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Insights from modelling Australia's tropical savannas

A.C. Liedloff [a] **and G.D. Cook** [b]

[a] *CSIRO Environment, Berrimah, Australia*
[b] *CSIRO Environment, Brisbane, Australia*
Email: adam.liedloff@csiro.au

Abstract: Savannas occupy approximately 20% of the earth's land area and 23% of Australia. They cover northern Australia from east to west and across a rainfall gradient from approx. 2000 mm yr^{-1} along the northern coastline to 500 mm at the southern boundary with the arid systems of central Australia. This region is characterised by strongly seasonal rainfall including cyclones, frequent fire, and low human population density, resulting in landscape dominated by sparse open eucalypt woodland with a native C4 dominated grasses occupying the gaps and understory (referred to as savanna), with smaller areas of wetland, monsoon rainforest, and grassland occurring where conditions allow. While relatively intact the system has undergone considerable disturbance and faces many management and climate challenges.

Modeling the savannas (or woodlands) requires understanding the unique equilibrium where both forest and grassland persist together, where treed systems elsewhere are more likely to shift to either forest or grassland through time. A few models have been developed internationally specifically for this biome as most physiological forest growth models do not provide the required processes and interactions, grassland models do not contain detailed interactions with trees, and few handle processes resulting from the high fire frequency experienced at landscape scales.

During our modelling journey we concentrated on the tree component, partly because we believed that trees were responsible for driving the form of the savannas. During model development we identified the importance of tree stand demographics which relates to the fate of individual trees in the stand as exposed to repeated fire or lack of water resulting from the water requirements of the total stand during an annual dry season "drought". This alludes to the proposition that we can never predict the exact tree stand for any location at a given time with any woodland stand somewhere on a continuum of recovery from previous disturbances.

Flames is a model of savanna tree stands that tracks the fate of individual trees exposed to fire and seasonal water availability as a function of their size. In creating a tree model capable of running across the rainfall gradient and exposed to different fire regimes we believe this approach represents the archetype tree system model for Australian forests and woodlands exposed to disturbance and change. In this presentation we will discuss the implications of building and validating a model in data poor environments, and what the fundamentals of the model allow us to infer about the function of the tropical savannas, and other systems, as we consider the consequences of future change.

We present some of the main Flames outputs as an indication of the model's benefits. These include simulations recreating historic drought related dieback events as reported in north Queensland and other woodland systems such the Great Western Woodlands of WA where very old, mature salmon gums persist on a mere 300 mm annual rainfall. We present a means of describing any savanna stand using a cumulative density curve which can be used for carbon stock estimates. We also push the model beyond the data used for development to further develop our understanding of savanna processes such the implications of woody thickening, introduced grasses providing large fuel loads for intense fires, altered fire regimes through management and climate change, and discuss what this might mean for other Australian forests in the future.

Keywords: *Trees, grass, fire, Flames model, stand demography*