STANDING COMMITTEE ON AGRICULTURE AND WATER RESOURCES

INQUIRY INTO THE IMPACT ON THE AGRICULTURAL SECTOR OF VEGETATION AND LAND MANAGEMENT POLICIES, REGULATIONS AND RESTRICTIONS

PUBLIC HEARING

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CSIRO - QUESTIONS ON NOTICE

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1. **QUESTION 1 - CSIRO uses controlled experiments that model the effects of air temperature, wind speed, humidity and fuel condition to investigate the behaviour of fire scenarios-**
    a. **Has there been any modelling/experiments done where only fuel conditions are varied (fire with minimal fuel scenario and then fire with maximum fuel)?**
    b. **If so, have comparisons been analysed and were there any surprising findings?**
    c. **Is there any data or reports produced from these experiments?**

a) There have been several experimental programmes conducted by CSIRO over the past two decades in many parts of the country with the objective of quantifying the effect of fuel arrangement (amount, structure, condition) on the behaviour of free-burning fires, all in conjunction with the local fire authority or land management agency. These include the Dry Eucalypt Fire (Project Vesta) experiments (1998-2001) conducted in dry eucalypt forests in south-west Western Australia (Gould et al 2007, Gould et al 2011, McCaw et al. 2012, Cheney et al. 2012), the Mallee-Heath project (2006-2008) in south-east South Australia (Cruz et al. 2010, Anderson et al. 2015), the Grassland Curing project (2012-2016) conducted in improved pasture in Victoria, New South Wales and Queensland (Cruz et al. 2015), the Grassland Fuel Load project (2015-2017) utilising the same set of experiments as the Grassland Curing project plus additional experiments conducted in south-east Queensland (Cruz et al. 2018) and our current project in Victoria investigating fire behaviour in croplands under different harvesting regimes.

   These experimental programs formed the basis for the reformulation of fire behaviour models currently used in Australia to support decision making during bushfire incidents, fire danger rating and risk analysis. Other related work that we have undertaken has highlighted the importance of management of bushfire fuels for suppression effectiveness, with fires burning in areas with higher fuel hazards to be more likely to escape containment efforts than those burning in recently burned areas (Plucinski 2012, Plucinski et al. 2012).

b) In the Project Vesta experiments (a joint project between CSIRO and WA Conservation and Land Management (now WA Department of Biodiversity, Conservation and Attractions) and supported by all state and territory fire authorities and land management agencies), the arrangement and amount of forest understorey fuel was manipulated using judicial application of spring and autumn prescribed burning conducted over a number of years to produce a range of fuel ages within the same forest at the time of burning. The range of fuel ages (time since last fire) ranged from 2 to 20 years. Simultaneous fires in each fuel age (up to five fires) were carried out to ensure the same atmospheric burning conditions for each fire such that the only variable was the state of the fuel.

The results of these experiments showed that the speed of a fire is directly related to the characteristics of understorey fuel layers, particularly the surface and near surface strata but only weakly related to surface fuel load alone. It was found that the near-surface fuel layer was the main layer responsible for determining a fire's rate of spread. The accumulation of fuel in these layers was found to increase with fuel age. The immediate effects of prescribed burning on fire behaviour can last up to about 7-15 years after application, depending on local fuel structure and dynamics.

The Mallee-Heath project investigated the effect of fuel age on fire behaviour through changes in fuel structure and availability. Rather than manipulating the fuel directly, locations within the Ngarkat Conservation Reserve were selected for burning based on the time since last fire. This project found that the forest fire model used to predict fire danger and propagation in semi-arid vegetation under-predicted the propagation of fires. A new model for fire propagation considering fire sustainability and the occurrence of crowning was proposed. This model is now used operationally in supporting fire management and suppression operations.

The Grassland Curing Project and Grassland Fuel Load project utilised a similar methodology in which improved pastures were manipulated to produce a range of curing states (curing is the relative amount of dead material found in a grass sward). By carrying out the experiments at different sites across eastern Australia, differing species and differing fuel structure was obtained. The fuel loads studied in these experiments ranged from 1.5 t/ha to 10 t/ha. Simultaneous fires were conducted at each of site to provide the same environmental conditions with only the fuel state differing. The project found that the implemented effect of curing was leading to a substantial under prediction of the speed a fire travels in the landscape. A revised curing function was developed (Cruz et al. 2015) and is currently being implemented in fire danger and behaviour prediction systems in Australia.

In a spin off analysis of these datasets, CSIRO bushfire researchers assessed the impact of fuel load on rate of spread, a contentious operational issue leading to potentially erroneous results and eroded trust in fire danger rating. Analysis showed that, contrary to certain ingrained beliefs, fuel load in grasslands is negatively related to fire rate of spread, with higher fuel loads resulting in slower fires (Cruz et al. 2018). This result confirmed earlier findings (Cheney et al. 1993) that the effect of fuel load on rate of fire spread only becomes significant beyond a value of approximately 5 t/ha. Between 1.5 and 5 t/ha, there is no significant effect of fuel load on rate of spread. New models for fire spread and flame dimensions (used for calculating radiative impact and suppression effectiveness) were developed from this research.

c) See the following reports and journal articles for more details of the experiments and results:

Dry Eucalypt fire (Project Vesta)

Cheney NP, Gould JS, McCaw WL, Anderson WR (2012) Predicting fire behaviour in dry eucalypt forest in southern Australia. *Forest Ecology and Management* 280, 120–131. doi:10.1016/j.foreco.2012.06.012.

Gould JS, McCaw WL, Cheney NP (2011) Quantifying fine fuel dynamics and structure in dry eucalypt forest (Eucalyptus marginata) in Western Australia for fire management. *Forest Ecology and Management* 262, 531–546.

Gould JS, McCaw WL, Cheney NP, Ellis PF, Knight IK, Sullivan AL (2007) '*Project Vesta–Fire in Dry Eucalypt Forest: fuel structure, dynamics and fire behaviour*.' (Ensis-CSIRO, Canberra ACT, and Department of Environment and Conservation, Perth WA: Canberra, ACT)

Gould JS, McCaw WL, Cheney NP, Ellis PF, Matthews S (2007) '*Field Guide: Fire in Dry Eucalypt Forest*.' (Ensis-CSIRO, Canberra ACT, and Department of Environment and Conservation, Perth WA)

McCaw LW, Gould JS, Cheney NP, Ellis PFM, Anderson WR (2012) Changes in behaviour of fire in dry eucalypt forest as fuel increases with age. *Forest Ecology and Management* 271 , 170–181. http://www.sciencedirect.com/science/article/pii/S0378112712000722.

Mallee-Heath

Anderson WR, Cruz MG, Fernandes PM, McCaw L, Vega JA, Bradstock RA, Fogarty L, Gould J, McCarthy G, Marsden-Smedley JB, Matthews S, Mattingley G, Pearce HG, van Wilgen BW (2015) A generic, empirical-based model for predicting rate of fire spread in shrublands. *International Journal of Wildland Fire* 24, 443–460. http://dx.doi.org/10.1071/WF14130.

Cruz MG, McCaw WL, Anderson WR, Gould JS (2013) Fire behaviour modelling in semi-arid mallee-heath shrublands of southern Australia. *Environmental Modelling & Software* 40, 21–34. doi:10.1016/j.envsoft.2012.07.003.

Cruz MG, Matthews S, Gould J, Ellis PF, Henderson M, Knight I, Watters J (2010) Fire dynamics in Mallee-heath: Fuel, weather and fire behaviour prediction in South-Australian semi-arid shrublands. Bushfire CRC, No. A.10.01. (Melbourne, Vic.)

Grass curing

Cruz MG, Gould JS, Kidnie S, Bessell R, Nichols D, Slijepcevic A (2015) Effects of curing on grassfires: II. Effect of grass senescence on the rate of fire spread. *International Journal of Wildland Fire* 24, 838–848. doi:10.1071/WF14146.

Cruz MG, Kidnie S, Matthews S, Hurley RJ, Slijepcevic A, Nichols D, Gould JS (2016) Evaluation of the predictive capacity of dead fuel moisture models for Eastern Australia grasslands. *International Journal of Wildland Fire* 25, 995–1001. doi:10.1071/WF16036.

Cruz MG, Gould JS, Sullivan AL (2013) Laboratory experiments to assess the effect of curing level in the behaviour of free spreading grass fires. CSIRO Ecosystem Sciences/Climate Adaptation Flagship Client Report No. EP137919. (Canberra, ACT).

Grass fuel load

Cruz MG, Sullivan AL, Gould JS, Hurley RJ, Plucinski MP (2018) Got to burn to learn: the effect of fuel load on grassland fire behaviour and its management implications. *International Journal of Wildland Fire* 27, 727–741. doi:10.1071/WF18082.

Cruz M, Sullivan A, Hurley R, Plucinski M, Gould J (2017) The effect of fuel load and structure on grassland fire behaviour and fire danger. CSIRO Land and Water, EP178976. (Canberra, ACT).

Other fuel related works

Cruz MG, Alexander ME, Plucinski MP (2017) The effect of silvicultural treatments on fire behaviour potential in radiata pine plantations of South Australia. *Forest Ecology and Management* 397, 27–38. doi:10.1016/j.foreco.2017.04.028.

Plucinski, MP (2012) Factors affecting containment area and time of Australian forest fires featuring aerial suppression. *Forest Science* 58, 390-398.

Plucinski, MP, McCarthy, GJ, Hollis, JJ, Gould, JS (2012) The effect of aerial suppression on the containment time of Australian wildfires estimated by fire management personnel. *International Journal of Wildland Fire* 21, 219-229.

Sullivan AL, Surawski NC, Crawford D, Hurley RJ, Volkova L, Weston CJ, Meyer CP (2018) Effect of woody debris on the rate of spread of surface fires in forest fuels in a combustion wind tunnel. *Forest Ecology and Management* 424, 236–245. doi:10.1016/j.foreco.2018.04.039.

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2. **QUESTION 2 - Could you give insight into the $119 million savanna burning projects, part of Emissions Reduction activity, mentioned in your submission? Also, how has that activity affected water runoffs into areas like the Great Barrier Reef? Does the risk assessment for these reduction burns counter runoff damage and how is this quantified?**

Over the past five years, CSIRO has worked with the Department of the Environment and Energy (DoEE), Charles Darwin University and the Tiwi Land Council to develop approaches to add carbon sequestration to the emissions reduction methodologies and to support Indigenous communities' participation in carbon farming.
This work enabled the DoEE to develop new methodologies that included both emissions abatement and carbon sequestration, and to produce new emissions abatement methodologies based on more robust science. These methodologies were released in May 2018.
Savanna fire management Emissions Avoidance methods (which have drawn on earlier work by CSIRO and partners) applied in 78 project areas have been associated with 54 per cent of high rainfall savannas (>1000 mm rainfall) and 11 per cent of semi-arid savannas (600-1000 mm) being under carbon farming projects. The savanna zone in total comprises 15 percent of the Australian continent. To date over 4 million Australia Carbon Credit Units (ACCU) have been issued and 13.8 million Credit Units contracted. The issued Credits represent 9 per cent of all Carbon Credits issued under the ERF. Average prices per ACCU of about $10-$12 have created a new business opportunity for remote landholders in northern Australia. The addition of carbon sequestration to the Emissions Avoidance calculations could see a trebling in the value of this work in terms of both GHG benefit and cash value. An independent assessment by consultants ACIL Allen has estimated the net present value of the benefits of the Savanna management project to be $119.47 million.

Although we have studied the effect of fire on erosion, it is problematic to isolate the unique effect of fire on erosion, relative to the effect of vegetation cover on erosion, since fire occurs in a vegetation-specific context. For example fire-induced erosion may be of reduced severity in the absence of trees but without trees other causes of erosion may results in higher erosion rates. Thus we cannot directly attribute the consequences of changed fire behaviour related to Emissions Reduction activity to water runoff.

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3. **QUESTION 3 - Your submission mentions your ability to study past fires and experimentally model air temperature, wind and fuel conditions to inform trajectories and**

impacts of future fires. How often is this capability accessed by state, territory and local governments, and how can this be accessed to inform better fuel–reduction burns in the future?

CSIRO has a long history of not just undertaking experimentally-based fire research but also developing tools and technology to put the science generated and other learnings created into operational practice in collaboration with state governments and relevant agencies.

CSIRO takes the task of operational prediction of the behaviour and spread of fires by fire authorities and land management agencies very seriously and it forms the foundation of our bushfire behaviour research and research publication strategies.

Our collaboration with state governments and relevant agencies includes contributing to on-going training of fire behaviour specialists within fire agencies, publication of general textbooks for lay readers (e.g. '*Grassfires*' book by Cheney and Sullivan 1997, 2008), general guides and meters for operational staff (Gould et al. 2007b, Cruz et al. 2010, CSIRO 2018), and summaries of fire behaviour models for operational use (Cruz et al. 2015a, 2015b, 2018). CSIRO also publishes and makes available on-line a regular bushfire science bulletin called the CSIRO Pyropage that details the latest published findings on fire behaviour related research. It can be found at https:\\research.csiro.au\pyropage.

The results of our research is used in a variety of forms for not just predicting the behaviour and spread of going wildfires but often also in agency-built tools for assessing hazard and risk of bushfires in a variety of settings for the purpose of prioritising hazard reduction. CSIRO has built software designed for fire behaviour specialists that incorporate the latest knowledge on bushfire behaviour science. These include the decision support and knowledge base software Amicus (Sullivan et al. 2013, Plucinski et al. 2017) and the Spark bushfire spread simulation framework (Hilton et al. 2015, Miller et al. 2015).

References and examples of other knowledge transfer publications:

Cheney P, Sullivan A (1997) '*Grassfires: Fuel, Weather and Fire Behaviour*.' CSIRO Publishing: Collingwood, Australia. Second edition published 2008.

Cruz MG, Alexander ME, Sullivan AL, Gould JS, Kilinc M (2018) Assessing improvements in models used to operationally predict wildland fire rate of spread. *Environmental Modelling & Software* 105, 54–63. doi:10.1016/j.envsoft.2018.03.027.

Cruz MG, Gould JS, Alexander ME, Sullivan AL, McCaw LM, Matthews S (2015a) '*A Guide to Rate of Fire Spread Models for Australian Vegetation'.* (AFAC Ltd: Melbourne, Vic)

Cruz MG, Gould JS, Alexander ME, Sullivan AL, McCaw WL, Matthews S (2015b) Empirical-based models for predicting head-fire rate of spread in Australian fuel types. *Australian Forestry* 78, 118–158. doi:10.1080/00049158.2015.1055063.

Cruz MG, Sullivan AL, Gould JS, Sims NC, Bannister AJ, Hollis JJ, Hurley RJ (2012) Anatomy of a catastrophic wildfire: The Black Saturday Kilmore East fire in Victoria, Australia. *Forest Ecology and Management* 284, 269–285. doi:10.1016/j.foreco.2012.02.035.

Cruz MG, Sullivan AL, Leonard R, Malkin S, Matthews S, Gould JS, McCaw WL, Alexander ME (2014) *Fire Behaviour Knowledge in Australia: A synthesis of disciplinary and stakeholder knowledge on fire spread prediction capability and application*. CSIRO Ecosystem Sciences, EP145189.

CSIRO (2018) CSIRO Grassland Fire Spread Meter Mk 2. Sandleford Holdings Pty Ltd.

Plucinski MP, Sullivan AL, Rucinski CJ, Prakash M (2017) Improving the reliability and utility of operational bushfire behaviour predictions in Australian vegetation. *Environmental Modelling & Software* 91, 1–12. doi:10.1016/j.envsoft.2017.01.019.

Sullivan AL, Gould JS, Cruz MG, Rucinski C, Prakash M (2013) Amicus: a national fire behaviour knowledge base for enhanced information management and better decision making. In: Piantadosi J, Anderssen RS, Boland J (eds) '*MODSIM2013, 20th International Congress on Modelling and Simulation*', pp 2068-2074.

Sullivan AL (2017a) Inside the Inferno: Fundamental processes of wildland fire behaviour. Part 1: Combustion chemistry and energy release. *Current Forestry Reports* 3, 132–149. doi:10.1007/s40725-017-0057-0.

Sullivan AL (2017b) Inside the Inferno: Fundamental processes of wildland fire behaviour. Part 2: Heat transfer and interactions. *Current Forestry Reports* 3, 150–171. doi:10.1007/s40725-017-0058-z.

Sullivan AL, Matthews S (2013) Determining landscape fine fuel moisture content of the Kilmore East 'Black Saturday' wildfire using spatially-extended point-based models. *Environmental Modelling & Software* 40, 98–108. doi:10.1016/j.envsoft.2012.08.008.

Sullivan AL, McCaw WL, Cruz MG, Matthews S, Ellis PF (2012) Fuel, fire weather and fire behaviour in Australian ecosystems. '*Flammable Australia: Fire Regimes, Biodiversity and Ecosystems in a Changing World*'. (Eds RA Bradstock, AM Gill, RD Williams). pp. 51–77. (CSIRO Publishing: Collingwood, Vic)

Sullivan AL, Sharples JJ, Matthews S, Plucinski MP (2014) A downslope fire spread correction factor based on landscape-scale fire behaviour. *Environmental Modelling & Software* 62, 153–163. doi:10.1016/j.envsoft.2014.08.024.