Measurement and modelling of evapotranspiration in three fynbos vegetation types

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ABSTRACT

Many studies have investigated the water relations of indigenous plants in the fynbos shrublands of the Cape, South Africa. These have mainly focused on understanding the mechanisms by which individual plant species respond to droughts, the frequency and severity of which is expected to increase due to climate change. However, comparatively little information exists on the dynamics of water use by indigenous plants in the region, and, in particular, how water use varies seasonally and between sites. In this study we determined water use by 3 fynbos vegetation types growing at 4 different sites, namely: (i) lowland Atlantis Sand Plain fynbos growing on deep sandy soils, (ii) Kogelberg Sandstone fynbos growing in a riparian zone on deep alluvial soils, (iii) dryland Kogelberg Sandstone fynbos growing on shallow sandy soils at a montane site, and (iv) alluvial Swartland fynbos growing in clayey soils. Evapotranspiration (ET) was quantified at each site during specific periods using a boundary layer scintillometer and energy balance system. A simple dual source model in which the stand ET was calculated as the algebraic sum of outputs from soil evaporation and transpiration sub-models was used to scale up the ET measurements to annual values. The data showed large differences in ET depending on site characteristics and on plant attributes. Dense stands of riparian Sandstone Fynbos had an annual ET of 1 460 mm which exceeded the reference ET of 1 346 mm. Dryland Sandstone Fynbos used only 551 mm of water per year while the Sand Plain Fynbos' annual ET was 1 031 mm, which was similar to the reference ET of 1 059 mm. We conclude that some indigenous plant species use large volumes of water which should be accounted for in, e.g., groundwater recharge estimates, and calculations of incremental water gains after clearing alien invasive plants, among other applications.

Keywords: Evapotranspiration, fynbos, scintillometer, Western Cape

INTRODUCTION

Indigenous vegetation in the Mediterranean-type climate region of South Africa is threatened by ongoing land transformation for agriculture, forestry, industrial development and urban developments (Jacobsen et al., 2007; West et al., 2012). Climate change, the encroachment of alien invasive plants and wild fires also threaten the region's biodiversity (Midgley et al., 2002; Rebelo et al., 2006). Fynbos, a sclerophyllous shrubland dominated by species of the Proteaceae, Ericaceae and reed-like Restionaceae, forms the dominant indigenous vegetation cover in the Cape Floral Region (CFR) (Rebelo et al., 2006). Climate change induced decreases in the area under fynbos in the CFR are projected to be extensive, possibly as much as 51–65% by 2050 (Midgley et al., 2003).

Compounding the threats to the region's biodiversity is the increased rate of spread of alien invasive plants which use large quantities of water (Le Maitre et al., 1996). The projected future climatic conditions are likely to be more conducive to the growth and dispersal of the alien invasive plants (Hellmann et al., 2008). It is therefore not surprising that numerous studies in the fynbos biomes have mainly focused on the mechanisms by which plant species respond to seasonal patterns in moisture availability and how these vary along rainfall gradients (Miller et al., 1983; Richards et al., 1995; Richardson and Kruger, 1990; Von Willert et al., 1989) and during droughts (West et al., 2012). These studies have largely targeted specific plant species and few were conducted at the community or vegetation-type levels (Jacobsen et al., 2007; Midgley et al., 2002). Quantitative information on water use by indigenous vegetation at the community scale is therefore generally sparse in the CFR. Indigenous vegetation water use information is important for a variety of applications. For example, the conservation of biodiversity in riparian areas strongly depends on adequate water allocations to meet environmental flows. Accurate information on water use by the riparian vegetation is crucial to ensure 'safe' abstraction levels from the region's rivers and groundwater sources (Dye et al., 2001; 2008). In studies to quantify the hydrological impacts of alien invasive plants, information on the water use by the indigenous vegetation is critical for determining the incremental water gains that can be achieved by clearing the alien plants (Doody et al., 2011; Dzikiti et al., 2013a). Potential water savings depend on the water use characteristics of the indigenous vegetation that replace the cleared alien plants (Bosch et al., 1986; Dye et al., 2001; Dzikiti et al., 2013b; Le Maitre et al., 1996). In a recent Water Research Commission study (Jovanovic et al., 2012), uncertainties in groundwater recharge estimates were reduced significantly by including accurate data on the water use by indigenous vegetation in the hydrological models. Lastly, in the emerging water footprint concept, accurate baseline information on the water use by indigenous vegetation is critical for the determination of the water footprints of various land use practices such as agricultural and forestry activities, among others (Hastings and Pelgrum, 2012).

The aim of this study was to provide estimates of the seasonal water use by 3 endangered fynbos ecosystems, the water consumptions of which are not known. These include Sand

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