
EXECUTIVE SUMMARY

Background

The water use of forest plantations remains a topical subject in light of recent changes to water law, as well as continuing debate over the hydrological impacts of various types of land use. While sap flow and micrometeorological techniques exist to allow direct measurement of forest water use, their usefulness in resolving land use disputes is currently limited for the following reasons:

- They are complex, and expensive in terms of both equipment and time. Funds are mostly insufficient to permit measurements of water use over a useful period of time. Measurements can generally only be sustained for a small fraction of a forest rotation.
- Forest water use is known to be affected by a wide range of weather, forest stand and site factors, and therefore our ability to extrapolate from relatively few research sites to the entire forestry region is limited. Growth and water use is especially sensitive to the availability of soil water at a site, which is mostly impractical to measure because of deep rooting depths, highly variable stoniness and depth to bedrock, and uncertainty over lateral soil water flow.

An alternative approach to the estimation of plantation water use was suggested by the results of a previous investigation into the relation between annual trunk volume increments and cumulative annual water use of *Eucalyptus grandis* trees. The study was conducted in Kruisfontein Plantation (White River district, Mpumalanga), and involved a full year of growth and sap flow measurement in 17 trees growing on a wide range of site quality. A surprisingly tight, linear relation was found between annual volume growth increment and cumulative annual sap flow (Figure 1), suggesting that this measure of the efficiency of water use did not differ significantly among the trees. Further data from a *Pinus patula* experiment in the White River area (Witklip Plantation) revealed a similar efficiency of water use.

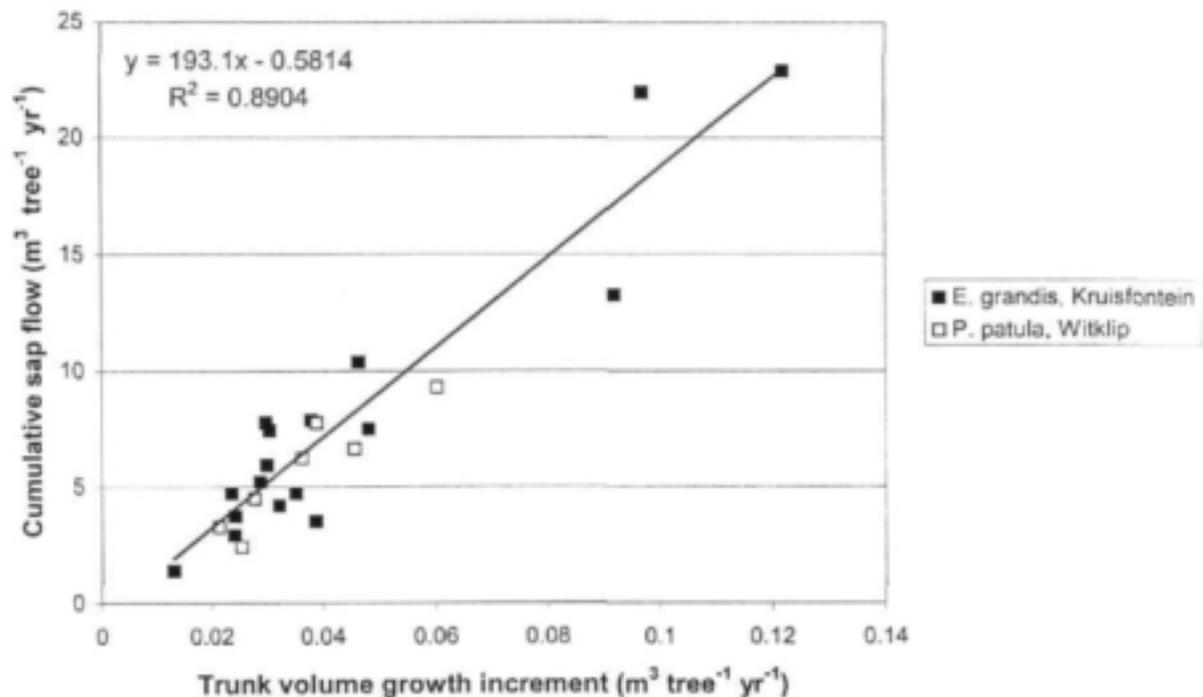


Figure 1. The relation between annual trunk volume growth increment and annual cumulative sap flow recorded in sample trees of *E. grandis* and *P. patula* at Kruisfontein and Witklip plantations, White River.

These results suggest that annual water use may be predicted from growth increment with useful accuracy. Forest growth increments are relatively easy to measure, and are known for most forestry compartments throughout the national forestry estate. A simple correlation to annual water use would bring much clarity to the issue of forest impacts on regional water supply.

Project objective

The Kruisfontein sample trees were mostly 6-years old, and no data were available to determine whether the relationship holds over an entire rotation. The purpose of this study was to examine the correlation in more detail in a selection of *E. grandis* and *P. patula* trees representing a wider range of age, site quality, management

regime and climate. The *P. patula* study was funded by the Department of Water Affairs and Forestry. In view of the similarity of the two projects, it was agreed between the WRC and DWAF that the results should be reported together in a single publication.

Data collection

Two adjacent sample trees representing dominant and suppressed size classes were selected in seven *E. grandis* and five *P. patula* forest compartments. These sites were all situated within an 80 km radius of Pietermaritzburg, and covered a range of altitude and tree age. Heat pulse probes were implanted into the sapwood of each tree to monitor hourly sap flow rates over 12 months. Annual trunk volume growth increment was calculated from diameter and height measurements at the start and end of the 12 months. A full year of sapflow data of acceptable quality was recorded at nine of the sites.

Results

The data were analysed together with water use efficiency (WUE) data obtained in five previous studies. The combined plot of data points (Figure 2) displays a more variable and curvilinear trend than suggested by the original Kruisfontein data, and physiological reasons for the non-linearity and variable WUE are reviewed. These results support some recent physiological evidence that the relation between above-ground growth and amount of water transpired may be significantly affected by altered patterns of carbon allocation by trees, with a greater proportion allocated to roots in trees that are stressed. Data reported here have yielded particularly clear evidence that the WUE of forest plantations is influenced by rainfall distribution. *Eucalyptus* clones sampled in the Kwambonambi district showed a distinctly lower WUE than the remaining sample trees, and this difference is attributed to a severe growing-season drought during the period of measurement.

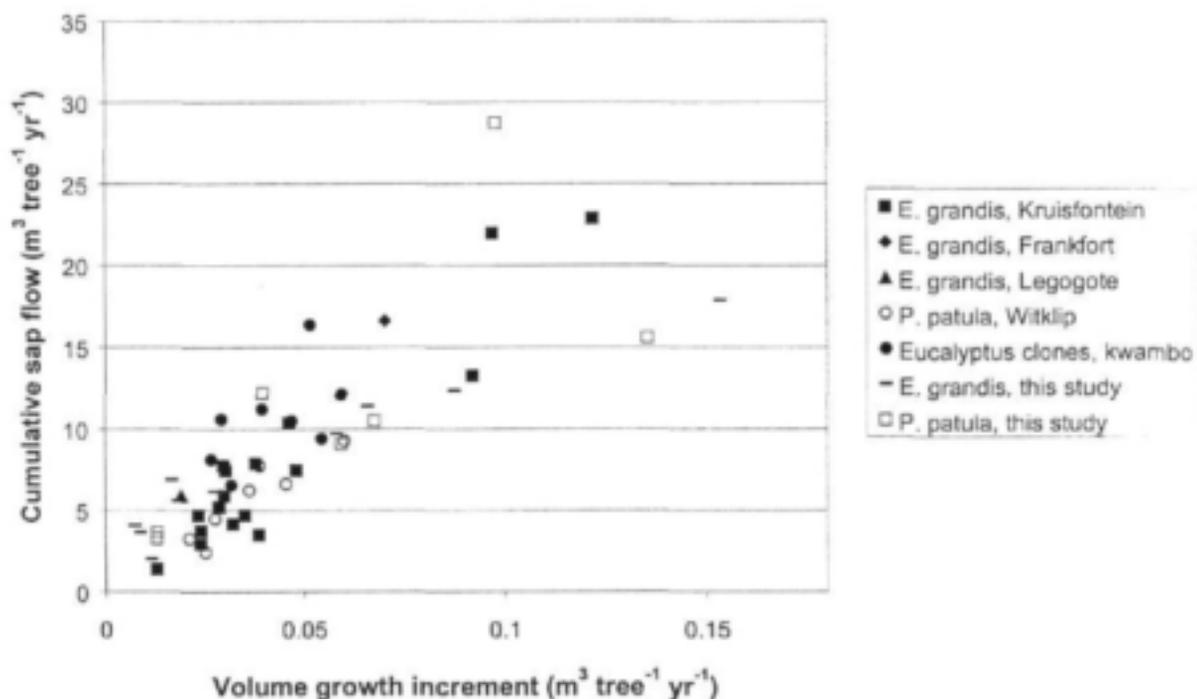


Figure 2. The relation between the annual trunk volume growth increment and the annual cumulative sap flow of sample trees in all the available WUE data sets.

The data reviewed in this report usefully define the range of WUE displayed by sample trees in a wide range of *Eucalyptus grandis* and *Pinus patula* stands, bringing greater clarity to this question, and providing an improved basis for comparisons of WUE with alternative crops. Such comparisons are already underway (e.g. WRC project no. 1133).

Recommendations for future research

In view of the growing trend of plantation establishment by small-scale emergent growers in areas considered marginal for forestry (DWAF, 1997), we believe that it is now timely to extend WUE research to investigate the scope for improving wood production and minimizing drought risk in such areas. Given the range of WUE

encountered in this study (Figure 2), it is appropriate to consider to what extent it can be altered through selection of appropriate genotypes and perhaps management strategy. Research should be focussed on *Eucalyptus* species for two reasons. Firstly, they are the preferred species in areas of relatively low rainfall that are marginal for forestry and where a high WUE would be most beneficial. Secondly, much physiological diversity is known to exist among *Eucalyptus* hybrid clones that are already widely planted in South Africa. The scope for improving WUE through an appropriate tree breeding and selection process is believed to be great. The challenge will be to tease apart the genetic and environmental influences on tree WUE for a range of clones and plantation sites.

This study has revealed the need for a new methodology in forest WUE research. Long-term monitoring of sap flow by the heat pulse technique is fraught with risks. These have included malfunction or theft of equipment, unscheduled clearfelling of sample trees, and occasional uncertainty over the long-term development of wounded sapwood tissue following probe insertion. Sustaining high-quality measurements of sap flow over a full year has proved difficult and a number of sample trees had to be abandoned. We believe that further advances in our understanding of WUE will flow from the use of process-based models of forest growth and water use, which allow the separate influences of weather, stand characteristics and site conditions on carbon allocation patterns and transpiration rates to be assessed. Such models, when validated against appropriate short-term measurements of critical physiological parameters such as sap flow rates, leaf area index, canopy temperatures and growth rates, will greatly improve our understanding of the link between growth and water use. One such model (3-PG) shows much promise in this regard (Dye, 2000a), and is undergoing further testing in WRC project 1194.

Capacity building

This project provided an opportunity to train four junior scientists and technicians in the theory, instrumentation, and data analysis procedures associated with the heat pulse velocity technique. These skills were efficiently applied by the project team to