Estimates of the impacts of invasive alien plants on water flows in South Africa

David C Le Maitre[1]*, Greg G Forsyth[1], Sebinasi Dzikiti[1] and Mark B Gush[1]
[1]*CSIR Natural Resources and the Environment, P.O. Box 320, Stellenbosch 7599, South Africa*

ABSTRACT

The adverse impacts of alien plant invasions on water flows have been a prime motivation for South Africa's Working for Water Programme. The approach used in this study builds on a previous national assessment in 1998 by incorporating factors that limit plant water-use, information from recent research and improved flow reduction models. The total reduction in flows is estimated to be 1 444 million $m^3 \cdot yr^{-1}$ or 2.9% of the naturalised mean annual runoff (MAR), less than half of the 3 300 million $m^3 \cdot yr^{-1}$ estimated in 1998. Two main factors account for this difference: (a) a decrease in the estimated unit-area flow reduction to 970 $m^3 \cdot ha^{-1} \cdot yr^{-1}$ compared with 1 900 $m^3 \cdot ha^{-1} \cdot yr^{-1}$ estimated in 1998, largely due to the new model being based on more representative reduction factors; and (b) the updated estimate of the condensed invaded area of 1.50 million ha (previously 1.76 million ha), although the taxa mapped for this assessment only accounted for 1.00 million of the 1.76 million ha reported in 1998. Reductions due to invasions in Lesotho are estimated to be about 161 million $m^3 \cdot yr^{-1}$ and those in Swaziland about 193 million $m^3 \cdot yr^{-1}$. The taxon with the greatest estimated impact was wattles (*Acacia mearnsii, A. dealbata, A. decurrens*) with 34.0% of the total reductions, followed by *Pinus* species (19.3%) and *Eucalyptus* species (15.8%). The revised estimate is considered on the low side largely because the extent and impacts of riparian invasions have been underestimated. If the current estimates that 4–6% of *Acacia mearnsii*, *Eucalyptus*, *Populus* and *Salix* invasions are riparian, are adjusted to a more representative 20%, 50%, 80% and 80%, respectively, the total reductions increase by nearly 70% to ~2 444 million $m^3 \cdot yr^{-1}$. Producing these estimates involved a number of assumptions and extrapolations, and further research is needed to provide more robust estimates of the impacts.

Keywords: plant water-use, flow reduction, mean annual runoff, riparian invasions, Working for Water Programme

INTRODUCTION

Estimates of the impacts of alien plant invasions on surface water runoff in South Africa were, and continue to be, a key factor in motivating for the establishment and continuation of the Working for Water programme (Van Wilgen et al., 1998). The last national estimate of the impacts (Versfeld et al., 1998) used a limited set of models for estimating the biomass of stands of invasive alien plants and then converted that to estimates of the impacts on mean annual surface runoff (Görgens and Van Wilgen, 2004; Le Maitre et al., 2000). Since then additional information has been gathered on the water-use of invasive alien plants (reviewed by Le Maitre et al., 2015) and a new dataset on the distribution, species composition and density of invasions has become available – The National Invasive Alien Plant Survey (NIAPS, Kotzé et al., 2010). These two advances provide the basis for new estimates of the impacts of invasions on both river flows and groundwater resources – termed water flows in this paper. Estimating the hydrological impacts of invasive alien plants at a national scale requires the use of assumptions, inferences and surrogates, and making pragmatic choices. In essence though, such choices are not too different to those used in, for example, estimating runoff in ungauged and modified catchments, as was done for national water resource assessments, such as Middleton and Bailey (2008). The results of the modelling exercise using the NIAPS data have been presented in detail for invasions in dryland, riparian and groundwater aquifer settings by Le Maitre et al. (2013). This paper focuses on the combined impacts of all invasions in South Africa and estimates for Swaziland and Lesotho are reported separately.

METHODS

Refining the water-use model

The model used for the first national estimates of reductions in water flows was based on biomass–age relationships for different plant growth-forms and a linear, biomass-based model which estimated reductions in mean annual runoff (MAR) in millimetres (Le Maitre et al., 2002, 2000, 1996; Van Wilgen et al., 1997):

$$\text{Streamflow reduction (mm)} = \text{biomass } (g \cdot m^{-2}) \times 0.238 \quad (1)$$

The invading species were grouped into three biomass classes and estimates of mean plant age were applied to different settings (e.g. fynbos versus grasslands, dryland versus riparian) to allow for the greater water use of plants in riparian zones. The model could overestimate reductions (Cullis et al., 2007) because it made no allowance for the fact that flow reductions caused by invasions cannot exceed the rainfall in the long-term (Calder et al., 1997). This weakness was addressed by reworking the model so that the flow reductions were expressed as proportions, based on revised biomass equations (Dzvukamanja et al., 2005; Le Maitre and Görgens, 2003), like the flow reduction models for forest plantations developed by Scott and Smith (1997). The revised models still require assumptions about mean plant ages and growth rates in dryland settings for estimating the biomass. But, because reductions are limited to a proportion of the current MAR, they conform to the Budyko (1974) model's principle of evaporation being limited by the available water.

* To whom all correspondence should be addressed.
☎ +27 21 888 2407; e-mail: dlmaitre@csir.co.za
Received 3 August 2015; accepted in revised form 20 September 2016

http://dx.doi.org/10.4314/wsa.v42i4.17
Available on website http://www.wrc.org.za
ISSN 1816-7950 (Online) = Water SA Vol. 42 No. 4 October 2016