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Effects of goat pastoralism on ecosystem carbon storage in semiarid thicket, Eastern Cape, South Africa

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Abstract Intensive pastoralism with goats transforms semiarid thicket in the Eastern Cape, South Africa from a dense vegetation of tall shrubs to an open landscape dominated by ephemeral grasses and forbs. Approx. 800 000 ha of thicket (which prior to the introduction of goats had a closed canopy and a *Portulacaria afra* Jacq. component) have been transformed in this manner. Ecosystem C storage in intact thicket and loss of C due to transformation were quantified. Carbon storage in intact thicket was surprisingly high for a semiarid region, with an average of 76 t C ha^{-1} in living biomass and surface litter and 133 t C ha^{-1} in soils to a depth of 30 cm. Exceptional C accumulation in thicket may be a result of *P. afra* dominance. This succulent shrub switches between C_3 and CAM photosynthesis, produces large quantities of leaf litter (approx. 450 g m^{-2} $year^{-1}$) and shades the soil densely. Transformed thicket had approx. 35% less soil C to a depth of 10 cm and approx. 75% less biomass C than intact thicket. Restoration of transformed thicket landscapes could consequently recoup more than 80 t C ha^{-1}.

Key words: biomass, carbon stocks, goats, pastoralism, soil carbon, thicket.

INTRODUCTION

Semiarid solid thicket (characterized by a dense canopy of tall shrubs and a *Portulacaria afra* Jacq. component) occupies approx. 1.7 million hectares in the Eastern Cape, South Africa (Lloyd *et al.* 2002). Despite a long association with a diverse assemblage of large and medium-sized indigenous herbivores (Midgley 1991; Kerley *et al.* 1995), thicket is surprisingly sensitive to injudicious pastoralism (Stuart-Hill & Danckwerts 1988; Stuart-Hill 1992). Heavy browsing by goats can transform thicket from a dense closed-canopy shrubland into an open savanna-like system with a cover of ephemeral grasses and forbs within a few decades, and possibly even within a decade (Hoffman & Cowling 1990; Kerley *et al.* 1995; Lechmere-Oertel *et al.* 2005a). Approximately 800 000 ha of semiarid thicket has been transformed in this manner, and the process of transformation is evident in another 600 000 ha (Lloyd *et al.* 2002). We hypothesized that transformation reduces total ecosystem C storage, as loss of above-ground biomass is highly visible (Fig. 1), and soil C is likely to be reduced where canopy cover is removed (Allsopp 1999; Mills & Fey 2003, 2004a). We asked the question: how much C is lost when thicket is transformed?

Warm, semiarid landscapes are not where one would intuitively expect to find large stocks of ecosystem C. Ecologists are accustomed to a pattern of increasing biomass along a rainfall gradient from deserts to forests (Woodward 1987). The common perception is that low water availability in warm, semiarid landscapes limits accumulation of biomass because water demand tends to increase with an increase in biomass. While this is true, multiple exceptions to such a pattern occur in semiarid and arid lands where water is not the primary limiting factor. Decoupling from water as a limiting factor occurs, for example, in desert areas dominated by phreatophytic species of *Prosopis* which tap groundwater pools. Moreover, with this example, nitrogen fixation by root nodules reduces limitations due to nitrogen as well. Physiological decoupling from water limitation can also occur where crassulacean acid metabolism (CAM) metabolic systems can allow highly efficient use of water and thus relatively high productivity and biomass in areas with very low rainfall. Accumulation of soil C also tends to be limited in these landscapes (Post *et al.* 1982) because soils are exposed to sunlight (as a result of limited plant cover), which enhances rates of mineralization of soil organic matter (via temperature effects) (Jenkinson 1981) and photo-

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