

**PROCEEDINGS OF THE AUSTRALIAN RANGELAND SOCIETY  
BIENNIAL CONFERENCE**

**Official publication of The Australian Rangeland Society**

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The reference for this article should be in this general form;  
Author family name, initials (year). Title. *In*: Proceedings of the nth Australian Rangeland Society Biennial Conference. Pages. (Australian Rangeland Society: Australia).

For example:

Anderson, L., van Klinken, R. D., and Shepherd, D. (2008). Aerially surveying Mesquite (*Prosopis* spp.) in the Pilbara. *In*: 'A Climate of Change in the Rangelands. Proceedings of the 15<sup>th</sup> Australian Rangeland Society Biennial Conference'. (Ed. D. Orr) 4 pages. (Australian Rangeland Society: Australia).

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# MODELLING THE EFFECT OF UTILISATION ON PLANT COMPOSITION IN RANGELANDS: IDENTIFYING KEY PLANT TRAITS AND ENVIRONMENTAL FACTORS

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## **Introduction**

Grazing by large herbivores is known to have caused important changes in plant species composition in rangelands around the world. These changes may be gradual and reversible in some environments but can be abrupt and irreversible elsewhere. In systems which behave non-linearly, response thresholds are sharp, which makes it difficult to determine optimum utilisation rates. Our modelling work aims to understand those thresholds and, in this stage, focuses on identifying the key plant traits and environmental factors that determine competitive ability and long-term survival of the main plant functional types (e.g. annual/perennial grasses, palatable/unpalatable shrubs, trees) under different management regimes.

At short time scales (i.e. < year), plant performance, and therefore competitive ability, is a function of the balance between the plant capacity to acquire resources and its potential to use those resources for growth (Wright and Westoby, 2000). The relative growth rate (RGR) increases with the surface area of photosynthetic tissue (a function of leaf mass and specific leaf area), while the capacity to capture the main resources - water and nutrients in subtropical drylands— depends on the surface area of the root system (a function of root mass and specific root area). Hence, optimal outcomes involve a trade-off between the two. While dryland conditions select for plants with extensive root systems, grazing selects for plants with high RGR, and thus high leaf to mass ratios.

At long time scales (i.e. > year), competitive ability not only depends on RGR but also on the reproductive success of the population, and hence additional plant traits such as leaf life span, plant longevity, seed production and germination become increasingly important. Plant traits that contribute to high RGR values tend to be associated with others that imply greater costs/risk for the long-term survival of the population. The traits that provide optimal performance at short time scales are favoured in environments with relatively short and unreliable growing seasons, while traits that provide optimal performance at long time scales are favoured in environments with relatively long and reliable growing seasons (e.g. Shmida et al., 1986).

We hypothesise that these plant traits and trade-offs largely explain the frequently observed changes of species composition in the rangelands, such as the loss of perennial grass species and the invasion of woody weeds following heavy grazing, or the variation in safe utilisation rates with soil type and climate. Locally, defoliation by grazing animals shortens the growing season, lowers the relative growth rate and the storage efficiency of plants, and in so doing strongly favours an annual life cycle (Iwasa and Cohen, 1989). In moisture-limited environments, soil texture may reinforce or dampen the impact of grazing on the competition between different plant functional types by affecting both the absolute amount and the potential uptake rates of plant available moisture, and therefore the length and reliability of the growing season.

## **Approach and model structure**

Our model is based on a general resource competition model developed by Huston & De Angelis (1994) and runs at a monthly timestep. It distinguished two types of soil compartments: fixed volumes for each individual plant ( $V_p$ ), and a much larger compartment ( $V_r$ ) that surrounds the individual plant volumes and forms the regional soil resource pool (see Figure 1). Plants can extract resources from  $V_p$ , but not directly from  $V_r$ . Differences in resource levels between  $V_p$  and  $V_r$ , generate flows in the direction of the lowest resource level. Hence, plants can compete indirectly with others by altering the regional availability of resources, but this strongly depends on the mobility of the resources in the soil. Currently, the model only simulates the competition for soil water by two functional plant types, annual and perennial grass. Flows between the different compartments are a function of differences in

soil water potential and hydraulic conductivity. In upcoming versions of the model we will add more functional plant types and include competition for nitrogen.

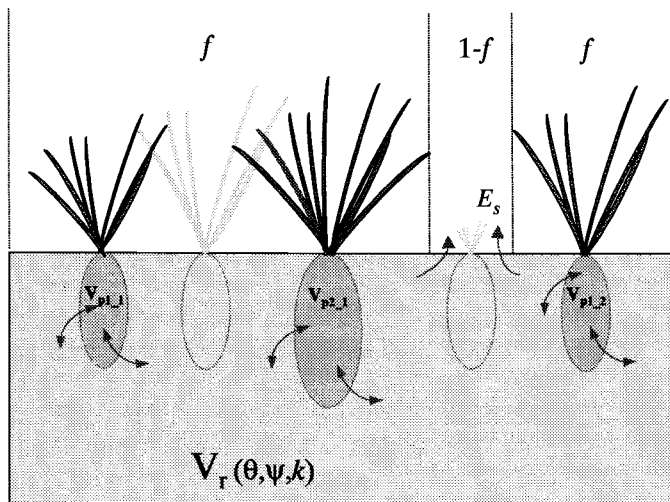


Figure 1: The model structure (after Huston and DeAngelis, 1994). Water losses from  $V_p$  occur by transpiration and fluxes to  $V_r$ . Water losses from  $V_r$  are as soil evaporation ( $E_s$ ), and fluxes to  $V_p$ . New plants can establish in the bare soil areas ( $1-f$ ), but not in the vegetated fraction ( $f$ ) of the area. Recruitment of new individuals and death of existing ones causes changes in the size, moisture content, soil water potential and hydraulic conductivity of  $V_r$ .

The model is initiated with a given population for both plant types or these can be generated from seed. Given a number of individual plants in each age class, the model first computes the size, moisture content, and remaining storage capacity of  $V_p$  for each class and plant type, and then computes the same properties for  $V_r$ . The annual plant has 12 age classes, while for the perennial plant species only two classes are distinguished: seedlings ( $< 1$  month old) and adults ( $\geq 1$  month old). Infiltrating rainwater is distributed according to the relative storage capacities of  $V_p$  and  $V_r$ . The water use of the plants in each age class is the minimum of soil water uptake (a function of the hydraulic conductivity of  $V_p$ , the below-ground biomass, and the specific root surface area), and potential transpiration (calculated from a crop coefficient, above-ground biomass, specific leaf area, and pan evaporation). Assuming a constant water-use-efficiency, the amount of new grown biomass is computed directly from the water consumption, and distributed over above- and below-ground compartments according to a given root:shoot ratio. A rainfall threshold triggers germination of seed. At the end of each timestep seedlings are allowed to the next age class only if their RGR over the preceding month was positive. Death of individuals due to age is regulated by species-specific survival curves.

The model will be used to simulate the impact of different grazing intensities and management strategies on plant species composition in north and central Australian rangelands. The results will be presented at the conference and will be compared with results from grazing trials and other field evidence to determine whether a quantitative prediction of “safe utilisation rates” can be made.

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