EXECUTIVE SUMMARY

INTRODUCTION

Several recent developments in South Africa have highlighted the need for better information on the water use of trees in riparian zones. The declaration of plantation forestry as a streamflow reducing activity (SFRA) has served to maintain interest in the issue of forest water use, and the extent to which their impact on catchment water yields may be minimized. One long-recognized option is to remove plantations a set distance away from streams, and promote indigenous, preferably herbaceous vegetation in its place. The trend towards forest certification has further encouraged growers to adopt this practice as a means of minimizing the hydrological impacts of their forests on catchment yields, and promoting the sustainability of their forestry enterprise.

It is, however, the problem of self-established alien invasive trees that has received the most publicity in recent years. Large scale funding by both the Government and the private sector continues in support of the Working For Water programme, which is active in many regions of the country. One justification for this programme of alien tree removal is the streamflow enhancement that is believed to follow the replacement of dense stands of invasive trees by indigenous, largely herbaceous or shrub-dominated plant communities. Often the densest stands of invader trees occur within riparian zones, where removal of trees in close proximity to stream channels is believed to strongly enhance streamflow.

Few data are available to quantify these assumptions. Portable weir experiments (Dye and Poulter, 1995; Prinsloo and Scott, 1999) document streamflow enhancement immediately following the clearance of trees, but do not take into account water use by the indigenous plant community that with time subsequently develops on the site. Scott and Lesch (1995) report changes in streamflow following clearance of riparian trees in four research catchments. Their paper illustrates how variable streamflow response may be to this treatment, and how important the characteristics of the post-felling vegetation are in determining this response.

Results from a number of research catchments have consistently shown that catchment-wide afforestation significantly decreases streamflow where the pre-afforestation vegetation was seasonally dormant mountain grassland or fynbos (Versfeld, 1994). The net difference in evapotranspiration (ET) between **riparian** thickets or plantations of alien trees and indigenous **riparian** vegetation may be quite different, however, due to the yearlong availability of soil water and enhanced plant growth in riparian zones, and the occurrence of many different types of indigenous riparian vegetation. The water use characteristics of thickets of alien self-established trees in South Africa remains largely unknown, adding further uncertainty to the effect of alien tree removal on streamflow.

OBJECTIVES

The objectives of this study were:

- To record the annual pattern of water use of the most widespread alien invasive tree species occurring in riparian zones in both the summer and winter rainfall regions of the country.
- To record the annual pattern of water use of indigenous riparian plant communities with which to compare to the alien invasive communities.
- To summarise the annual reduction in water use by riparian vegetation that can be achieved through the removal of alien invasive trees.

METHODOLOGY AND RESULTS

A riparian fynbos site was chosen in the upper reaches of the Jonkershoek valley, close to the Eerste River that flows past Stellenbosch. A 12-month record of 20-minute evaporation rates from this site was recorded using the Bowen ratio energy balance (BREB) technique. A closed-canopy, mature stand of self-established wattle in the Wellington area of the Western Cape was selected to provide comparative water use data. The heat pulse velocity technique was used to record hourly sap flow rates in six sample trees representing the range of tree sizes in the thicket. Total daily sap flow in all sample trees was closely correlated to a daily air humidity index defined as the product of mean daily vapour pressure deficit (VPD) of the air and the number of daylight hours. A wildfire destroyed the sample trees after seven months of data collection. However, the daily sap flow/VPD index relation was found to be constant over the entire data record, which spanned both wet conditions in late winter, and very hot and dry conditions in late summer, indicating an absence of stress due to soil water deficits. It was assumed therefore that the same relationship would hold throughout an entire year, and could be used to predict wattle transpiration at the Jonkershoek site using the VPD data recorded there by the BREB system.

A replacement *A. mearnsii* riparian site was chosen on the slopes of the Groot Drakenstein mountains close to Pniel in the Stellenbosch district. Hourly sap flow was monitored in six sample trees over a period of seven months, until the experiment was terminated by another wild fire. Daily sap flow over the entire period of measurement showed a distinct and progressive reduction over the second half of the dry summer, which is shown to be caused by stress due to soil water deficits. Sap flow rates recorded over the period prior to the commencement of transpiration reduction were found to be very similar to those recorded at the Wellington site. Both data sets were used to develop a simple model of daily sap flow (under conditions of no water stress) for this species on the basis of tree DBH and the product of mean daily VPD and the number of daylight hours.

This model of daily sap flow by *A. mearnsii* was used to predict the annual transpiration of a thicket of this species at the Jonkershoek site. Rainfall interception by the canopies was predicted from the number of rain days recorded at Jonkershoek, and daily rainfall interception estimates for this species provided by Schulze *et al.* (1995)

In the summer rainfall region, the annual ET of riparian grassland at Gilboa forest plantation in the Karkloof hills of the KwaZulu-Natal midlands was estimated from 20 minute Bowen ratio data over a full growing season. Six months of hourly sap flow data were recorded in five sample trees growing within a riparian zone situated in a mature *A. mearnsii* compartment on Mistley-Canema plantation in the Seven Oaks district. Instrument problems at the Gilboa site caused gaps in the data record during the mid-summer period. A model of daily ET based on daily solar radiation and an empirical leaf area function provided satisfactory patching. Problems were experienced with the heat pulse measurements at Seven Oaks. Sap flow

measurements declined with time to unusually low levels. Examination of sectioned stems at the conclusion of the monitoring period revealed heavy resin impregnation of the region surrounding the probe positions. Comparison of sap flow rates recorded over the first four to eight weeks (presumed to be the least affected by the wound reaction), to those recorded in the Western Cape, showed the Seven Oaks trees to be transpiring at relatively low rates. Possible reasons for this are discussed, and the most likely is believed to be the result of heavy defoliation of the canopies by a high population of bagworm observed in the area.

In view of the difficulties associated with the Seven Oaks plantation data, the *A. mearnsii* model developed from the Western Cape sites was used, together with daily mean VPD data from Gilboa, to predict annual transpiration of *A. mearnsii* at this site. Rainfall interception by the canopies was again estimated from the number of rain days recorded at the site, and daily rainfall interception estimates for this species provided by Schulze *et al.* (1995)

Table I summarises the annual ET recorded or modelled at each site.

TABLE I: A summary of transpiration and rainfall interception estimates recorded or modelled at the study sites.

Locality	*Vegetation*	*Annual water use (mm)*			
		Transpiration	*Rainfall Interception*	*ET*	*Difference*
Jonkershoek	*A. mearnsii*	1304	171	1475	143
	Fynbos			1332	
Gilboa	*A. mearnsii*	1188	183	1371	535
	Grassland			836	

CONCLUSIONS AND RECOMMENDATIONS

The principle conclusions and recommendations arising from this project are as follows:

- Reduction in annual ET following removal of *A. mearnsii* from riparian zones is potentially large, but is also highly variable, depending on the characteristics of the pre- and post-clearing plant communities, and climate regime. The results of this research cannot be extrapolated to other sites without taking careful account of these factors.
- Assuming that soil water availability remains high throughout the year in riparian habitats, annual ET will be greatest in vegetation that maintains a high state of physiological activity and green leaf area through the year, and lowest where water use is curtailed by seasonal dormancy or any other cause of low green leaf area.
- The impact on catchment water yield of clearing *A. mearnsii* from riparian zones will vary in proportion to the area of riparian zone present in the catchment.

- Where *A. mearnsii* is present in non-riparian areas of a catchment, the potential for streamflow enhancement following clearing is greatly magnified. However, the hydrological effects of clearing these areas will depend on the annual ET characteristic of the pre- and post-clearing plant communities. The more constrained this is by soil water deficits, the less scope there is for large differences in annual ET between pre- and post-clearing vegetation.

- Clearing alien invasive trees in different parts of the country will lead to different catchment yield responses. Local assessments of such responses are required for prioritising clearing efforts and evaluating the cost-benefit of such actions. Simple predictive models are required to make such assessments.

- This study has demonstrated that annual water use of diverse plant communities may be adequately modelled on the basis of the factors most limiting ET rates. This is the basis of the "limits concept" propounded by Calder (1999). Models described in this report for predicting the water use of riparian *A. mearnsii*, grassland and fynbos are examples of such models.

- We recommend that a research programme be initiated to provide a simple modelling framework for assessing the annual water use of a wider range of vegetation types occurring in areas of the country invaded by alien invasive plants.

- Difficulties were experienced in applying the heat pulse velocity technique to *A. mearnsii*. These are described in order to assist researchers in future HPV studies involving this species. Project funds supported the development of efficient analysis programmes for HPV and Bowen ratio data that will greatly assist in any future studies of alien invader trees involving these techniques.

- The significant effect of seasonal soil water deficit on the annual water use of *A. mearnsii* was demonstrated at the Groot Drakenstein site. We recommend that research into the possibility of using remote sensing data to map plant physiological activity and water use over time should be supported.

CAPACITY BUILDING

This project has been effective in building the technical capacity of previously disadvantaged members of the team. Mr Godfrey Moses gained much experience with meteorological and sap flow instrumentation, and attended a scientific symposium where a paper co-authored by him was presented. Mr Vilakazi and Mr Ndlela were trained in the installation and maintenance of heat pulse and Bowen ratio equipment, while Ms Royappen played a major role in analysing the heat pulse velocity data.