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A conceptual model of vegetation dynamics in the semiarid Highland savanna of Namibia, with particular reference to bush thickening by *Acacia mellifera*

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ABSTRACT

Namibian rangelands are encroached with *Acacia mellifera*, partially resulting from a poor understanding of vegetation dynamics. A conceptual state-and-transition model of vegetation dynamics in the semiarid Highland savanna in central Namibia, emphasising bush thickening by *A. mellifera*, is described. Two main states, a grassy and a bushy state, are identified. These are further subdivided, and 11 transitions are identified. The key transition initiating a change from grassy to bushy state can be termed a "leap" (an occasional, infrequent mass recruitment event) following a long "sleep" (no or little change in *A. mellifera* density). It is rare because it requires three consecutive years of above-average rainfall for seedling establishment. Fire, coinciding with seedling establishment, can interrupt it, while a low biomass grass sward facilitates it. The phenology and physiology of the encroaching species, seed predation and sapling herbivory influence this transition. The model proposes opportunistic management interventions, particularly the use of fire, to minimise the risk of further landscape-scale transitions to a bushy state. It highlights areas where understanding of vegetation dynamics is lacking and recommends crucial research foci. Conceptual models of bush-thickening processes need to account for differences in climate and phenological details of encroaching species.

1. Introduction

An appropriate conceptual model of vegetation dynamics is an important prerequisite for effective and predictive management of rangelands. Rangeland managers use conceptual models, but these may be flawed, or consist of uncoordinated viewpoints regarding separate phenomena of rangeland change. Namibian semiarid rangeland managers largely rely on the classical rangeland succession model based on Clements (1928) to explain changes in the composition of the grass sward, yet draw from the two-layer competition model of Walter (1971) to explain the dynamics between the woody and herbaceous components of savanna vegetation.

Flawed or incoherent conceptual models may result in poor rangeland management that results in declining productivity and biodiversity (Milton et al., 1994). In semiarid savanna, bush thickening or the densification and increase in

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the cover of indigenous woody species is a major economic and ecological problem in many semiarid parts of the world (Archer et al., 1988; Hodgkinson and Harrington, 1985) including southern Africa (Donaldson, 1967; Skarpe, 1990). Nearly 50% of the commercial ranching areas of Namibia are affected by bush thickening, mainly by *Acacia mellifera* subsp. *detinens* (hereafter referred to as *A. mellifera*). As a result, Namibian ranchers forego an estimated *N*$700 million in lost meat production annually (De Klerk, 2004). Reactive interventions are the norm. Despite interventions, bush thickening remains a problem.

Non-equilibrium theories have permeated mainstream rangeland management, and state-and-transition models have been used to describe vegetation changes and management strategies in semiarid rangelands (Milton and Hoffman, 1994; Westoby et al., 1989) including savanna (Distel and Bóo, 1995; Dougill et al., 1999). However, no complete cohesive conceptual model of semiarid savanna dynamics has usurped the traditional rangeland succession model in southern Africa (Ward, 2005), especially in Namibia. Existing models neglect phenological cycles, the timing of different environmental and anthropomorphic events and animal/plant interactions. Bush-thickening species differ widely with respect to phenological and physiological aspects of their life history, resulting in different pathways of bush thickening. Mechanistic explanations proposed by Brown and Archer (1999) for *Prosopis glandulosa* in Texas, USA, by Skowno et al. (1999) for *Euclea* species in South Africa and by Roques et al. (2001) for *Dichrostachys cinerea* in Swaziland are thus not necessarily generally applicable.

In this paper we contribute to the debate on bush thickening by proposing a state-and-transition model for vegetation dynamics of the semiarid Highland savanna of central Namibia that focuses on bush thickening by *A. mellifera*. Information to formulate a model is based on ongoing long-term research at several sites, particularly Krumhuk Farm (20 km south of Windhoek) and Neudamm Agricultural College (30 km east of Windhoek). This paper aims to stimulate further research to test the model's underlying hypotheses.

2. Characteristics of the Highland savanna vegetation type

The Highland savanna lies between 22° and 23.30°S and 15.30° and 18.30°E and occupies approximately 45 000 km^2 or 5.5% of Namibia's land area (Fig. 1) (Coetzee, 1998). Precipitation is highly variable and seasonal, 80% of the annual rainfall occurring from January to March. Windhoek's long-term mean annual rainfall (1892–2003) is 361 mm (CV = 40%). The annual water deficit is approximately 2000 mm (Mendelsohn et al., 2002). In summer, average maximum temperatures are lower (about 29 °C) than in lower-lying savannas while winters are fairly cold (average minimum temperature: 3 °C). Frost occurs between 10 and 20 nights/year (Mendelsohn et al., 2002). The terrain is broken and undulating, at altitudes of

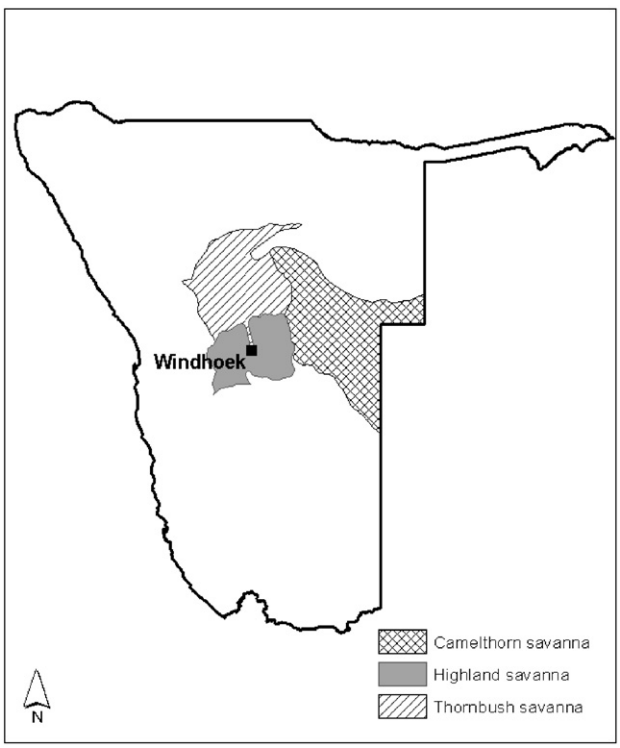

Fig. 1. The position of the Highland savanna in Namibia with the adjacent Camelthorn and Thornbush savannas indicated.