Greenhouse gas emissions from fire and their environmental effects

Fire in the Landscape (Carbon)

FACULTY OF AGRICULTURE
& ENVIRONMENT

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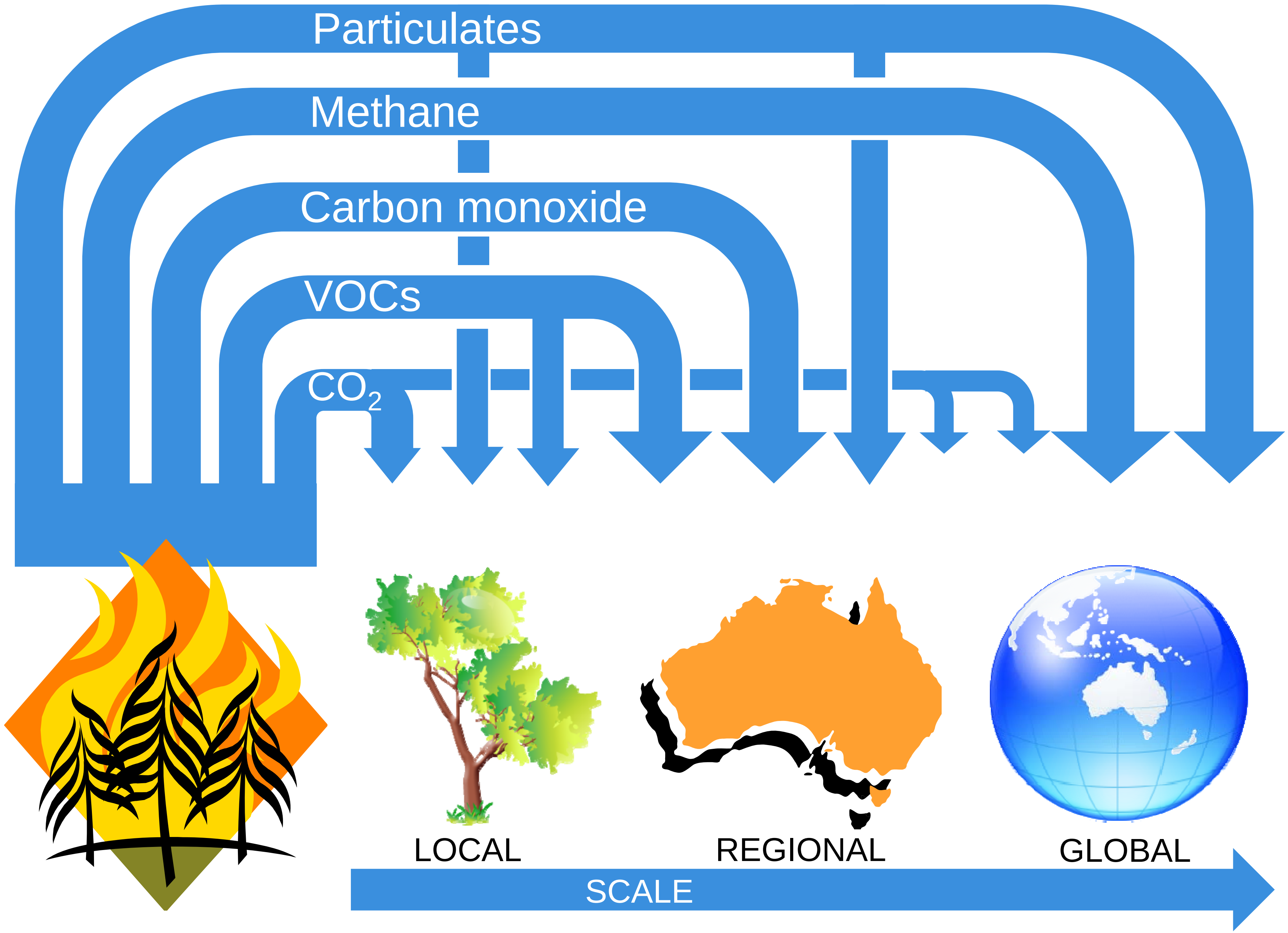
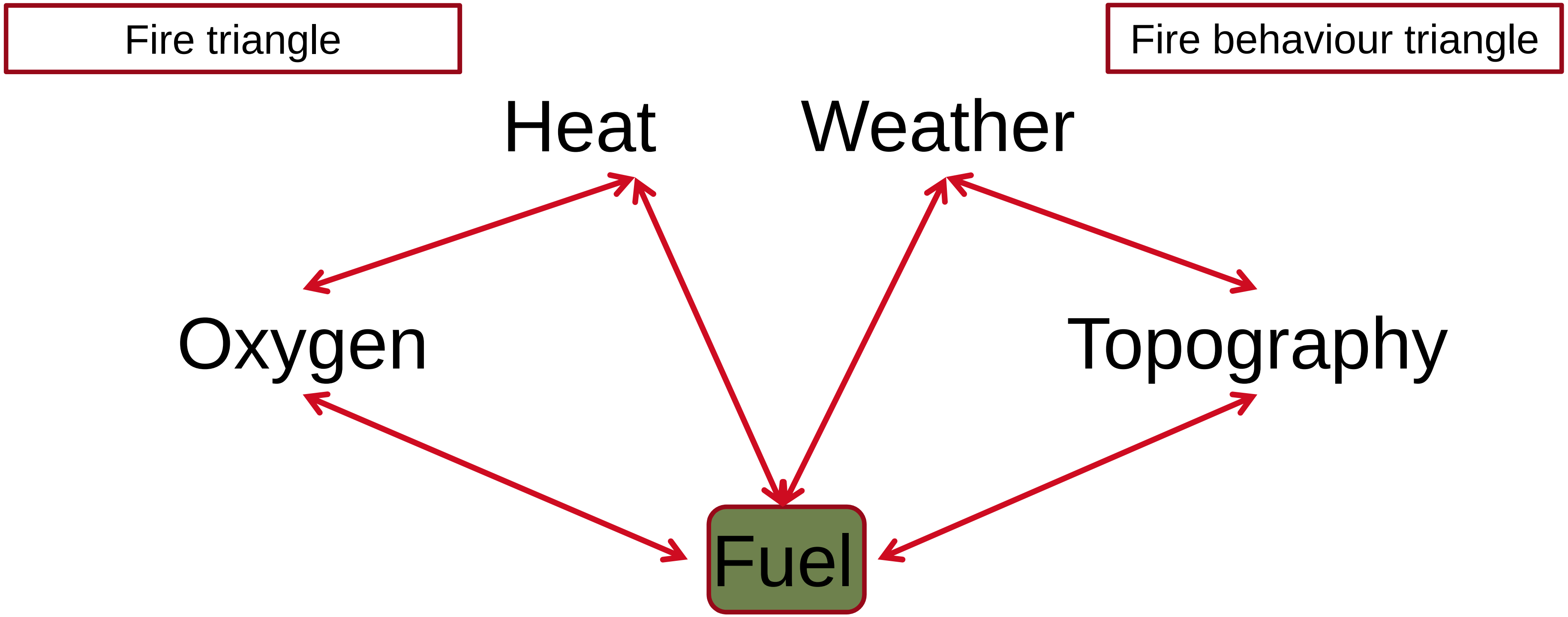
THE UNIVERSITY OF SYDNEY

bushfire CRC


Particulates
Methane
Carbon monoxide
VOCs
CO_2
LOCAL
REGIONAL
GLOBAL
SCALE

Environmental variables and smoke



Smoke composition affected by:

- Fuel characteristics: type of fuel, moisture content, size, arrangement and amount.
- Heating intensity

How we estimate smoke concentrations

Estimate of emissions

$$E_x = A \times FL \times CC \times EF_x$$

Where: E_x = emission, A = area burnt, FL = fuel loading,
CC = combustion completeness, EF = emission factor

Meteorological conditions

Chemistry-transport model

Estimates of smoke concentration

Emission factors from the literature

Andreae and Merlet (2001)

- Groups together studies from all over the world

Shirai et al. (2003)

- Compared Australian savanna results with other studies including Australian Forests

Data for many compounds and particles is not publicly available for SE Australia

GLOBAL BIOGEOCHEMICAL CYCLES, VOL. 15, NO. 4, PAGES 955–966, DECEMBER 2001

Emission of trace gases and aerosols from biomass burning

M. O. Andreae and P. Merlet
Biogeochemistry Department, Max Planck Institute for Chemistry, Mainz, Germany

Abstract. A large body of information on emissions from the various types of biomass burning

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 108, NO. D3, 8406, doi:10.1029/2001JD000841, 2003

Emission estimates of selected volatile organic compounds from tropical savanna burning in northern Australia

T. Shirai,[1] D. R. Blake,[2] S. Meinardi,[2] F. S. Rowland,[2] J. Russell-Smith,[3] A. Edwards,[3] Y. Kondo,[4] M. Koike,[5] K. Kita,[6] T. Machida,[7] N. Takegawa,[8] N. Nishi,[9] S. Kawakami,[1] and T. Ogawa[1]

BIB 10 - 8 SHIRAI ET AL.: EMISSION ESTIMATES OF VOLATILE ORGANIC COMPOUNDS

Table 4. Emission Factors Observed for Various Vegetation Types (g Species/kg dm)

	Australian Savanna			Brazilian Cerrado[b]	Global Savanna[c]	Australian Forest[d]	North American Deciduous Forest[e]	Alaskan Boreal Forest[f]
	This Study	*Hurst et al.* [1994a][a]	*Hurst et al.*, [1994b][a]					
CO_2	1613 ± 86	1595 ± 121	1646 ± 106	1722 ± 23	1640	1558	1671	1660
CO	88 ± 7	91	61	58	65	106	84.0	88.8
CH_4	2.22 ± 0.32	2.34	2.36	1.31	2.4	3.60	5.18	2.79
C_2H_6	0.53 ± 0.07	-	-				-	0.66
C_2H_2	0.24 ± 0.08	0.06	0.14				-	0.24
C_6H_6	0.21 ± 0.02	0.05	0.07				-	-

[a]Data originally presented in the different form [gC/gC DM (dry matter)] were converted into the common form [g species/kg DM].
[b]From *Ward et al.* [1992].
[c]From *Andreae et al.* [1996].
[d]From *Hurst et al.* [1996].
[e]From *Yokelson et al.* [1999a, 1999b].
[f]From *Goode et al.* [2000].

This project aims to improve our understanding of the relationships among fuel type and condition on emissions of greenhouse gases

Experiments

- Experiment 1 – Effect of fuel moisture on GHG emissions and flammability (Year 1)

  Leaves with different levels of fuel moisture content combusted in MLC

- Experiment 2 – Effect of moisture availability on flammability and emissions (Year 2)

  Examine the effect of water availability on leaf moisture content and any consequent effect on energy release and combustion products

- Experiment 3 – Field validation of GHG emissions and flammability (Year 2)
- Experiment 4 – Modelling GHG emissions with fuel condition (Year 3)

Methods for determining emission factors

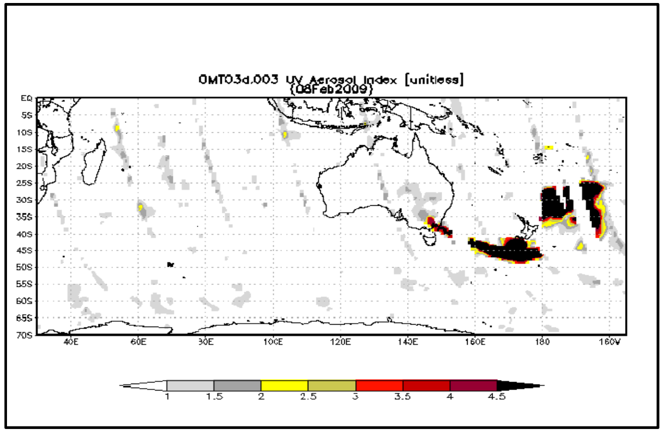
Laboratory: e.g. US Forest Service Fire Sciences Laboratory, Missoula, Montana

Field: ground level

(picture: courtesy F. Reisen)

Field: aircraft

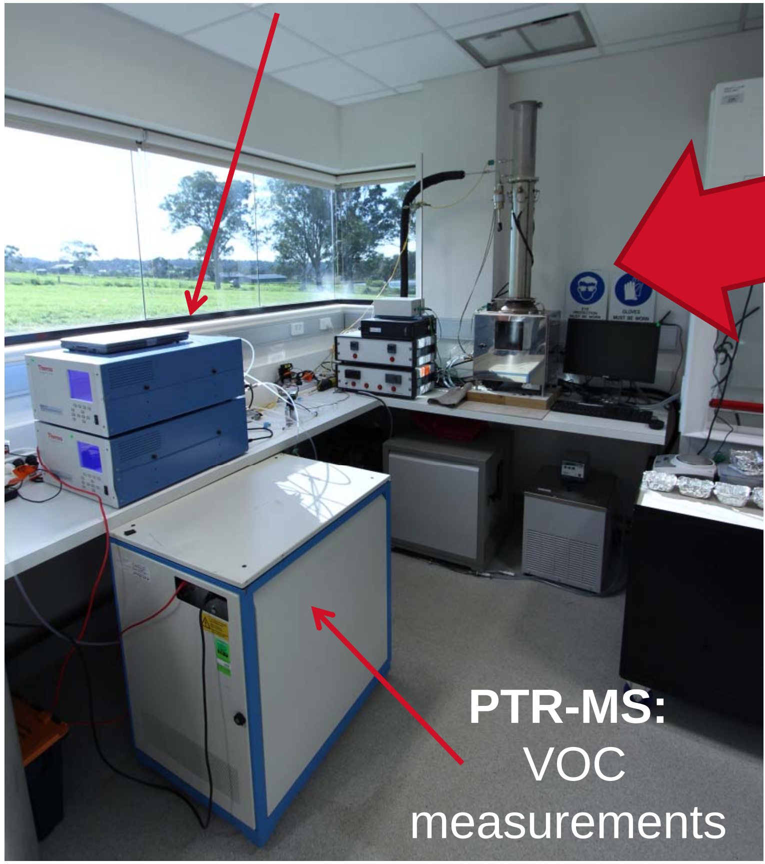
(Figure: http://research.metoffice.gov.uk/research/obr/aerosol/safari.html)



Satellite

Smoke composition and flammability measurements

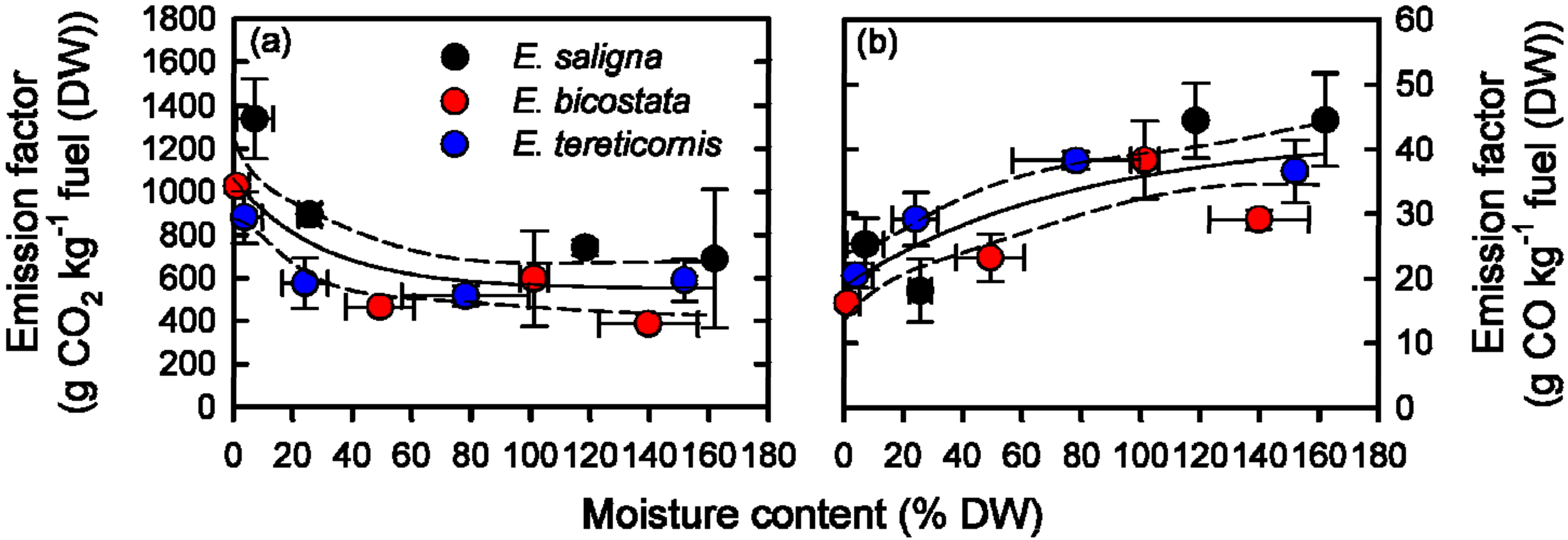
IRGAs:
CO_2 and CO concentrations



PTR-MS:
VOC measurements

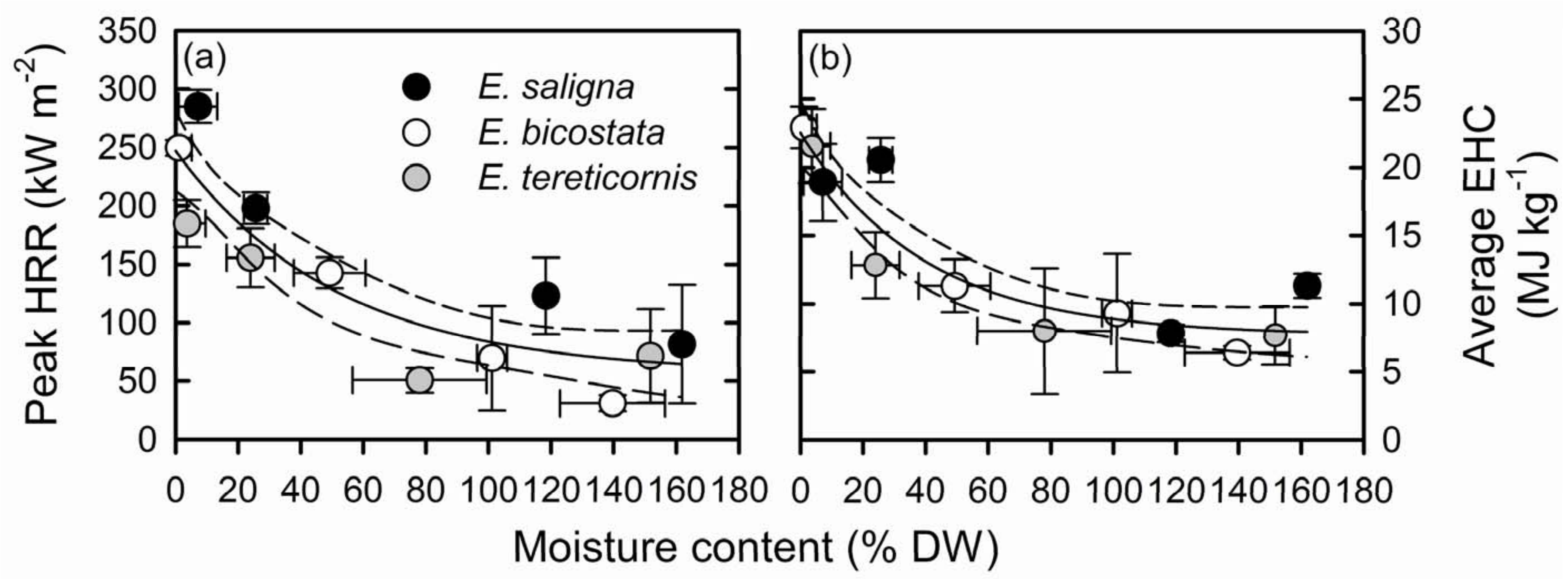
Mass-loss calorimeter:
Energy release and mass loss under a fixed irradiance

Experiment 1: Effect of fuel moisture content on greenhouse gas emissions



Figures: Possell and Bell (2013)

Experiment 1: Effect of fuel moisture content on greenhouse gas emissions



Figures: Possell and Bell (2013)

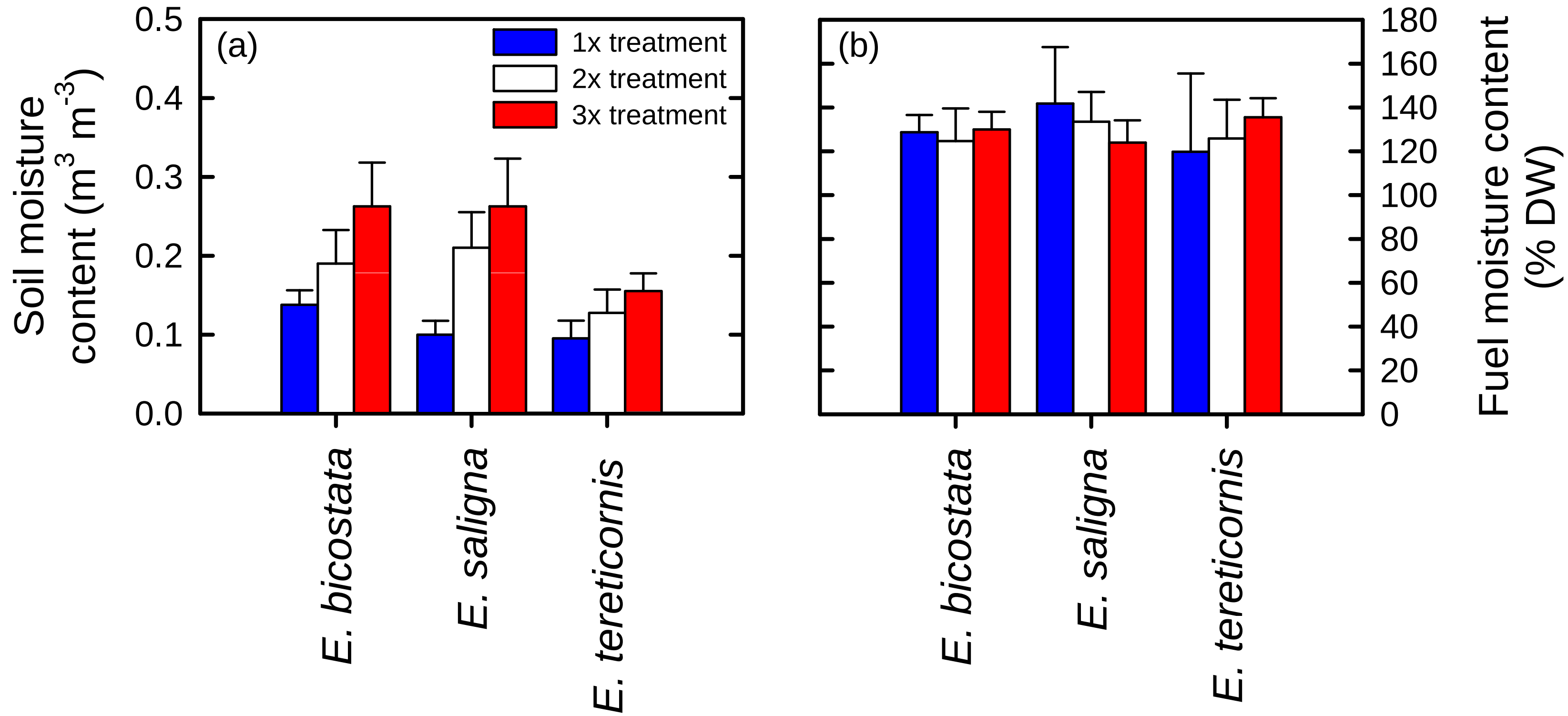
Experiment 2: Effect of fuel moisture content on greenhouse gas emissions

Aim: examine the effect of water availability on leaf moisture content and any consequent effect on energy release and combustion products

- 3 *Eucalyptus* species
- 3 watering regimes
- Soil moisture content measured regularly
- Leaf material collected after 12 weeks – analysed fresh or oven dried

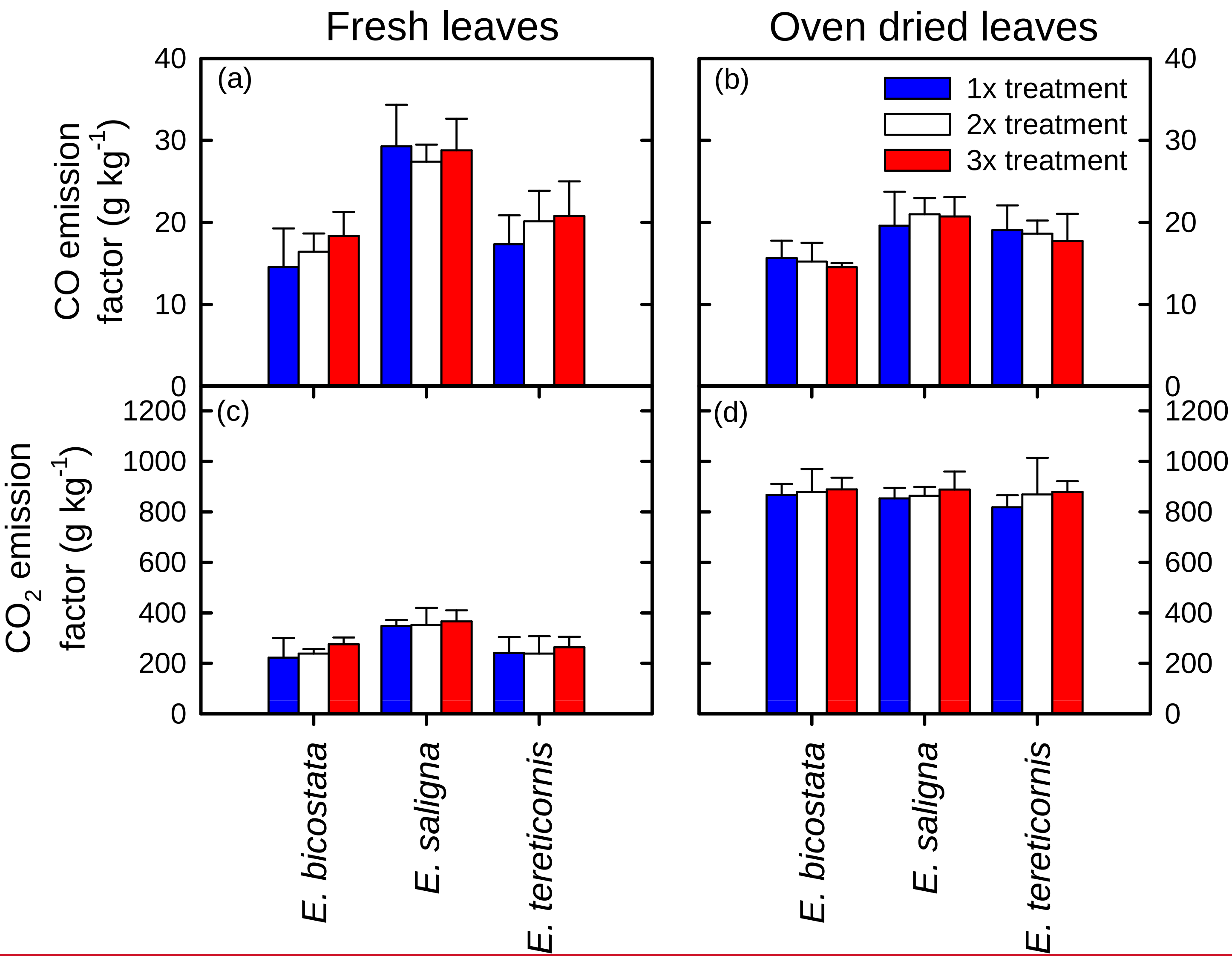
Photo: M. Possell

Experiment 2: Effect of fuel moisture content on greenhouse gas emissions



Figures: Possell and Bell (unpublished)

Experiment 2: Effect of fuel moisture content on greenhouse gas emissions

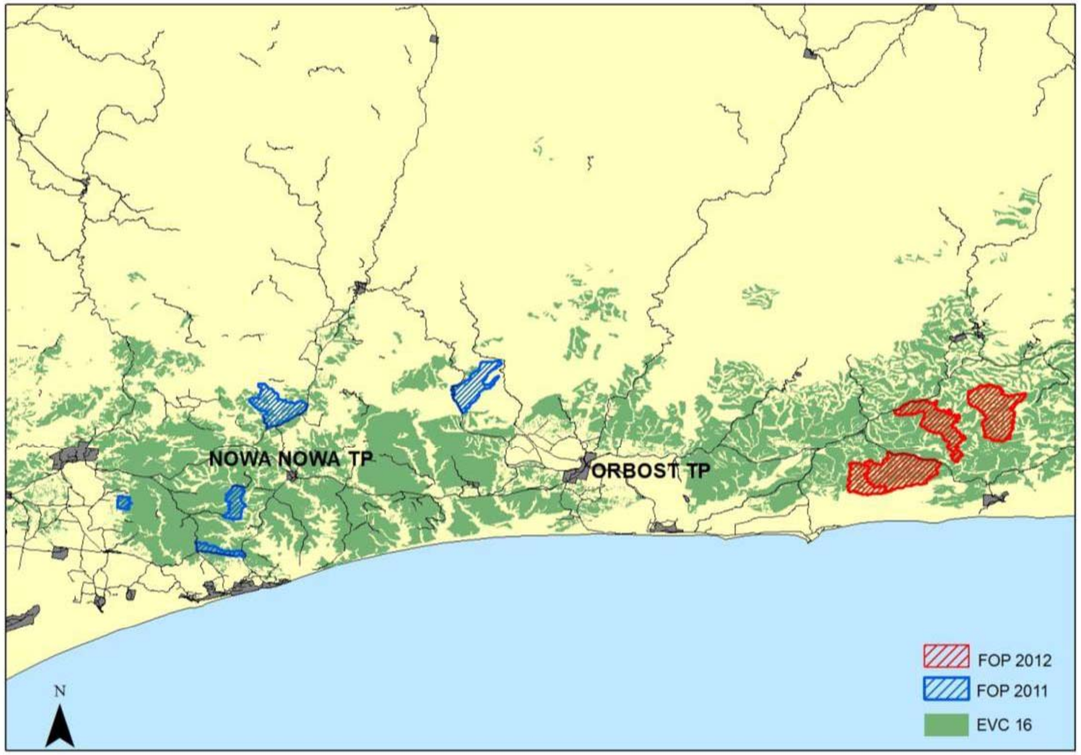


Figures: Possell and Bell (unpublished)

Experiment 3: Field validation of GHG emissions and flammability

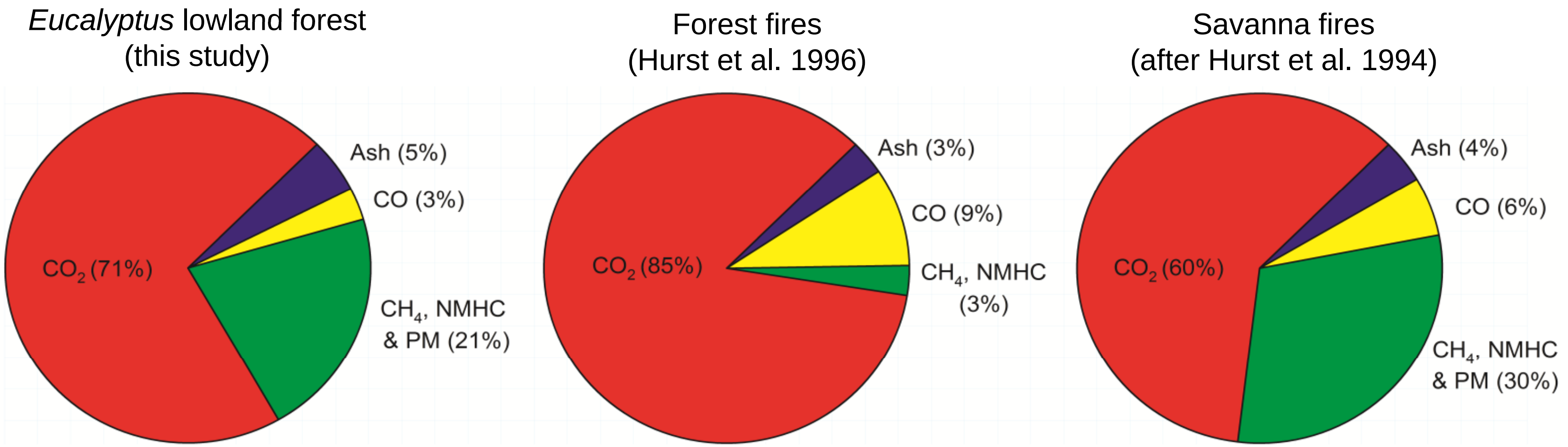
- The material analysed was collected from 4 sites near Orbost, VIC.
- Sites classified as *Eucalyptus* lowland forests
- Overstory dominated by eucalypts.
- Understory in the west is acacia and bracken. Grasses dominate in east.
- 5 fuel fractions analysed:
  - Overstory, understory, litter, duff, twigs.

East Gippsland Sites



Map courtesy of DSE

Experiment 3: Field validation of GHG emissions and flammability



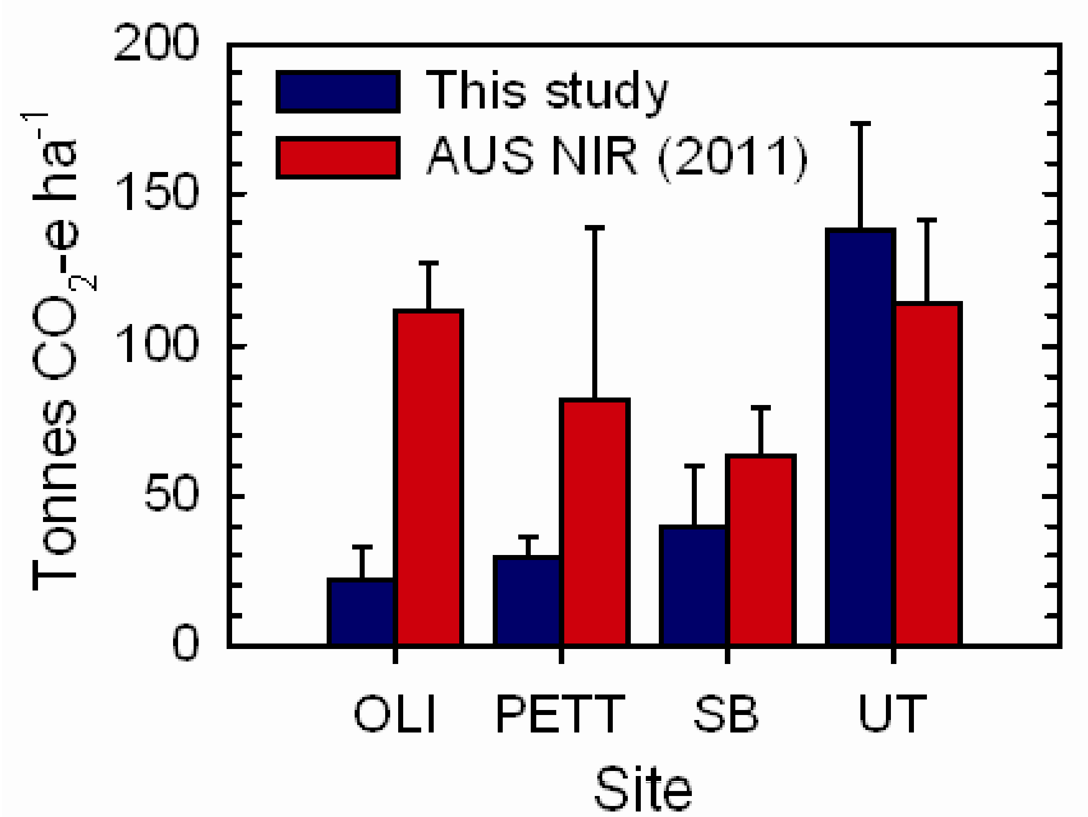
Average fuel carbon partitioning:

Carbon content measured before combustion and in the ash remaining.

The partitioning of carbon loss from lowland *Eucalyptus* forests is dissimilar to other locations.

Figures: Possell, Jenkins & Bell (unpublished)

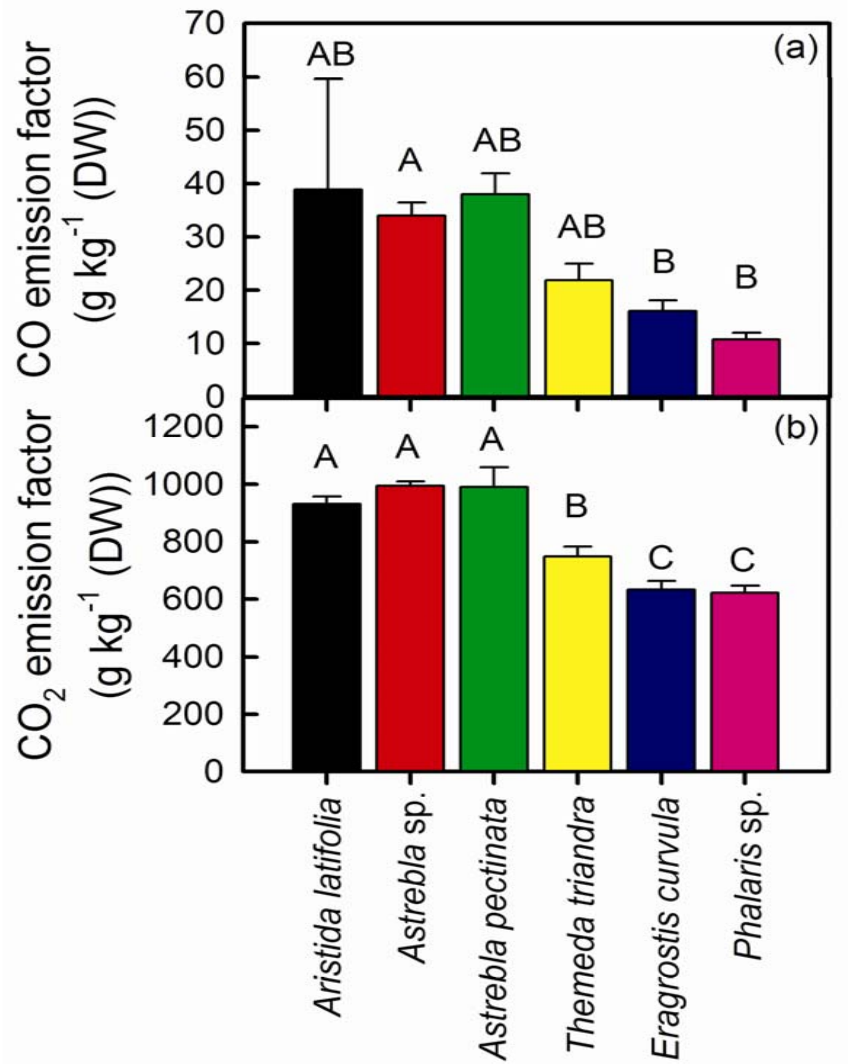
Experiment 4: Modelling of GHG emissions



Fire emissions from four *Eucalyptus* lowland forest sites. Emissions were calculated using the methodology in the AUS NIR (2011) with the data collected in this study and the AUS NIR (2011) default values. Site codes: Oli = Oliver Road, PETT = Pettman's Road, SB = South Boundary Road and UT = Upper Tambo Road.

Figures: Possell, Jenkins & Bell (unpublished)

Experiment 5: Smoke composition and flammability of sub-tropical and temperate grasses



Figures: Possell and Bell (unpublished)

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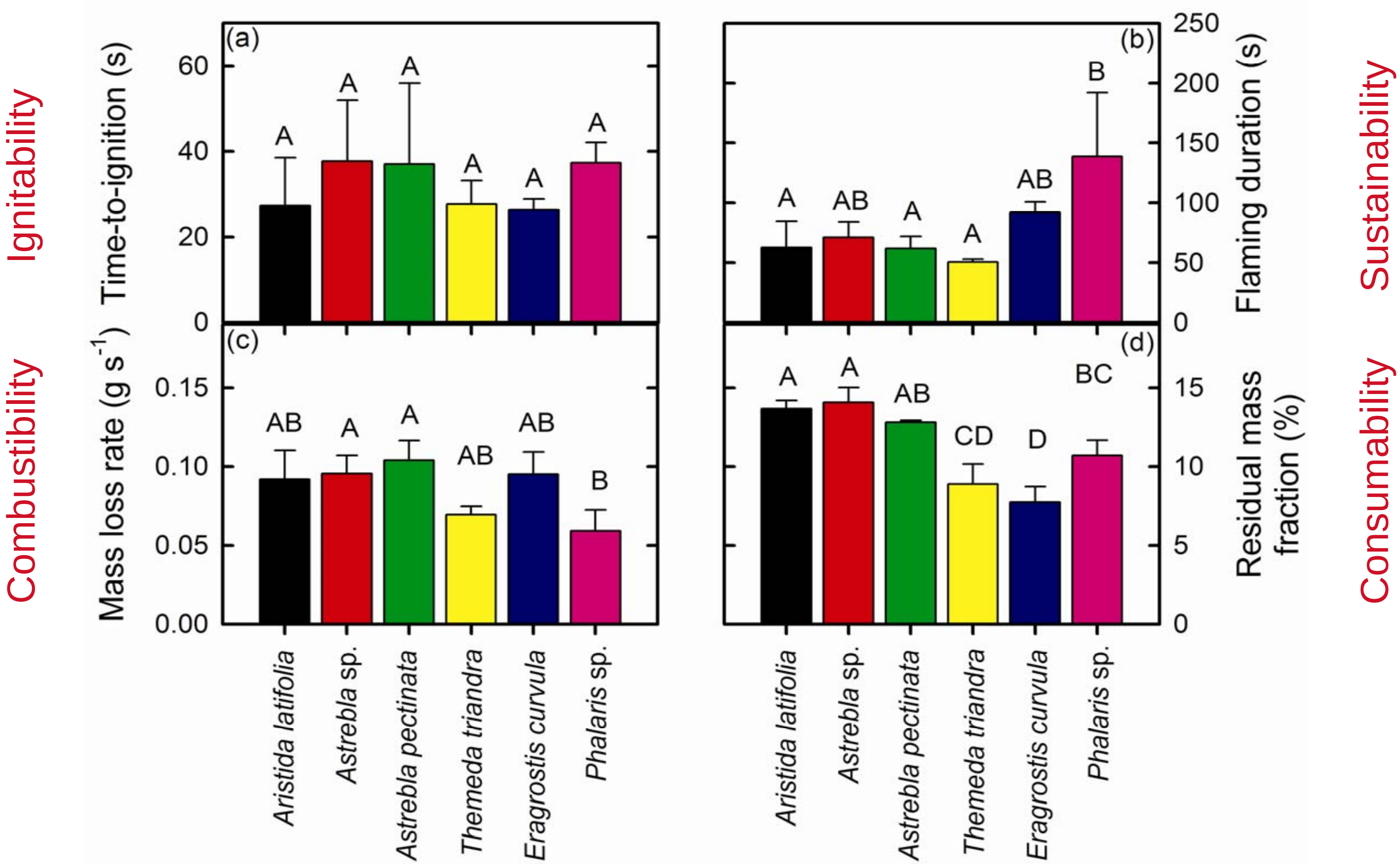

Figures: Possell and Bell (unpublished)

Outputs

Publications

- Possell M, Bell TL (2013) The influence of fuel moisture content on the combustion of *Eucalyptus* foliage. *International Journal of Wildland Fire*, 22, 343-352..
- Bell TL, Stephens SL, Moritz MA. Short-term physiological effects of smoke on wine grapevine leaves. *International Journal of Wildland Fire.* (accepted March 2013).
- Possell M and Bell TL (2013) Smoke composition and the flammability of forests and grasslands. Fire Note 110, BCRC
- Possell M, Bell TL (2011) Volatile organic compounds in smoke. Bushfire CRC report.

Presentations

- Possell M and Bell T, 2012, Greenhouse gas emissions from fire and their environmental effects: a comparative study of smoke composition and flammability between tropical and temperate grasses. AFAC and Bushfire CRC conference 2012, Perth.
- Bell TL, Possell M, project presentation. Greenhouse gas emissions and their environmental effects, NSW Fire and Rescue, July 2011
- Bell TL, oral presentation. Fire and resilience of Australian ecosystems. Faculty of Agriculture and Environment Annual Research Forum, University of Sydney.

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Current state of knowledge

- We have increased the number of emission factors available for different chemical species from:
  - Leaves of common *Eucalyptus* species in south-eastern Australia
  - Different fuel fractions of a lowland *Eucalyptus* forest
  - A number of different grass species found in Australia
- Shown that emission factors can be modified by fuel moisture content and that this can be modelled
- Shown that the proportion of carbon lost to the atmosphere because of fire in a lowland *Eucalyptus* forest is similar to other vegetation types but the composition is different

Current state of knowledge

- Developed a simple method to assess flammability
- Emission factors have been shared with CSIRO for use in their Bushfire CRC projects

Remaining challenges:

- Getting response curves for energy release and formation of combustion products in relation to fuel moisture content adopted
- If data and algorithms are incorporated into chemistry and carbon models, end users will get a better overall picture of what is happening to their carbon stocks during and after prescribed burns.

Where to from here?

Simplified version of current emission models:

Emission flux of '*i*'

Area burned at location *x* and time *t*

Fraction of the biomass burned

$$E_i = A(x,t) \times B(x,t) \times CC \times EF_i$$

Species '*i*' may be CO_2, CO, any VOC

Biomass (or fuel loading) at location *x* and time *t*

Emission factor for species '*i*' (mass of species *i* per mass of fuel burnt)