Satellite-based annual evaporation estimates of invasive alien plant species and native vegetation in South Africa

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ABSTRACT

In this study we assessed the impact that invasive alien plant species (IAPs), and the clearing thereof by the Working for Water (WFW) programme, have on total evaporation (ET) and the availability of water resources in two highly-invaded provinces of South Africa. The Surface Energy Balance Algorithm for Land (SEBAL) model, using MODIS satellite imagery, was used to estimate the annual total ET at 250 m pixel resolution. ET was estimated for 3 climatically different years for the Western Cape and KwaZulu-Natal. The average annual ET from areas under IAPs, native vegetation, exotic plantation forestry species and control (clearing) areas were compared. The ET of the 5 dominant IAPs (*Acacia mearnsii*, *Acacia saligna*, *Eucalyptus* spp., *Hakea* spp. and *Pinus* spp.) in the Western Cape province was 895 mm, which was significantly higher than the ET of most of the native vegetation (thicket 575 mm and fynbos 520 mm), but similar to the ET of dominant exotic plantation forestry species (805 mm). On average, the ET was reduced by 13% to 780 mm, following clearing. In KwaZulu-Natal Province, the ET of the 5 dominant IAPs (*Acacia mearnsii*, *Chromoleana odorata*, *Eucalyptus* spp., *Lantana camara* and *Solanum mauritanium*) was 875 mm, which was also higher than the ET of the native vegetation (thicket 755 mm, savanna 685 mm and grassland 640 mm). Following IAP control the ET was decreased by 6%, to 825 mm.

This study has demonstrated that spatial ET data with GIS-information on land use can be used to assess the impact of IAPs, and clearing thereof, on water resources. We confirmed results from previous studies, which showed that ET from invaded areas exceeded that from native vegetation. The ET data needs further validation as validation appeared to be impossible. Our results are likely conservative since the majority of invaded areas considered in this analysis represent non-riparian areas. The impact of WFW control of densely-invaded riparian areas is likely more pronounced. We concluded that the clearing of IAPs by the WFW programme has a positive effect on the availability of water resources through a reduction in ET.

Keywords: invasive alien plants; indigenous vegetation; remote sensing; water use; evapotranspiration; SEBAL; Western Cape; KwaZulu-Natal

INTRODUCTION

Internationally, invasive alien plant species (IAPs) are recognised as the 'most important direct drivers of change in ecosystems' (Millennium Ecosystem Assessment 2005 p. 14 in Cavaleri and Sack, 2010). Although researchers believe that IAPs often have a negative impact on water resources through their high water use (ET) compared to native vegetation (Calder and Dye, 2001), little is actually known about the impact of IAPs on ecological processes (Calder and Dye, 2001; Cavaleri and Sack, 2010).

In South Africa (SA), IAPs not only impact on the water resources, but also on land productivity and biodiversity. IAPs occur across the SA landscape and it is estimated that about 10 million ha (8.28%) of SA has been invaded to some extent, at an average species density of 17% (Le Maitre et al., 2000). IAP spread and density across the Western Cape and KwaZulu-Natal provinces of SA is shown in Fig. 1 (Kotzé et al., 2010). Dense invasions are generally confined to small areas often associated with riparian zones. IAPs are controlled through legislation, with a total of 198 IAPs being declared as weeds and an additional 36 species potentially invasive (Henderson, 2001). The top ten invaders of SA are listed in Table 1 (Le Maitre et al., 2000).

Concerns about the impact of exotic plantation species on streamflow arose as early as 1932 (Dye and Bosch, 1999), which led to the establishment over time (1935–1980) of paired catchment experiments across SA, where the impact of land use changes (replacing grasslands or shrublands with exotic tree species) on streamflow were studied. It was only in the mid 1990s that the potential impact of IAPs on SA's available water resources was recognised by the government (Le Maitre et al., 1996). At the time, predictions of the impact of IAPs on water resources were based on the results from the paired catchment studies (Bosch et al., 1986), considering information on IAP spread (Versfeld et al., 1998; Görgens and Van Wilgen, 2004). Bosch et al. (1986) stated that a post-fire reduction in biomass (of fynbos, a native vegetation type) would lead to increased streamflow (Dye and Bosch, 1999). It was therefore predicted that woody IAPs would likely use significant amounts of water and reduce streamflow. These concerns and predictions led to the launch of the acclaimed Working for Water (WFW) programme in SA in 1995. The aim of this programme is to control (mainly by removing) IAPs, and in so doing protect the biodiversity and water resources of SA, whilst providing social-economic benefits to communities through job creation.

Following the launch of the WFW programme, studies continued to investigate the impact of IAPs on streamflow and total evaporation at various scales. Streamflow-biomass-based

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