

FIRE NOTE

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PREDICTING WOODY FUEL CONSUMPTION: CAN EXISTING MODELS BE USED?



▲ Large downed woody fuel is a substrate for moss in Mt Field National Park, Tasmania.

SUMMARY

The ability to accurately predict woody fuel (*diameter* > 0.6 cm) consumption during a fire is important for both forest and fire management. Information on woody fuel consumption in Australian southern eucalypt forest fires is scant and the predictive capacity of existing models unknown.

The predictive capacity of five existing models was evaluated against a dataset representing a range of fire behaviour characteristics of prescribed burning conditions. Model evaluation statistics showed that the minimum level of error can be achieved by applying a simple model which assumes that 50% of the woody fuel load at a site is likely to be consumed under the majority of fuel and fire scenarios. The *CONSUME* Activity and Southern Woody models under-predicted observations while the *CONSUME* Western Woody model had very little bias and a good proportion of predictions (59%) within $\pm 10\%$ of the observed woody fuel consumption. The *BURNUP* model showed the greatest level of error when used with natural fuels. However, its performance improved when applied to heavy modified fuel loads resulting from clearcut operations.

ABOUT THIS FIRE NOTE

This *Fire Note* is a summary of a scientific manuscript in Volume 260 Issue 6 (pp. 948-961) of the journal *Forest Ecology and Management*. This work is part of Bushfire CRC Program A: Safe Prevention, Preparation and Suppression, and has been made possible due to partnerships with the CSIRO Bushfire Dynamics and Applications team, the Department of Environment and Conservation (Western Australia), the Department of Sustainability and Environment (Victoria) and the USDA Forest Service's Pacific Wildland Fire Sciences Laboratory in Seattle. The author of this *Fire Note*, Jennifer Hollis (right), is a PhD candidate at the University of NSW at ADFA and recipient of a Bushfire CRC scholarship. For more information about this research Jennifer can be contacted at Jennifer.Hollis@csiro.au



BACKGROUND

Woody fuels (also referred to as coarse woody debris) have an important ecological role within Australian forest ecosystems. Providing structural complexity and habitat on the forest floor, woody fuels are a source for nutrient cycling and a substrate for many organisms that depend on dead wood for their survival.

The consumption of woody fuel in forest fires contributes to:

- Total energy output and rate of heat release.
- Convection column development.
- Potential for re-ignition.
- Suppression/mop-up difficulty.
- The thermal and smoke environment to which firefighters are exposed.

Woody fuel consumption also impacts a variety of first and second order fire effects such as the degree of soil heating and tree mortality associated with the heating of tree boles and superficial roots. In the current context of climate change, when woody fuels are consumed it is essential to know what their contribution is to carbon sinks and greenhouse gas and smoke emissions.

Several models have been developed internationally that could improve both the understanding and prediction of woody fuel consumption in Australian southern eucalypt forests. These include: empirical models such as *CONSUME* (primarily developed using statistical relationships derived from measured woody fuel consumption data); process-based models using simulations of fundamental biological and physical relationships and processes such as Albin's early *Burnout* model; and combinations of both such as the *BURNUP* (semi-physical) model based on an improved and calibrated *Burnout* model.

▶ A prescribed fire ignites a log in the Tallarook State Forest. Will it continue to burn and if so, what proportion will be consumed? These questions may be answered using predictive models and this study aims to test the accuracy of some models using data collected in Australian southern eucalypt forests.



▶ More research is needed on woody fuel consumption in southern eucalypt forest fires.



HOW THE RESEARCH CAN BE USED: END USER STATEMENTS

“Understanding how and under what conditions woody fuels are consumed is a significant knowledge gap. Understanding woody fuel consumption is an important consideration in developing prescribed fire regimes intended to provide a diversity of habitat or to minimise the mobilisation of stored carbon and greenhouse gases. This work provides an insight into the current understanding of these processes and identifies relationships between fire intensity, fuel condition and woody fuel consumption in many of the forest fuels found in southern Australia.”

– **Rick Sneeuwjagt, Principal Fire Projects Officer, and Roger Armstrong, Senior Fire Planner, Department of Environment and Conservation, Western Australia**

“Woody fuel consumption research is very significant for forest and fire management agencies such as the Department of Sustainability and Environment. By identifying the accuracy of woody fuel consumption models, this research provides us with the ability to better understand and quantify the amount of carbon released as a result of fire and to identify potential savings. Identifying or developing a model for woody fuel consumption in Australia will help fire managers to better understand the total energy released from fires and potential consequences. It will also guide the development of prescribed burn prescriptions that enable the protection of coarse woody debris habitat that many plants and animals rely on.”

– **Alen Slijepcevic, Assistant Chief Officer Capability, Department of Sustainability and Environment, Victoria**

BUSHFIRE CRC RESEARCH

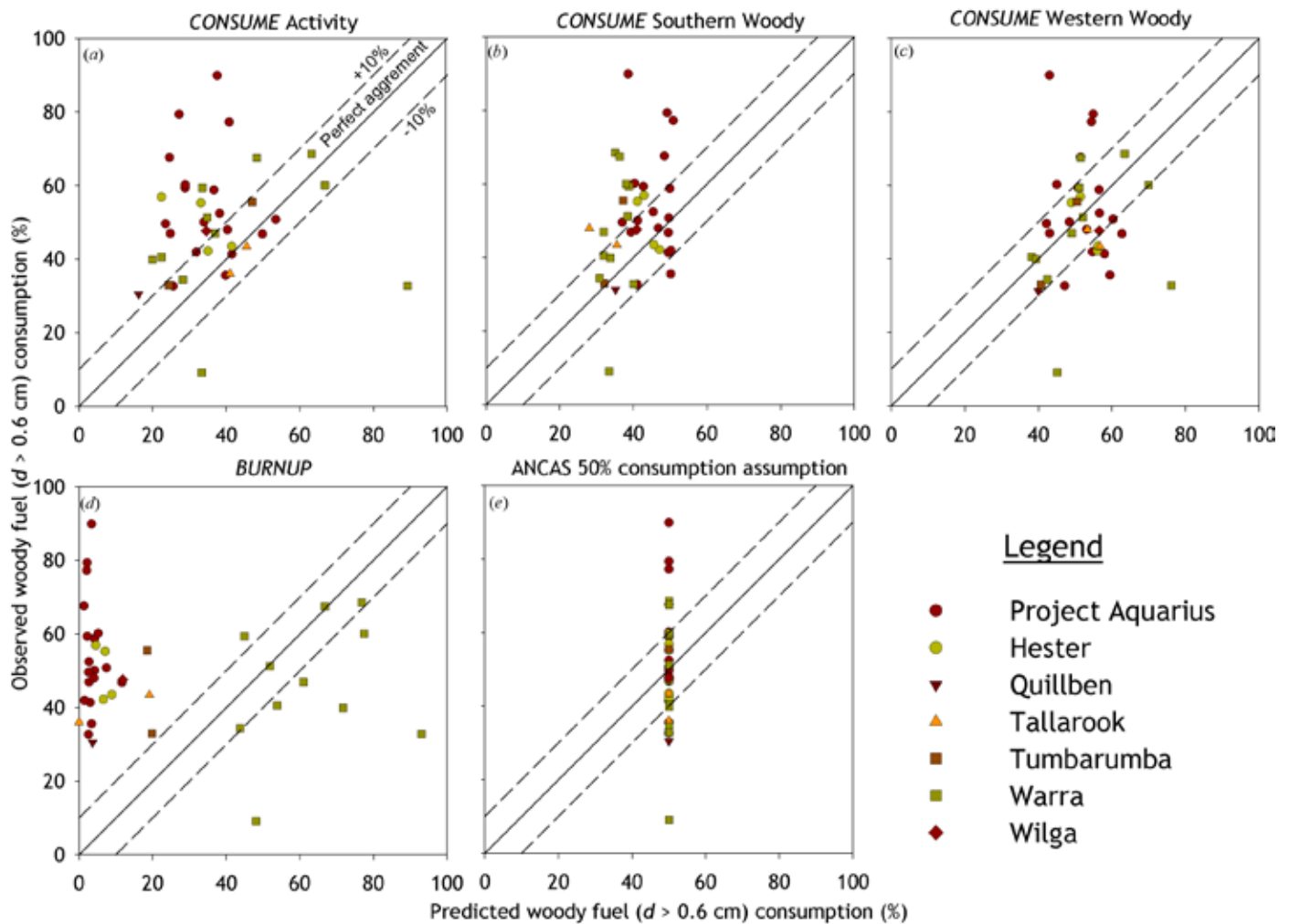
The predictive capacity of the following five models is evaluated using woody fuel consumption data collected throughout southern Australian eucalypt forests:

1. *CONSUME* Activity.
2. *CONSUME* Western Woody.
3. *CONSUME* Southern Woody.
4. *BURNUP*.
5. Australian National Carbon Accounting System (ANCAS) recommended 50%.

Field data was collected at Wilga, Hester and Quillben blocks in south-west Western Australia and at Tallarook in northern-central Victoria. To increase variability within the data analysed, data was also sourced from McCorkhill block in Western Australia (collected as part of Project Aquarius), Tumberumba in New South Wales and the Warra Long Term Ecological Research site in Tasmania.

RESEARCH OUTCOMES

Model performance varied when compared against observations of woody fuel



▲ Predicted versus observed woody fuel consumption for (a) CONSUME Activity, (b) CONSUME Southern Woody (c) CONSUME Western Woody, (d) BURNUP and (e) ANCAS assumption of 50% for site woody fuel consumption.

consumption in Australian southern eucalypt forests. Model evaluation indicates that the minimum level of error can be achieved by applying a simple model that assumes 50% of the woody fuel load at a site is likely to be consumed under the majority of fuel and fire scenarios. While this simple model can be easily interpreted and applied by forest and fire managers, the assumption fails to capture extremes in woody fuel consumption. The CONSUME Activity and Southern Woody models under-predicted observations, while the CONSUME Western Woody model had little bias, with 59% of predictions within $\pm 10\%$ of the observed woody fuel consumption.

The BURNUP model showed the greatest overall level of error when used with natural fuels. However, its performance improved when applied to heavy, modified fuel loads resulting from clear-cut operations.

These model evaluation results should be interpreted with care. The results are based on a dataset where woody fuel consumption is highly variable (ranging between 9 and 90%), limited to relatively low to moderate

Table 1: Comparison of model error for site woody fuel consumption (%).

	MAE	MBE	RMSE	MAPE
CONSUME Activity	18.20	13.07	23.35	40.40
CONSUME Southern Woody	13.61	9.27	17.23	30.06
CONSUME Western Woody	12.11	-1.94	16.13	33.18
BURNUP (All data except Warra)	45.16	45.16	47.96	86.99
BURN-UP (Warra Data)	19.03	-16.28	25.63	77.49
ANCAS Woody Fuel Consumption = 50% of Fuel Load	11.15	0.12	14.86	31.87

MAE: mean absolute error; MBE: means bias error; RMSE: root mean square error; MAPE: mean absolute percentage error.

intensity and mostly prescribed burning conditions. The CONSUME and BURNUP models were developed for North-American conifer forests. Fundamental differences in fuel particle characteristics (e.g. decay) and fuel-bed structure exists between these conifer forests and the eucalypt forests used in this study. This might make the models

not fully applicable to Australian forests. Another issue regards whether woody fuel consumption in Australian southern eucalypt forest fires, particularly prescribed burns, is so variable that the development of an improved model would require an alternative approach that considers distinct, underlying processes.

FUTURE DIRECTIONS

Further research is required to improve our understanding of the determinant variables and physical processes influencing woody fuel consumption in southern eucalypt forest fires. Such research requires additional data, particularly representing fires burning under higher fire potential and intensities.

The next stage in the woody fuel consumption project includes the development of an empirical model based on Australian field data. This model will subsequently require testing against CONSUME, BURNUP and ANCAS models to assess predictive capacity and determine the most accurate model suitable for application in Australian southern eucalypt forest fires.

REFERENCES/ FURTHER READING

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WHAT AFFECTS WOODY FUEL CONSUMPTION?

Fire can significantly modify woody fuel structure and volume with outcomes that vary greatly between forest types, fuel complex structures and the conditions under which they are burnt (e.g. season, weather and ignition patterns). When observed fuel consumption data was analysed against the primary drivers of the CONSUME and BURNUP models, results showed there was little correlation with any of the variables tested. In fact, the best relationship explained only 10% of the variation in consumption outcomes (as determined by the largest R^2). This result suggests that no simple linear regression relationships exist with primary model drivers. On top of this, many of the variables reported to affect woody fuel consumption are auto-correlated and so development of an improved model will require an alternative approach, possibly considering the distinct underlying processes determining consumption.



▲ Fire engulfs a large, decayed marri log, slowly consuming the log and leaving only an ash bed at Hester block in south-west Western Australia.



▲ In a collaborative research effort, a camera records the consumption of a large, decayed marri log in an effort to study the variables that affect woody fuel consumption as part of the woody fuel consumption project.

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