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Title: **Fuel discontinuities and associated nonlinear fire dynamics in Australian Mallee-heath vegetation**

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Mallee-heath vegetation occurring in semiarid and Mediterranean climates develops a vertically non-uniform and spatially discontinuous fuel complex. The heterogeneity of the fuel layers sustaining fire propagation leads to fire behaviour characterized by nonlinear dynamics where small changes in the drivers of fire spread lead to large changes in observed fire behaviour. Within this fuel complex fire behaviour is not just determined by the effect of fuels and weather, but to a large extent determined by the interactions between those variables and the structure of the flame front. Aiming at understanding the processes determining this nonlinear dynamics and ultimately fire behaviour in this fuel type an experimental burning program was carried out in the Ngarkat Conservation Park, South Australia from 2006 to 2008. Fuel complexes in the experimental burning program comprised mallee and heath vegetation with ages (time since fire) ranging from 7 to 50 years old. Dominant overstorey mallee vegetation comprised *Eucalyptus calycogona*, *E. diversifolia*, *E. incrassate* and *E. leptophylla*. Fuel complex structure was assessed through destructive sampling and visual hazard scoring methods. Vertical wind profiles (from 10-m above ground to ground height) were characterized for each fuel complex. A total of 67 fires were completed. The range of fire environment conditions within the experimental fire dataset were: air temperature 15 to 39 C; Relative humidity 7 to 80%; 10-m open wind 3.6 to 31.5 km/h; Forest Danger Index from 1.7 to 53.3. Fire behaviour measurements included rate of spread, flame geometry, residence time and fuel consumed. Total fuel load ranged from 3.8 Ton/ha in young (7-year old) mallee to 10 Ton/ha in mature stands. Measured rate of spread varied between 50 and 3,310 m/h whereas fireline intensity varied between 144 and 16,800 kW/m.

The dataset provided insight into the mechanisms that allow the development of a coherent flame front necessary to overcome the fine scale fuel discontinuities that characterize semi-arid mallee-heath fuel types and allow self-sustained fire propagation. The dataset was also used to develop models to predict the likelihood of fire propagation (go/no-go threshold) and rate of fire spread aimed to support prescribed burning decision making. For each fire behaviour characteristic (fire sustainability and rate of spread) two models were developed, one based on eye-level wind speed for field use and another based on 10-m open wind speed, for prescribed burn planning purposes. The models aimed at describe the probability of sustained fire propagation in mallee-heath fuel complexes were developed based on logistic regression analysis incorporating the effect of wind speed (either eye level or open wind), near surface fuel moisture content and a discrete fuel category describing the state of development of the fuel complex. The models predicted correctly the type of fire (sustained or not-sustained propagation) 93% of the time. Models aimed at describe the rate of fire spread in mallee-heath vegetation were developed through non linear regression analysis with inputs wind speed and near surface fuel moisture content. A S-shaped equation was chosen to incorporate the observed rapid increase in rate of spread that occurs with the involvement of the overstorey canopy in the propagation processes. The model for fire spread in mallee-heath fuels using 10-m open wind speed explained 70% of the variation in the dataset. The model relying on eye-level wind speed explained only 30% of the variation in rate of spread.

The aim of this modelling exercise was to produce simple models that provide estimates of prescribed fire potential based on easily measured fire environment properties. Fuel type was purposely characterized in simple terms. Three discrete classes of fuel complex development stage were identified: (1) young fuel complex with incipient and sparse fuel distribution; (2) fuel complex with distinct low (3-4 meter tall) overstorey development and low horizontal fuel continuity; and (3) mature fuel complex dominated by large mallee clumps. The aim of such simple fuel classification is to allow users to apply the model with a few easy to estimate input characteristics.

Future work will aim at develop more robust models that take into account fuel structure, either through physical measures of fuel continuity (both horizontal and vertical) or Fuel Hazard Scores, and the type of fire propagation (surface or crown fire). It is expected that such models will provide higher accuracy than the simple logistic and nonlinear regression models developed to date.