

## EXECUTIVE SUMMARY

Transpiration from South African forest plantations is believed to account for a large fraction of the total rainfall falling in afforested catchments (Dye, 1993). A model of potential transpiration rates from different age classes of *Eucalyptus grandis* (the most widely planted hardwood species) has recently been developed from plantations in relatively high rainfall areas east of Sabie (Olbrich, 1994). This species is frequently grown in areas receiving relatively low rainfall where the trees experience periodic, significant soil water deficits. The use of potential transpiration models to simulate transpiration rates in such areas will lead to overestimates of water use when soil water deficits limit transpiration rates.

The aim of this study was to determine the relationship between soil water availability and transpiration rates by plantation *E. grandis*, and to assess the feasibility of modelling the soil water balance in order to estimate the degree of reduction in transpiration under conditions of sub-optimal soil water supply. Some of the more specific questions relating to the practicality of the approach were as follows:

- What is the maximum rooting depth, and how does it vary with tree age?
- Is soil water abstracted and recharged uniformly?
- Does the moderating function change as the trees grow older?
- Is this function altered by seasonal changes and site differences?
- Do potential transpiration models apply to all stands with sufficient soil water

availability?

- What is the progression of physiological response to soil water stress, and how is transpiration rate reduced?
- How fast does the transpiration rate recover after water stress is relieved?

Three different sites were selected for investigation. At each site, plastic sheeting was laid over the ground to prevent soil water recharge and thereby allow the tree roots in the soil to induce a continuous progressive depletion of soil water. Initial work took place at two experimental sites in Frankfort Plantation in the Sabie area of Mpumalanga. Site 1 supported a stand of three-year-old *E. grandis* trees, while nine-year-old trees were growing on site 2, situated 2 km away. At site 1, measurements of pre-dawn xylem pressure potential (XPP), leaf area index (LAI), stomatal conductance, growth and sap flow rates took place from June 1992 to June 1993, while measurements of pre-dawn XPP, LAI, growth and sap flow at site 2 lasted from June 1992 to January 1993. At both sites, prevention of soil water recharge resulted in only relatively low levels of stress developing in the trees. Neutron probe readings at site 1 showed the trees to be vigorously abstracting water down to the deepest measurement depth (8 m below the surface). Similarly, at site 2, the trees were found to be obtaining much of their water requirement from depths below 8 m. Neutron probe readings at the start and end of the treatment periods were converted to volumetric soil water contents to determine the total water abstraction over these periods. The calculations showed that only 46 % of the recorded sap flow in the sample trees came from the 8 m profile at site 1, and only 37 % at site 2. The conclusion at both sites was that the relation between

transpiration and soil water availability could not be defined, since the rooting zone extended well below the deepest measurement depth, and that the trees displayed only early signs of stress in consequence of their ability to obtain significant quantities of water below 8 m. Modelling the soil water balance of such deep profiles is considered to be impractical, especially on the scale of whole catchments, in view of the problem of measuring soil water content at depth, the heterogeneity of deep subsoil material, the unknown volume of stones, and the likely non-uniform infiltration of water through the deeper strata.

With the above conclusion in mind, a third site was chosen in an area with a lower mean annual rainfall (950 mm) and with a shallower soil profile (18 m). This site was situated on the HL&H estate of Legogote North East in the vicinity of White River. Measurements of sap flow, trunk growth, xylem pressure potential, leaf area index, stomatal conductance, and soil water contents took place between February 1994 and December 1995. In contrast to the Frankfort results, the trees experienced substantial late-winter stress in 1994 due to soil water deficits. This was prior to the plastic sheeting being laid out in April 1995. This stress was sufficiently high to cause a marked decline in leaf area index, and reduced water use by the trees. Partial recovery took place during the following summer. Soil water abstraction amounted to 48 % of measured sap flow in the seven months the soil surface was covered by plastic sheeting. In contrast to the Frankfort sites, the deeper strata contained very little available water, and some evidence for a limited amount of lateral flux of water from the edge of the plot was recorded.

Comparison of sap flows, leaf area index and stomatal conductance between the Frankfort sites and the Legogote site led to the realization that potential transpiration models developed from trees in sites with high rainfall and deep soils will overestimate water use of trees in such drier sites, even during the summer months when soil water availability is high. I hypothesize that the site 3 trees experience regular stress during each winter which has led to adaptations involving lower leaf stomatal conductances, sapwood moisture content and leaf area indices, all of which serve to reduce the water use of the trees. This is a further complication to the original goal of moderating potential transpiration models on the basis of soil water contents to predict tree water use under water limited conditions.

The foregoing has led the author to believe that the only practical alternative to estimating the water use of eucalypt plantations on sites with limited water availability is to use the growth of the trees as an index of the water use. This project inspired a separate study of the correlation between *E. grandis* growth and water use. Data from 17 six-year-old trees from a wide range of sites in the White River area have shown a remarkably good correlation between annual volume growth increment and total yearly sap flow (Figure 1). The annual growth and water use data from the sites in this study conform to the trend. The implication of this good correlation is that maps of volume growth increments can be obtained for even the most heterogeneous catchments and used to estimate the annual water use of the trees. The growth/water use relation would obviously need to be verified for a

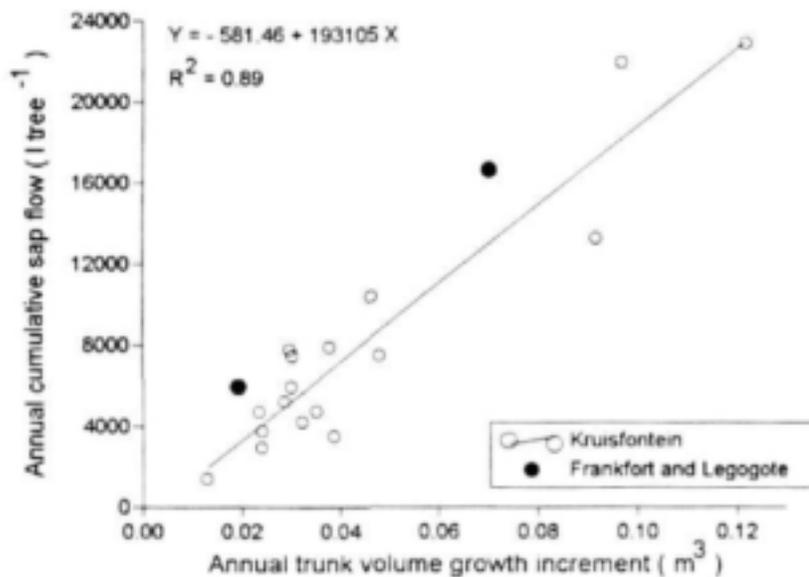


Figure 1. The relation between yearly volume growth increment and yearly total sap flow recorded in 17 sample trees at Kruisfontein. The mean volume growth and total sap flow recorded at sites 1 and 3 are also shown.

representative range of tree ages, site qualities, climates and genotypes. This verification has already commenced.

In conclusion, the aim of this study was to determine the feasibility of deriving and using a moderating function to simulate reductions in transpiration during times of significant soil water deficit. Results have demonstrated that this approach is impractical. However, they have provided many valuable insights into the relation between trees and soil water, and have led to an alternative strategy for estimating

water use by trees subject to a highly variable soil water supply. It is anticipated that the data collected during this study will be of great use in verifying models such as ACRU, and perhaps indicating where modifications are required.

**KEYWORDS:** *Eucalyptus grandis*, sap flow, transpiration, drought stress, soil water abstraction, water use efficiency