A Conceptual Model to Explain Increasing Woody Biomass in Arid and Semi-Arid Regions

Anthony R. Palmer
Agricultural Research Council, South Africa

D. Eamus
University of Technology Sydney, Australia

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A conceptual model to explain increasing woody biomass in arid and semi-arid regions

A .R . Palmer [1,2] and D . Eamus[2]
[1]ARC-Livestock Business Division , PO Box 101 , Grahamstown , South Africa and [2]IWERM , University of Technology Sydney , PO Box 123 , Broadway , NSW , 2007 Australia . E-mail : Anthony .palmer@uts .edu .au

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Introduction An increase in woody biomass in semi-arid and arid rangelands has been reported from Africa , Australia the Americas . This trend impacts negatively on the ability of rangelands to support livestock . The trend has been attributed to changes in 1) the fire regimes , 2) the type and amount of herbivory , 3) the timing and intensity of climatic factors (e .g . drought) and 4) increased atmospheric carbon dioxide concentrations ($[CO_2]_a$) . $[CO_2]_a$ are increasing and simultaneously , pan evaporation rates have been declining and the density of woody biomass has been increasing in arid and semi-arid regions . The rate of CO_2 fixation by leaves increases as the supply of $[CO_2]_a$ to chloroplasts increases . The increase in biomass production is generally larger under xeric than mesic conditions . An increase in photosynthesis and the observed decline in stomatal conductance explains increased water-use efficiency , which , in conjunction with decreased pan evaporation rates , is equivalent to an increased availability of water . We propose that woody thickening could be attributable to the enhanced soil and plant water status . We highlight observations of increased tree water-use-efficiency , reduced global run-off and increased soil moisture as evidence supporting the mechanism .

Materials and methods We explored long-term climate data sets for southern Africa to determine whether site wetness has been increasing . This included analysing records from evaporation pans , rainfall and run-off at these sites . We review evidence of decreased stomatal conductance and resulting increased climate wetness index" , and test the three predictions detailed above that increased tree water-use-efficiency , reduced global run-off and enhanced plant water status occur in response to CO_2 enrichment . We explored trends in the leaf area index for areas with a known history of woody biomass increase using the MODIS LAI .

Results Pan evaporation rates have decreased for arid and semi-arid regions of southern Africa and Australia . There is no discernable trend in annual precipitation . The MODIS LAI data confirmed that leaf area index has increased in rangelands experiencing woody encroachment in Australia , South Africa and the USA . Vapour pressure deficit (VPD) has decreased for water-limiting ecosystems of Africa , Australia and the Indian sub-continent (Nemani et al . , 2003) . There is evidence of global soil moisture increasing (Robock et al . , 2005) , with a positive soil moisture trend from Jornada LTER . Elevated moisture levels across land-use gradients have been documented in the southern Kalahari .

Conclusions If CO_2 enrichment is reducing stomatal conductance and enhancing soil moisture stores , we predict a more positive plant water status will be observed under CO_2 enriched conditions . As pan evaporation rates have declined , the availability of soil moisture has increased , effectively equivalent to increased rainfall . This , coupled to the increase in N deposition , has increased canopy LAI and hence CO_2 uptake and has resulted in an increased ecosystem-scale woody thickening . Super-imposed on this is the decrease in stomatal conductance resulting from increased atmospheric $[CO_2]a$. The model proposed here has wide-ranging ramifications to policies on afforestation , woody weed control and carbon sequestration .

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