Mitigation Branch.	Approx. fortnightly discussions on project, provision of feedback following review project outputs, field meeting at WRF test site, planning for ongoing WRF review for Qld fuel types and establishment of new WRF test sites.
Queensland Fire and Emergency Services.	John Myles, Station Officer - Predictive Services Unit, Queensland Fire and Rescue.	Approx. fortnightly discussions on project, provision of feedback following review project outputs, provision of data, field meeting at WRF test site, planning for ongoing WRF review for Qld fuel types and establishment of new WRF test sites.

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